Mission Folder: View Mission for 'Team Stumptown'

State	Oregon
Grade	8th
Mission Challenge	Food, Health and Fitness
Method	Engineering Design Process
Students	Shreyas Ananth (shreyas) Kapil Kakodkar (Erobot) TEJASWANI DATLA (Teju2020) Rishab Madhusudhan (r_m2007)

Team Collaboration

(1) How was your team formed? Was your team assigned or did you choose to work with each other?

Please see page 8 in the attached PDF file

(2) Provide a detailed description of each team member's responsibilities and jobs during your work on the Mission Folder.

Please see page 9 in the attached PDF file

(3) Did your team face any problems working together? If so, how did you solve them? If not, why do you think you were able to work together so well?

Please see page 10-11 in the attached PDF file

(4) What were some possible advantages to working together as a team on this project? How would working as individuals have made this project more difficult?

Please see page 12 in the attached PDF file

Uploaded Files:

- [**View**] **Team Stumptown mission folder** (By: Advisor, 03/06/2021, .pdf)

  According to the arthritis Foundation, more than 54 million adults and almost 300,000 children in the U.S. have arthritis or another type of rheumatic disease, and by conservative estimates, this number is expected to increase 49% by 2040. Physiotherapy and Medication for people with arthritis costs nearly $200B annually, and requires patients to visit doctors multiple times weekly. We have built a Virtual Physiotherapy experience that allows people with arthritis to exercise virtually anytime in the comfort of their own homes for less than $150 instead of monthly recurring expenses.

Engineering Design

Problem Statement

(1) What problem in your community will your team attempt to solve using the engineering design process? Why did your team choose this problem to try to solve?

Please see pages 19 in the attached PDF file

(2) Research your problem. You must learn more about the problem you are trying to solve and also what possible solutions already exist. Find AT LEAST 10 different resources and list them here. They should include books, periodicals (magazines, journals, etc.), websites, experts, and any other resources you can think of. Be specific when listing them, and do not list your search engine (Google, etc.) as a resource.

Please see page 20 and pages 86-89 in the attached PDF

(3) What did you find out about your problem that you didn't know before? What kinds of possible solutions already exist? Be sure to put this in your OWN words, do not just copy And paste information. Also, be sure to cite your sources.

Please see pages 21-24 in the attached PDF

Design Development

(4) What MUST be a part of your solution? These are called the criteria. Explain what criteria are needed to solve the problem. Make sure your criteria are measureable, connected to the problem, and related to your research.

Please see page 25 in the attached PDF

(5) What limits are there on your solution? These are called constraints. Does it need to be a certain size? A certain weight? Is the cost a factor? Write down all of the limits on your solution.

Please see page 26 in the attached PDF

(6) Based on your criteria and constraints, what is your proposed solution to the problem you chose? Explain what it will look like and how it will work. If you can, include a detailed, labeled drawing.

Please see page 27 in the attached PDF

(7) How will you test your solution? The BEST way to test your solution is to build a working model or a prototype that you can actually use. Or you can guess how your solution will work BASED ON your research. Which method will you use and why?

Please see page 28-31 in the attached PDF

Build Model or Prototype

(8) If you built a prototype or model, explain how you built your prototype or model, step-by-step including ALL SAFETY PRECAUTIONS. If you guessed how your solution would work BASED ON your research, explain important information from your research that you used to prove how your solution would work and be sure to cite your sources.

Please see pages 31 and 33 in the attached PDF

Test Model or Prototype

(9) Explain how you tested your prototype or model. Be sure to include every step of your testing including all safety precautions that were taken. If not stated it will be assumed no safety precautions were taken. If you are using research to guess how your solution will work, explain step-by-step how it will work and why.

Please see pages 31, 33, 56-63 in the attached PDF

(10) What problems did you find with your solution? Be specific since you will need to redesign based on these problems.

Please see pages 77-79 in the attached PDF

(11) Describe all of the changes you made to your prototype or model (or proposed prototype) after your first test. Why will these changes improve your solution?

Please see page 77-79 in the attached PDF

(12) Present the data you collected from your tests or from your research. If you tested a prototype or model then include all of the numbers you gathered during your testing and all observations you made. Use of graphs and charts is HIGHLY encouraged. If you used research to prove how your solution would work, be sure to include all of the numbers, charts, and graphs you used to make your case. Be sure that all data is related to your solution.

Please see pages 34-56, 64-76 in the attached PDF

(13) What are your potential sources of error? Remember, this doesn't mean "Did everything work?", all tests have potential sources of error, so make sure you understand what that means. Explain how these sources of error could have affected your results.

Please see page 77-79 in the attached PDF

Drawing Conclusions

(14) What conclusions can you draw based on the data you gathered during your tests? Your conclusion should be related to your original problem and your testing, include the data you collected, and refer to your proposed solution.

Please see page 80-82 in the attached PDF

Uploaded Files:

- [**View**] **Team Stumptown mission folder** (By: Advisor, 03/06/2021, .pdf)

  According to the arthritis Foundation, more than 54 million adults and almost 300,000 children in the U.S. have arthritis or another type of rheumatic disease, and by conservative estimates, this number is expected to increase 49% by 2040. Physiotherapy and Medication for people with arthritis costs nearly $200B annually, and requires patients to visit doctors multiple times weekly. We have built a Virtual Physiotherapy experience that allows people with arthritis to exercise virtually anytime in the comfort of their own homes for less than $150 instead of monthly recurring expenses.

Community Benefit

(1) Explain how investigating the problem your team chose will help the community. Be sure to include the impacts your research will have on individuals, businesses, organizations, and the environment in your community (if any). Make it very clear why solving this problem would help your community.

Please see pages 84-86 in the attached PDF file

Uploaded Files:

- [**View**] **Team Stumptown mission folder** (By: Advisor, 03/06/2021, .pdf)

  According to the arthritis Foundation, more than 54 million adults and almost 300,000 children in the U.S. have arthritis or another type of rheumatic disease, and by conservative estimates, this number is expected to increase 49% by 2040. Physiotherapy and Medication for people with arthritis costs nearly $200B annually, and requires patients to visit doctors multiple times weekly. We have built a Virtual Physiotherapy experience that allows people with arthritis to exercise virtually anytime in the comfort of their own homes for less than $150 instead of monthly recurring expenses.

Mission Verification

We have reviewed the eCYBERMISSION Rules and Guidelines

Yes

We have worked with our Team Advisor and we have discussed the possible risks involved in the project and completed the Risk Assessment Form (and attached it to our Mission Folder).

Yes

The project involves hazardous chemicals, activities, or devices.

No

The project involves potentially hazardous biological agents (If yes, complete this form and attach to your Mission Folder).

No

We acknowledge that we followed proper safety precautions during the work on our project.

Yes

The project involves testing one or more of the following and requires prior approval by an Institutional Review Board (IRB):

Humans

Yes

Non-Human Vertebrates

No

You will need to include an abstract of 250 words or less. As part of the abstract you will need to describe your project and explain how you used STEM (Science, Technology, Engineering and Mathematics) to improve your community

For IRB form please see page 7

According to the arthritis Foundation, more than 54 million adults and almost 300,000 children have arthritis or another type of rheumatic disease, the leading cause of disability among adults in the US, costing nearly $200B annually in physiotherapy and medication. “arthritis” is an informal way of referring to joint pain or joint disease. People of all ages, genders and races can and do have arthritis. By conservative estimates, the number of adults in the U.S. with doctor-diagnosed arthritis is projected to increase 49 percent to 78.4 million by 2040. Based on the research Physical activity and physical therapy can reduce pain and improve physical function by about 40 percent. Existing solutions require patients to visit physiotherapists multiple times weekly and is cost prohibitive. We asked ourselves, ”how can we cost-effectively and reliably offer a virtual physiotherapy experience for people with arthritis?”, and have built a Virtual PhysioTherapist solution that allows people with arthritis to exercise virtually anytime in the comfort of their own homes without excessive premiums or recurring expenses. We offer a set of exercise routines via enjoyable video games for PC/Mac that allows people of all ages to play by exercising. Based on the patient's age group and performance, we adjust the complexity level of those routines, tracking daily, weekly and monthly progress that can be viewed by both the patients and therapists online. We have received positive feedback from both patients and physiotherapists on the viability of our solution. In the future, we hope to expand our set of exercise routines and games to address multiple forms of arthritis and also share statistics with family and doctors to keep them informed of patients' progress.

Uploaded Files:

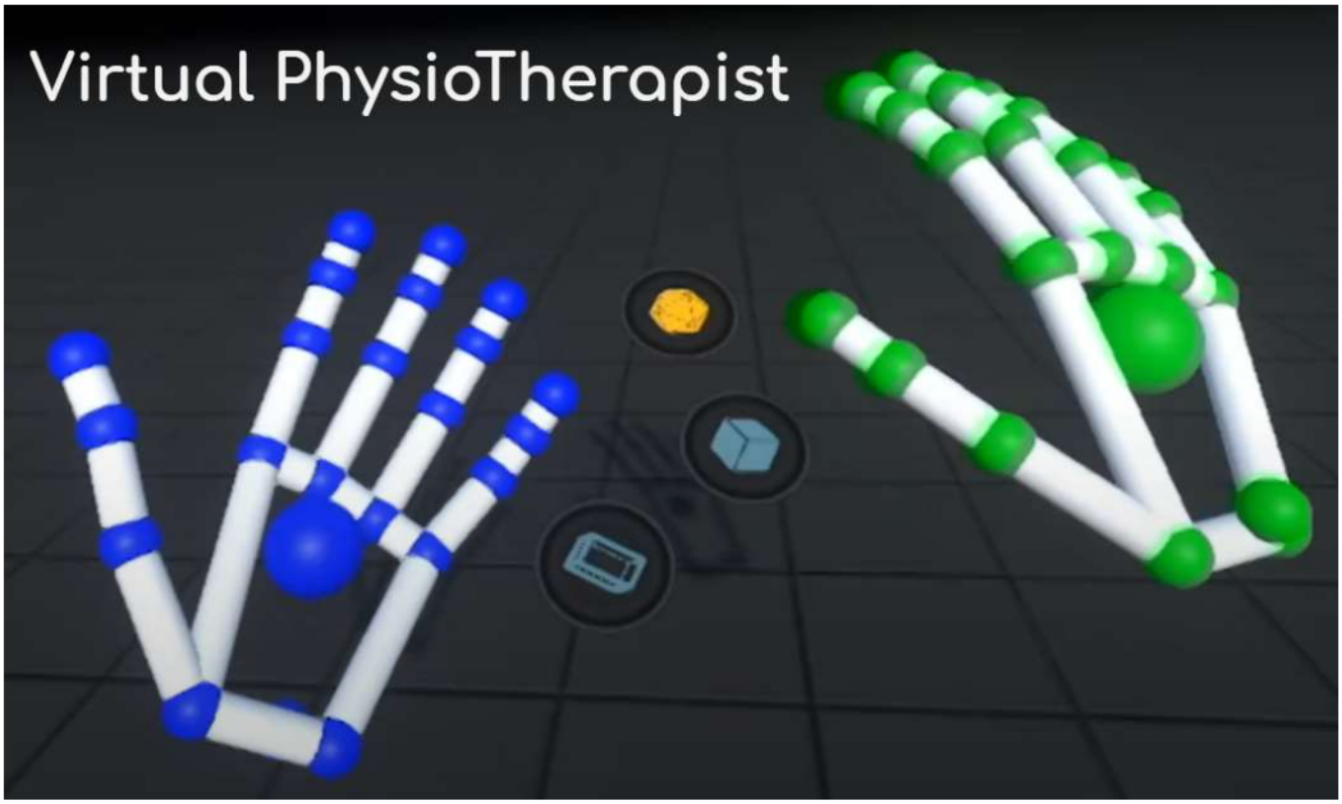
- [**View**] **Team Stumptown mission folder** (By: Advisor, 03/06/2021, .pdf)

  For IRB form please see page 7
- [**View**] **Risk assessment form** (By: Advisor, 03/06/2021, .pdf)

  Risk assessment form

A Cost-effective and Reliable Virtual Physiotherapy Experience for People with arthritis

Team Stumptown, 2020-21 Season



According to the arthritis Foundation, more than 54 million adults and almost 300,000 children in the U.S. have arthritis or another type of rheumatic disease, and by conservative estimates, this number is expected to increase 49% by 2040. Physiotherapy and Medication for people with arthritis costs nearly $200B annually, and requires patients to visit doctors multiple times weekly. We have built a Virtual Physiotherapy experience that allows people with arthritis to exercise virtually anytime in the comfort of their own homes for less than $150 instead of monthly recurring expenses.

We are affiliated with

http://www.stem4girls.org/roborink/

Special thanks to our team advisor and to our parents for their support throughout the season

Table of Contents

Abstract

According to the arthritis Foundation, more than 54 million adults and almost 300,000 children have arthritis or another type of rheumatic disease, the leading cause of disability among adults in the US, costing nearly $200B annually in physiotherapy and medication. “arthritis” is an informal way of referring to joint pain or joint disease. People of all ages, genders and races can and do have arthritis. By conservative estimates, the number of adults in the U.S. with doctor-diagnosed arthritis is projected to increase 49 percent to 78.4 million by 2040. Based on the research Physical activity and physical therapy can reduce pain and improve physical function by about 40 percent. Existing solutions require patients to visit physiotherapists multiple times weekly and is cost prohibitive. We asked ourselves, ”how can we cost-effectively and reliably offer a virtual physiotherapy experience for people with arthritis?”, and have built a Virtual PhysioTherapist solution that allows people with arthritis to exercise virtually anytime in the comfort of their own homes without excessive premiums or recurring expenses. We offer a set of exercise routines via enjoyable video games for PC/Mac that allows people of all ages to play by exercising. Based on the patient's age group and performance, we adjust the complexity level of those routines, tracking daily, weekly and monthly progress that can be viewed by both the patients and therapists online. We have received positive feedback from both patients and physiotherapists on the viability of our solution. In the future, we hope to expand our set of exercise routines and games to address multiple forms of arthritis and also share statistics with family and doctors to keep them informed of patients' progress.

Resources: IRB Form

aeop eCYBERMISSION
ACCEPT THE CHALLENGE

INSTITUTIONAL REVIEW BOARD

APPROVAL FORM

Student(s) User Name(s): Shreyas Ananth, Kapil Kakodkar, Tejaswani Dalla, Rishab Madhusudhan

Grade: 08 Team Advisor: Ananth Sankaranarayanan

Team Name: Team Stumptown (Virtual Physiotherapist)

Brief Description of Project:
According to the Arthritis Foundation, 54 million people in the US have arthritis, a form of rheumatic disease, and this number is expected to increase 49% by 2040. Physiotherapy sessions and medication cost more than $100B annually. We have built a solution to experience physiotherapy virtually without excessive premiums or recurring expenses.

Team Advisor: Please sign here if the project proposed is a viable eCYBERMISSION Project in which neither animals nor humans will be harmed.
Team Advisor Approval Signature: ____________ **Date:** 08/18/2020

IRB Waiver of Written Informed Consent for Human or Animal Participation

The IRB may waive the requirement for documentation of written informed consent/assent/parental permission if the research involves **only minimal risk and anonymous data collection and if it is one of the following**. (NOTE: This statement only applies to providing the written certification mentioned in 1a or 2a above).

- Research involving normal educational practices.
- Research on individual or group behavior or characteristics of individuals where the researcher does not manipulate the subjects' behavior and the study does not involve more than minimal risk.
- Surveys, questionnaires, or activities that are determined by the IRB to involve perception, cognition, or game theory and do NOT involve gathering personal information, invasion of privacy or potential for emotional distress.
- Studies involving physical activity where the IRB determines that no more than minimal risk (Daily Activity) exists and where the probability and magnitude of harm or discomfort anticipated in the research are not greater than those ordinarily encountered in DAILY LIFE or during performance of routine physical activities.

If there is any uncertainty regarding the appropriateness of waiving written informed consent/assent/parental permission, it is strongly recommended that documentation of written informed consent/assent/parental permission be obtained.

HUMAN or ANIMAL SUBJECTS
Permission Slips needed? (see above to determine) Yes ☐ No ☑ (Scan and attach slips to Mission Folder)
Check-up of Human or Animal Subjects required by Doctor, school nurse or Veterinarian? (see above to determine) Yes ☐ No ☑ If yes, Doctor's, Nurse's or Veterinarian's (before and after experimentation) current evaluation report must be attached to Mission Folder.

APPROVALS –

Principal / Administrator Signature ____________ Date Reviewed ____________

Doctor or Medical Professional Signature ____________ Date Reviewed ____________

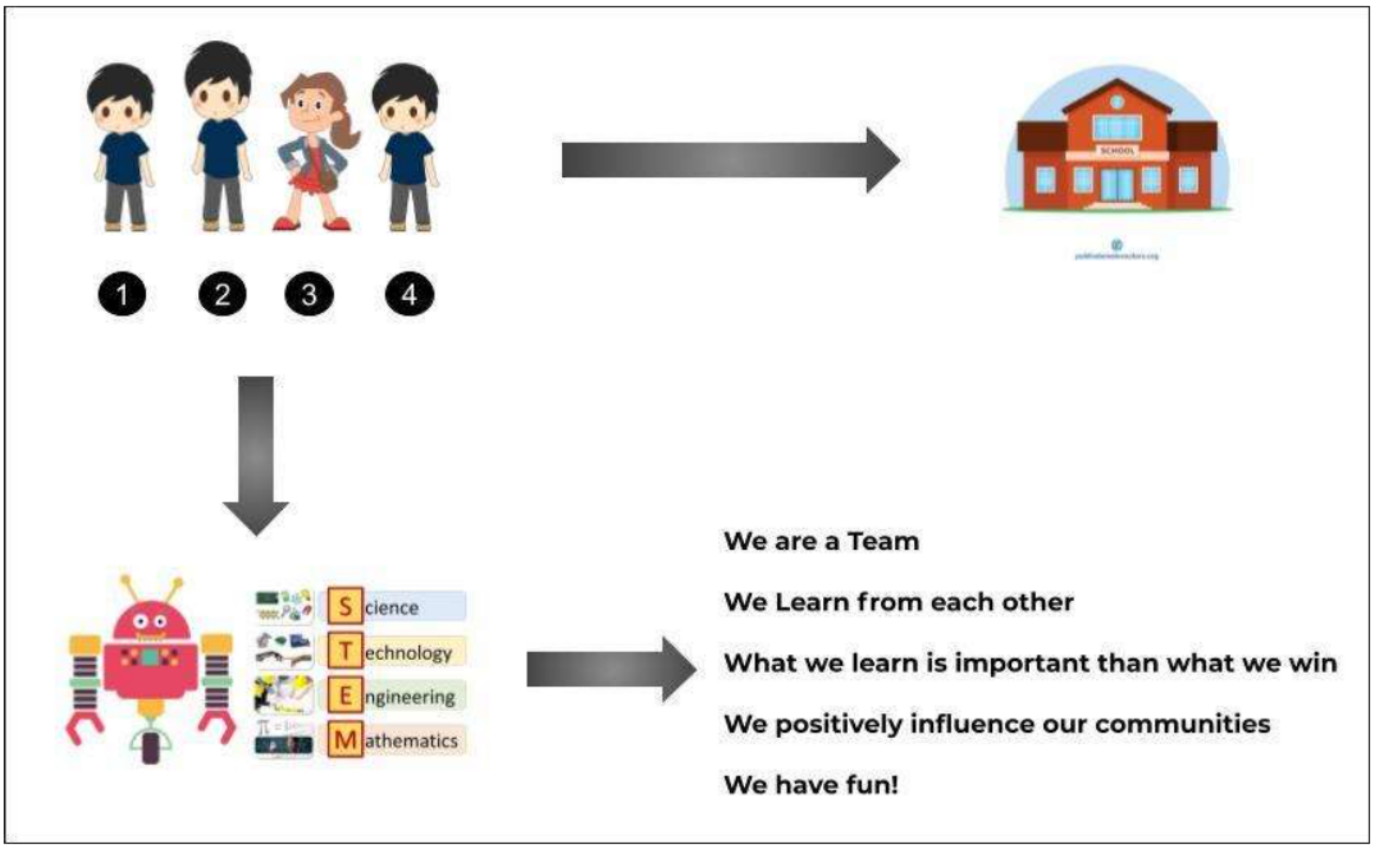
Science Fair Coordinator or other Science Teacher Signature ____________ Date Reviewed ____________

Team Collaboration

How was your team formed? Was your team assigned or did you choose to work with each other?:

Team Formation

We are Team Stumptown, a group of 8th graders from Portland, Oregon, participating in this year's 2020-21 eCYBERMISSION season. We formed in 6th grade as the Stumptown Glucobots, and reprised our team for last year's 2019 season as Lost & Found. We go to the same school, Stoller Middle, which makes communication and cooperation a lot easier. We've known each other for a while, participating in competitions like OBOB (Oregon Battle of the Books) and FLL (First Lego League). We also all hold similar interests like programming, robotics, research and STEM that make working together so much more enjoyable.



Provide a detailed description of each team member's responsibilities and jobs during your work on the Mission Folder:

Roles & Responsibilities

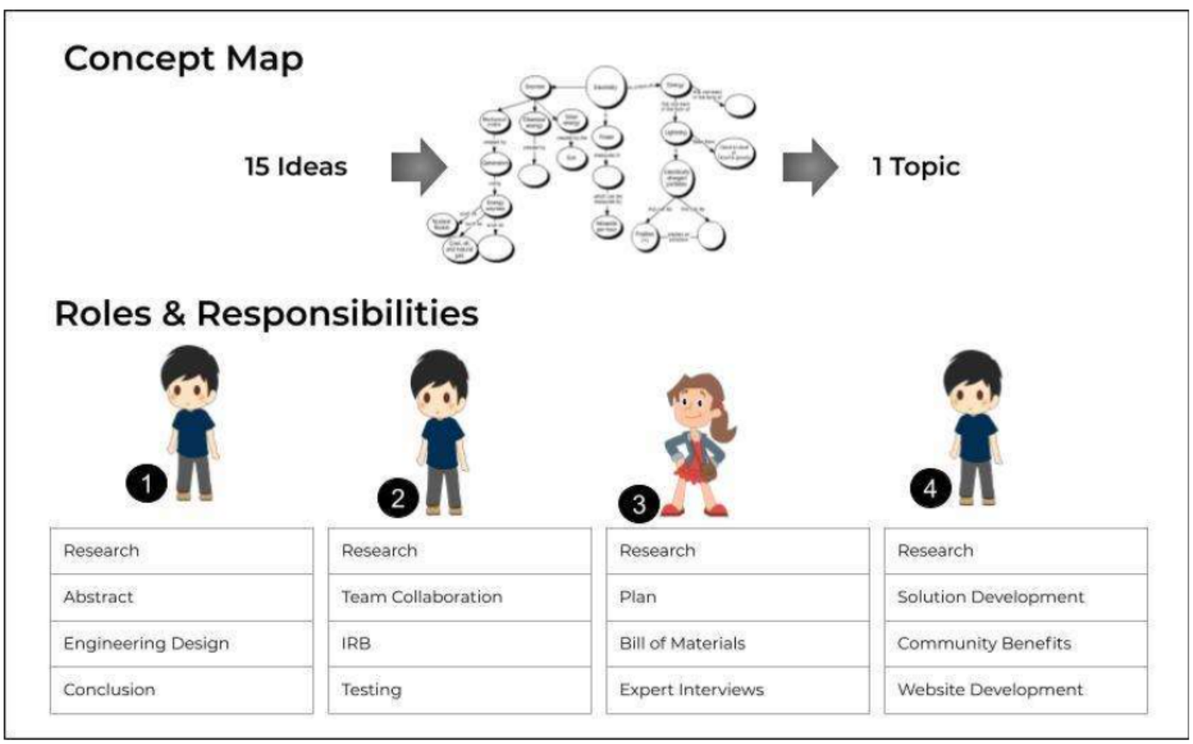
In our last two years, we had explored over 40 different topics that we had arranged into several different concept maps. This year, we took some of those ideas as well as newer ones and narrowed it down to 20 topics, 5 for each team member Each meeting, we would present a new topic and receive feedback from the others with the Rose, Bud, and Thorn analogy. A Rose is an idea that will work well, a Bud is an idea to improve on, and a Thorn is an idea that we didn't think would work. After we decided on the issue we would solve, we broke our mission folder responsibilities into 4 roles:

Team Member # 1: Research, Abstract, Engineering and Design, Conclusion

Team Member #2: Research, Team Collaboration, IRB Form, Testing

Team Member #3: Research, Plan, Bill of Materials, References

Team Member # 4: Research, Engineering, and Design, Community Benefits

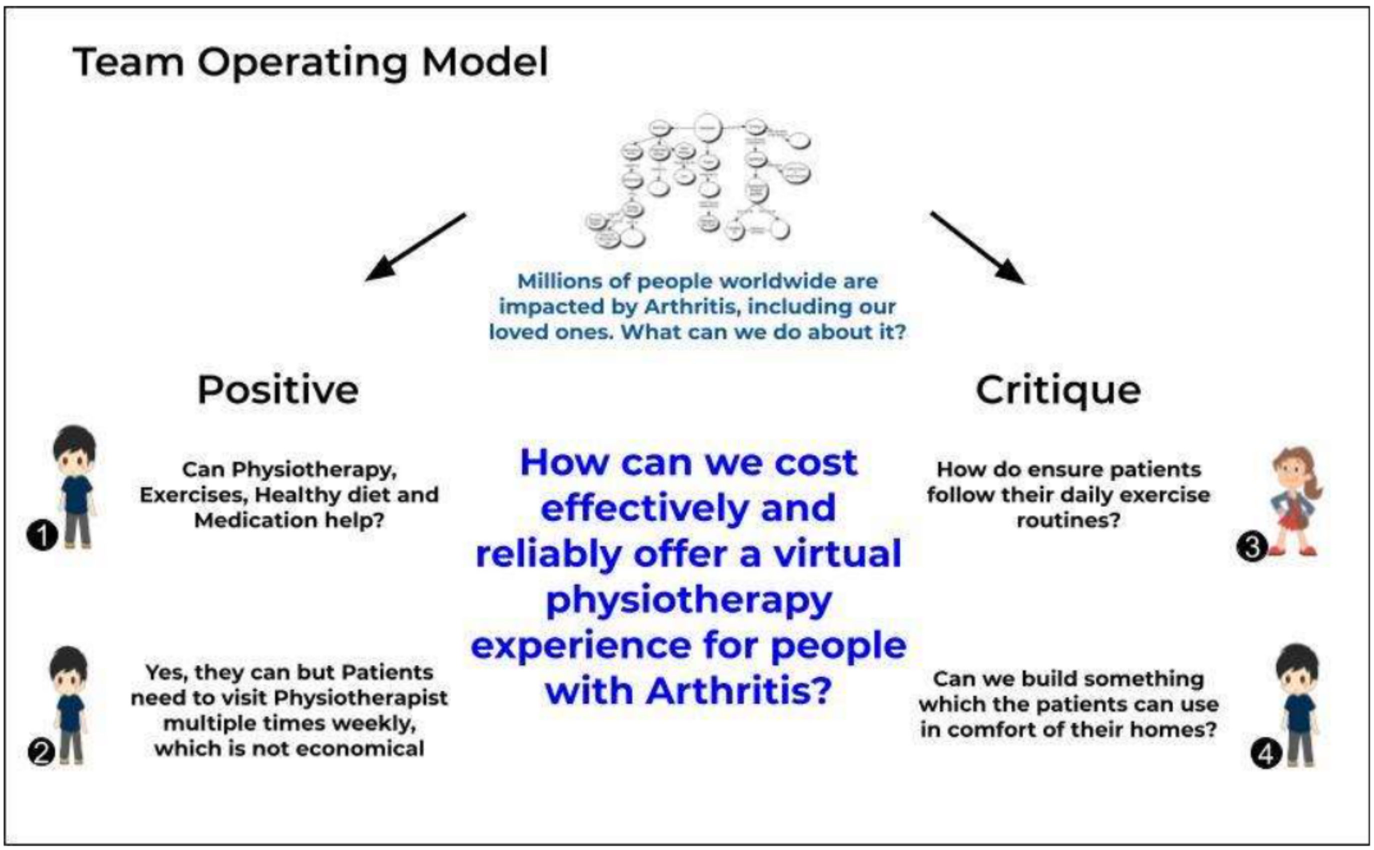


Did your team face any problems working together? If so, how did you solve them? If not, why do you think you were able to work together so well?:

Operating Model

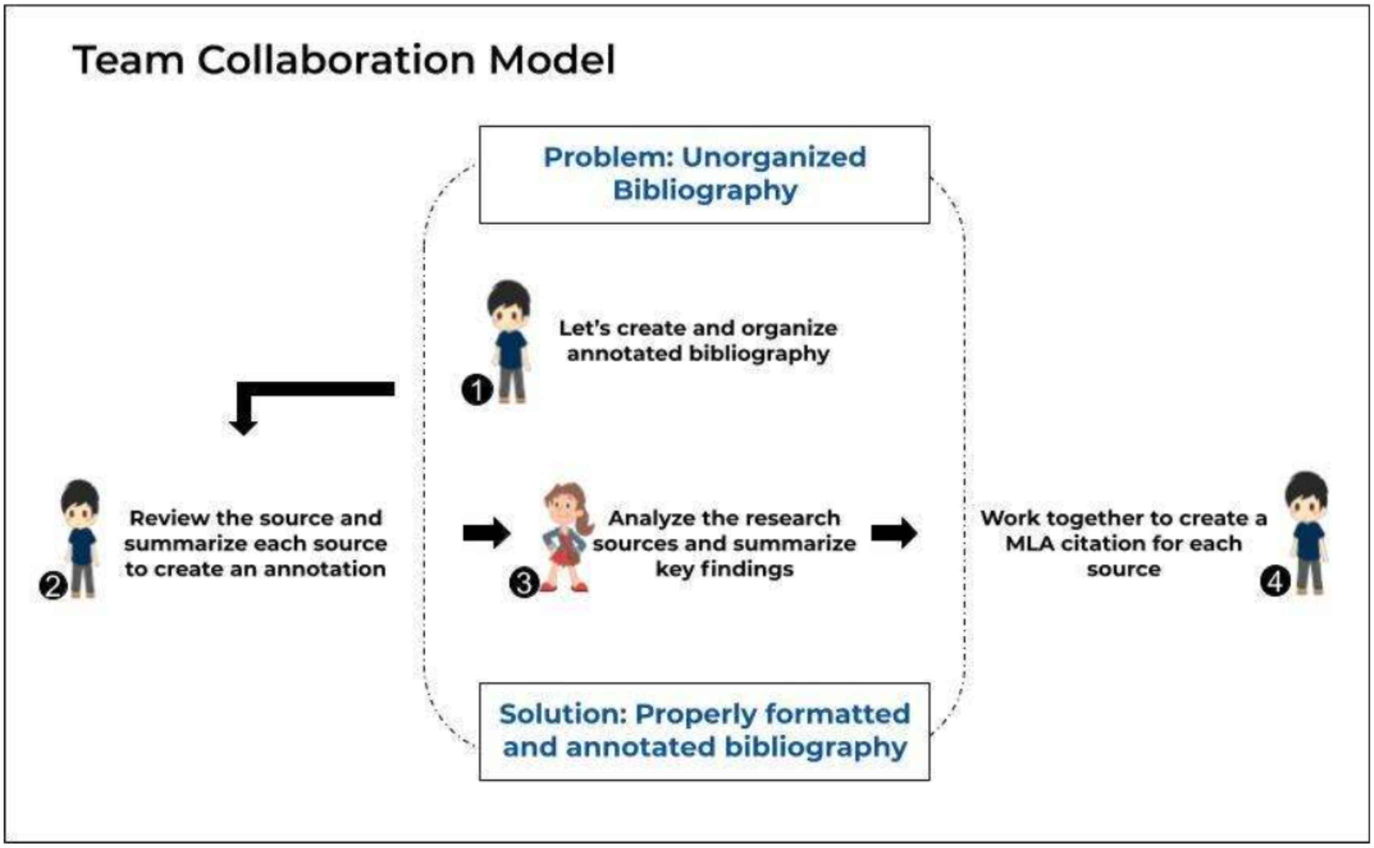
This season due to COVID-19 all our schools converted to full-time online distance learning mode and during most part of our season due to statewide lockdown, we were not able to travel outside our homes. Therefore, when we brainstormed various ideas, we intentionally focused on ideas that can be explored and solved completely virtually with expert and team meetings that can be done online via zoom or google Meet. Thankfully, none of our families were impacted by COVID-19, however, we feel very sorry for the nearly 500,000 Americans who have lost their lives and their families due to this pandemic. Observing several people with arthritis who could not visit their doctors or physiotherapists due to office closures during this pandemic, we wanted to explore ideas on how to creatively and most-efficiently address that problem.

When we formed the team, we originally faced some challenges in keeping track of our progress and updating each other with our research. We adopted a Google team shared drive to keep track of each other’s work and stay organized throughout the season. By constructively critiquing each other's ideas, we were able to work together well as one team to achieve our goals.



We shared our research work with each other between our meetings and its benefits to the community. We would collect as many resources as possible and we would decide if that source was usable. Most of the time we would scrap it for two main reasons. One, because the source was unreliable and two was because it was not something that helped the community.

While each of us had specific focus areas for the mission folder mapped to our areas of interest, we learned from each other based on our research work and challenged each other to perform at our very best. For example, for every source that we used in our research, we had to follow the MLA format for the reference section in the mission folder. Team Member #1 took the responsibility of holding all of us accountable for following the MLA standard, so overall as a team we met all our objectives.



What were some possible advantages to working together as a team on this project? How would working as individuals have made this project more difficult?:

Importance of Teamwork

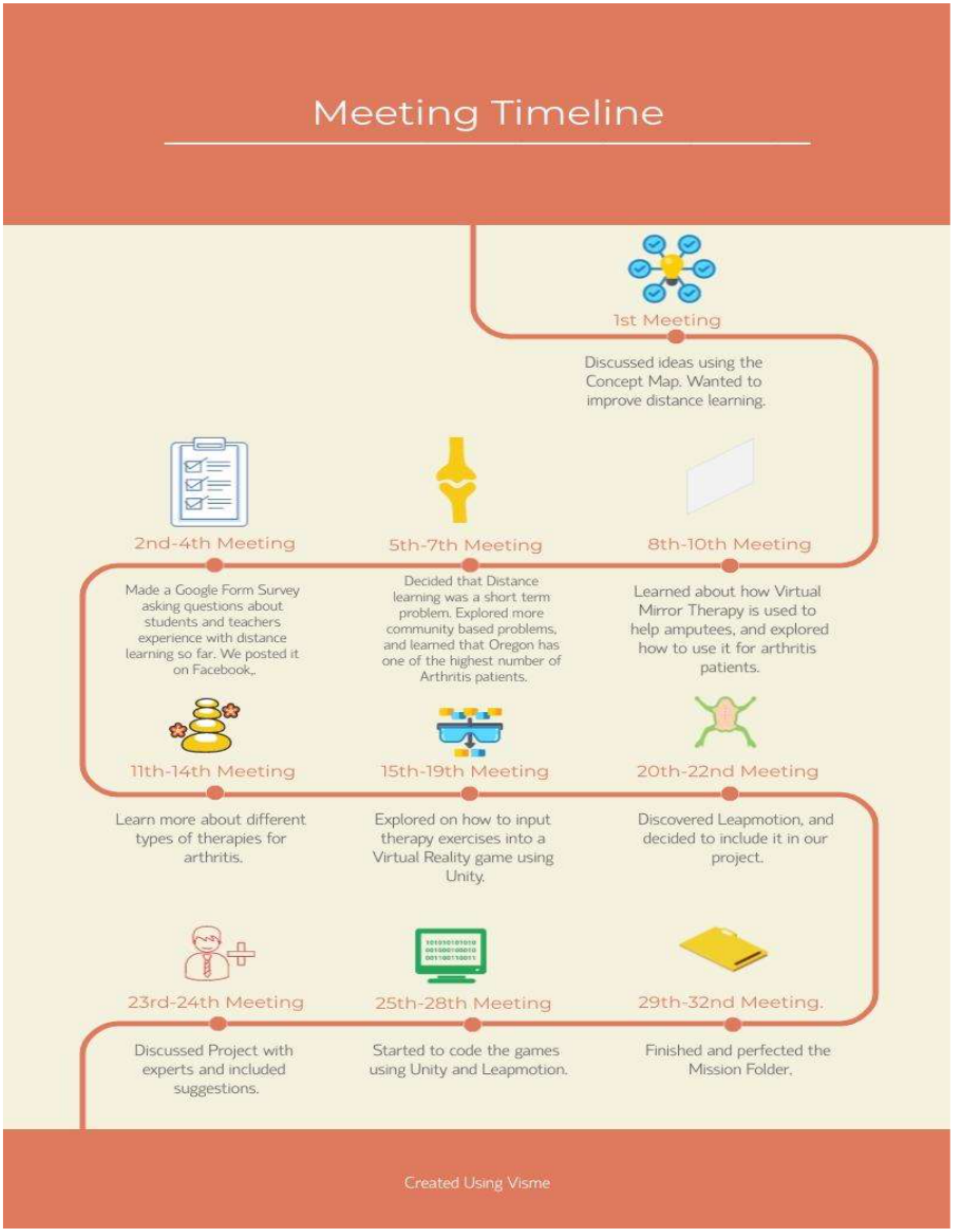
Our coach taught us, "teamwork is the ability to work together toward a common vision". We observed several advantages of working together as a team. As a team, we were able to learn a lot more new topics than as individuals. We shared what we learned with each other in team meetings, and while each of us had specific roles and responsibilities, we also helped each other when we were not able to make progress. Working as individuals, each of us would have had to do at least three times more work in conducting research, building and testing our prototype, meeting with experts to gather feedback and in completing mission folder requirements.

Our teamwork was very effective in many ways. We gave each other a lot of feedback, learned from each other, finished all the work by the due dates we set for ourselves and had fun. For example, our brainstorming process involved the use of a whiteboard to produce concept maps and write ideas that we thought affected our community. We all split the fifteen total relevant ideas and did a page long research segment on each topic. At our next meeting, we went over what we learned from the topic and any feedback or related queries we had with the topic. We used the provided resources to develop team-building skills which we used to conduct research, solve arguments and make important decisions. We also worked together to edit and review the others' work which provided a more polished final product.

After working out the details of our problem statement and coming up with a rough idea for our solution, we decided to split up the work. Although our research and designing were handled individually, we worked as a team to assist each other throughout the way, for ex., taking on someone's work with them if they were stuck in an area that was not their core expertise.

Plan

Timeline



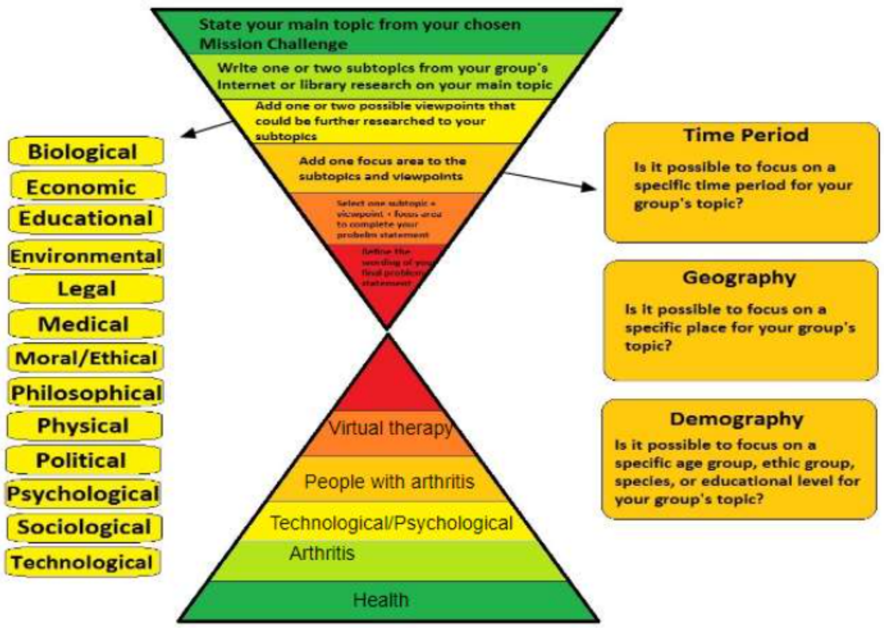
Meeting Logs

Meeting #	Goal	Accomplishment
1(Aug)	Team Kick-Off	Created Concept Map and Generated more than 20 ideas!
2(Aug)	Narrow down our Ideas	Narrowed down to focus on Distance Learning.
3(Aug)	Reach out to students and teachers to hear their opinions on distance learning.	Created a Google Form Survey, and sent it out on Facebook.
4(Aug)	Review Survey	Got back 30 answered surveys.
5(Sep)	Research	Decided that Distance learning was a short-term problem.
6(Sep)	Research	Discovered community based problems in Oregon, including hunger, homeless veterans, arthritis, depression, and air pollution.
7(Sep)	Research and Pick a topic	Researched the different problems based on the previous meeting and chose arthritis
8(Sep)	Research	Researched about arthritis
9(Oct)	Research	Researched about arthritis
10(Oct)	Research	Discovered mirror therapy.
11(Oct)	Research	Learned about different arthritis therapies.
12(Oct)	Research	Learned about different arthritis therapies
13(Nov)	Research	Learned about different exercises.
14(Nov)	Research	Learned about different exercises.
15(Nov)	Research	Explored more about Virtual Reality
16(Nov)	Research	Explored more about Virtual Reality
17(Dec)	Research	Learned how to program a VR

		setting in Unity
18(Dec)	Research	Learned how to program a VR setting in Unity
19(Dec)	Research	Learned how to program a VR setting in Unity
20(Dec)	Research about different VR controllers	Discovered the Leap Motion controller
21(Dec)	Research	Learned more about the Leap Motion Controller
22(Dec)	Research	Learned more about the Leap Motion Controller
23(Jan)	Expert Meeting	Learned more about the experiences of having arthritis.
24(Jan)	Expert Meeting	Learned more about the procedures and exercises from a therapist.
25(Jan)	Prototype	Started Coding the Exercises In a VR setting using Unity and Leap Motion
26(Jan)	Prototype	Coding the Exercises In a VR setting using Unity and Leap Motion
27(Jan)	Prototype	Coding the Exercises In a VR setting using Unity and Leap Motion
28(Jan)	Prototype	Coding the Exercises In a VR setting using Unity and Leap Motion
29(Feb)	Mission Folder	Worked on the Mission Folder
30(Feb)	Mission Folder	Worked on the Mission Folder
31(Feb)	Mission Folder	Worked on the Mission Folder
32(Feb)	Mission Folder	Finished the Mission Folder

Concept Map Creation

Developing Problem Statement



How can we cost-effectively and reliably improve the virtual therapy experience for people with arthritis?

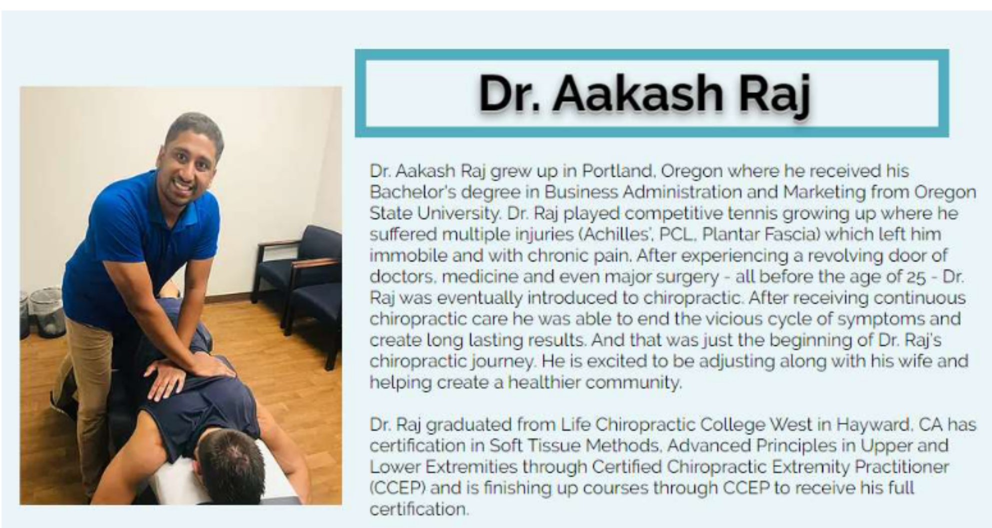
Expert Discussions

As many of the offices in Portland were closed during the global pandemic, many of our expert interviews had to be done via email and phone meetings. Below we summarize the experts we interacted with and information we gathered from those interactions.

1) Dr. Swati Kakodkar

- There are more than ten types of arthritis
- All age ranges can suffer from arthritis
- During quarantine, patients had fewer opportunities to visit the clinic

2) Kinetic Family Chiropractic



- While not regularly exercising, patients pain levels increase substantially
- Cost of therapy varies from $300-$5,000+
- Most patients need to be reminded to exercise by family members

3) Bethany Physical Therapy

- Regular exercise (physical therapy) and healthy-diet are critical
- Sometimes patients have to take pain medication as well
- Virtual experience for physical therapy is a great concept and can work

4) Advanced Physiotherapy Associates

- Patients visit physical therapists multiple times weekly
- They don't have a way to connect with the physical therapists virtually

Engineering Design

Problem Statement

What problem in your community will your team attempt to solve using the engineering design process?:

Problem Statement

According to the Arthritis Foundation, more than 54 million adults and almost 300,000 children have arthritis or another type of rheumatic disease. This is the leading cause of disability among adults in the US, costing nearly $200B annually in physiotherapy and medication. “Arthritis” is an informal way of referring to joint pain or joint disease. People of all ages, genders and races can and do have arthritis, including several of our friends and grandparents, however, it is most prevalent in adults over 60. By conservative estimates, the number of adults in the U.S. with doctor-diagnosed arthritis is projected to increase 49% to 78.4 million cases by 2040. Physical activity and therapy can reduce pain and improve physical function by around 40%. Existing solutions require patients to visit physiotherapists multiple times weekly and are cost prohibitive. We asked ourselves, ”How can we cost-effectively and reliably offer a virtual physiotherapy experience for people with arthritis?” We’ve built a Virtual PhysioTherapist solution that allows people with arthritis to exercise virtually anytime in the comfort of their homes for less than $250 without recurring expenses.

How can we cost-effectively and reliably improve the virtual physical therapy experience for people with arthritis?

Research

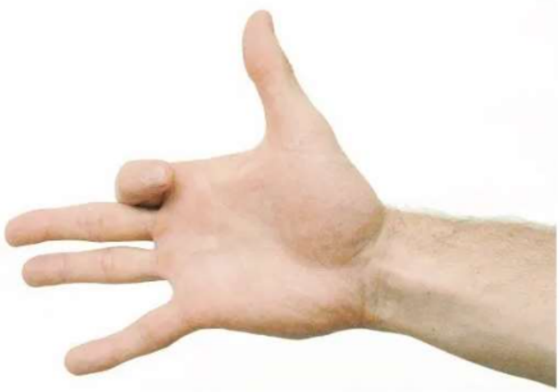
Explain what you learned from your research. What did you find out about your problem that you didn't know before? What kinds of possible solutions already exist? Be sure to put this in your OWN words, do not just copy and paste information. Also, be sure to cite your sources:

According to the Center for Disease Control (CDC) there are ten types of arthritis that affect roughly 23% of adults in the United States [2]. There are several types of arthritis that have a variety of symptoms including joint pain and limited mobility. A 2019 article by the Arthritis Foundation defined arthritis as "'not a single disease; it is an informal way of referring to joint pain or joint disease" [9]. In our research, we found that Mayo Clinic recommends several exercises to ease the pain and difficulty of arthritis, which we confirmed with physical therapy experts. Most of the exercises involve repeated movement of the wrist and fingers [36]. After talking to our local physical therapy clinics, we realized that it was far harder for therapists to evaluate and communicate with their patients. We looked into several methods of virtualizing the therapy process. During the research process we found a 2018 paper describing virtual reality games intended for arthritis rehabilitation [18].

Existing Solutions

Hand Exercises to ease arthritis

Doctors recommend ten noninvasive ways to keep the joints flexible, improve range of motion, and relieve arthritis pain by doing hand exercises [35]. Hand exercises can help strengthen the muscles that support the hand joints. This can help patients perform hand movements with less discomfort [34].

Exercise Routine	**Action**
1) Make a Fist You can do this easy exercise anywhere and anytime your hand feels stiff. ● Start by holding your left hand out with all of your fingers straight. ● Then, slowly bend your hand into a fist, placing your thumb on the outside of your hand. Be gentle, don't squeeze your hand. ● Open your hand back up until your fingers are straight once again. **Do the exercise 10 times with the left hand. Then repeat the whole sequence with the right hand.**	
2) Finger Bends 1. Start in the same position as in the last exercise, with your left hand held up straight. 2. Bend your thumb down toward your palm. Hold it for a couple of seconds. 3. Straighten your thumb back up. 4. Then bend your index finger down toward your palm. Hold it for a couple of seconds. Then straighten it. **Repeat with each finger on the left hand. Then repeat the entire sequence on the right hand.**	

3) Thumb Bend

1. First, hold your left hand out with all of your fingers straight.
2. Bend your thumb inward toward your palm.
3. Stretch for the bottom of your pinky finger with your thumb. If you can't reach your pinky, don't worry. Just stretch your thumb as far as you can.
4. Hold the position for a second or two, and then return your thumb to the starting position.

Repeat 10 times. Then do the exercise with your right hand.

4) Make an 'O'

Start with your left hand out and fingers straight.

1. Curve all of your fingers inward until they touch. Your fingers should form the shape of an "O."
2. Hold this position for a few seconds. Then straighten your fingers again.

Repeat this exercise a few times a day on each hand. You can do this stretch whenever your hands feel achy or stiff.

5) Table Bend

1. Place the pinky-side edge of your left hand on a table, with your thumb pointed up.
2. Holding your thumb in the same position, bend the other four fingers inward until your hand makes an "L" shape.
3. Hold it for a couple of seconds, and then straighten your fingers to move them back into the starting position.

<table>
<tr><td>Repeat 10 times, and then do the same sequence on the right hand.</td><td></td></tr>
<tr><td>6) Finger Lift

Place your left hand flat on a table, palm down.

1. Starting with your thumb, lift each finger slowly off the table one at a time.
2. Hold each finger for a second or two, and then lower it.
3. Do the same exercise with every finger of the left hand.

After you’re done with the left hand, repeat the entire sequence with the right hand.</td><td></td></tr>
<tr><td>7) Wrist Stretch

Don’t forget about your wrists, which can also get sore and stiff from arthritis.

1. To exercise your wrist, hold your right arm out with the palm facing down.
2. With your left hand, gently press down on the right hand until you feel a stretch in your wrist and arm.
3. Hold the position for a few seconds.

Repeat 10 times. Then, do the entire sequence with the left hand.</td><td></td></tr>
</table>

8) Fingertip Touch 1. Start with holding your hand and fingers straight and close together. 2. Form an O shape by touching your thumb to each fingertip. 3. Moving slowly and smoothly, touch your index finger to your thumb, then follow with your middle, ring and small fingers. **Repeat this exercise five times with each hand.**	
9) Knuckle Bend Hand exercises can help improve joint flexibility and range of motion in people who have arthritis. 1. Start by holding your hand and fingers straight and close together. 2. Bend the end and middle joints of your fingers. Keep your knuckles straight. 3. Moving slowly and smoothly, return your hand to the starting position. **Repeat this exercise five times with each hand.**	
10) Finger Walk 1. Rest your hand on a flat surface, such as a tabletop, with your palm facing down. 2. Move your thumb away from your hand. Beginning with your index finger, move it up and toward your thumb. 3. Follow with moving your middle, ring and small fingers one at a time up and toward your thumb. **Repeat this exercise five times with each hand.**	

Design Development

What MUST be a part of your solution? This is called the criteria. What does your solution need to have in order to solve the problem? (NOTE: Don't discuss a specific solution here, just the characteristics of a good solution):

Criteria Statement

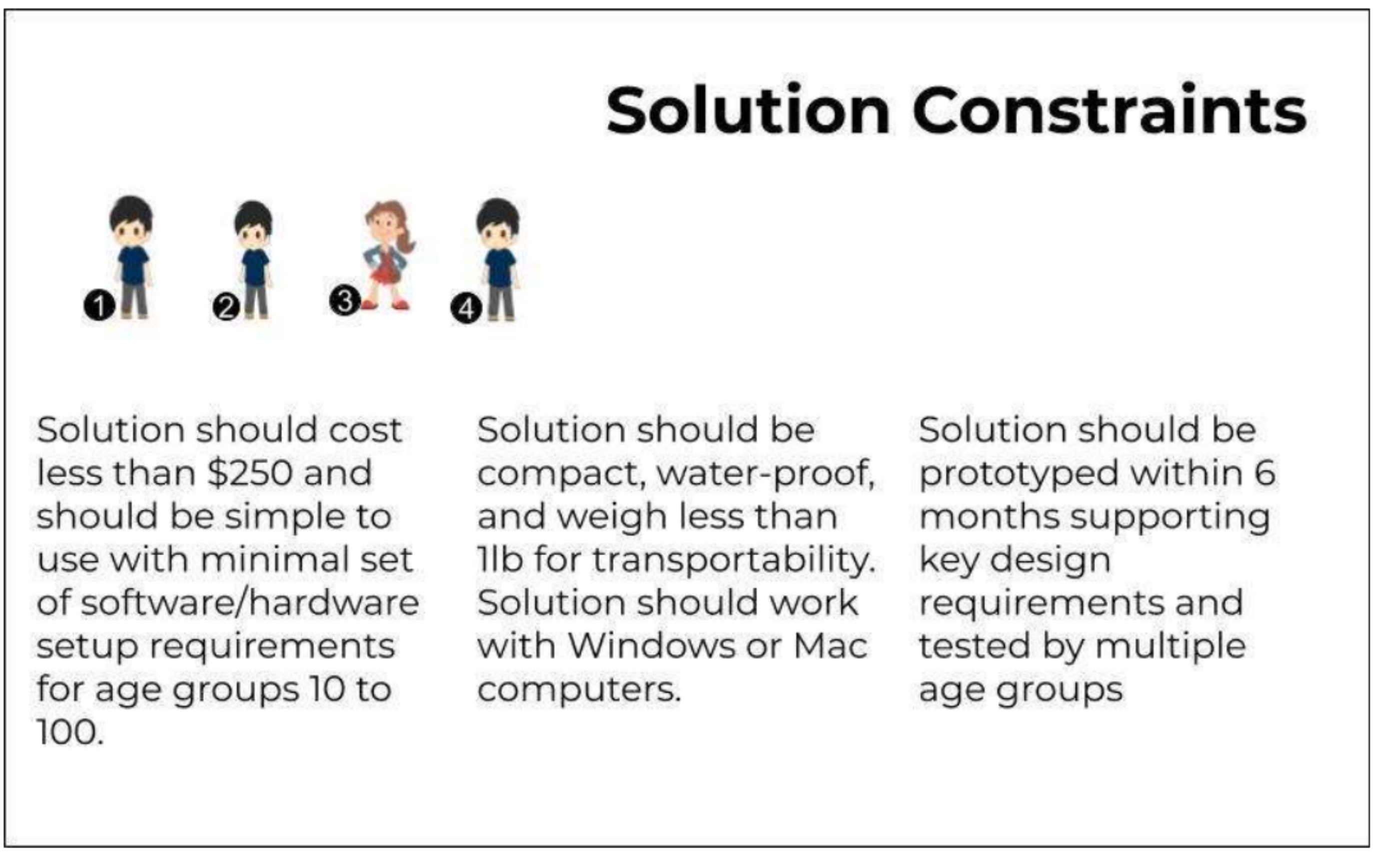
- Our solution should focus on solving problem in a specific community
- Our solution should be usable by all age groups of people
- Our solution should offer equal or better experience than existing solutions
- Our solution should be cheaper than existing solutions
- Our solution should not introduce any side-effects to people who are using it
- Our solution should not require recurring maintenance costs or service fees

Constraints

What limits are there on your solution? These are called constraints. Does it need to be a certain size? A certain weight? Is the cost a factor? Write down all of the limits on your solution:

There were a few constraints on our solution that restricted us:

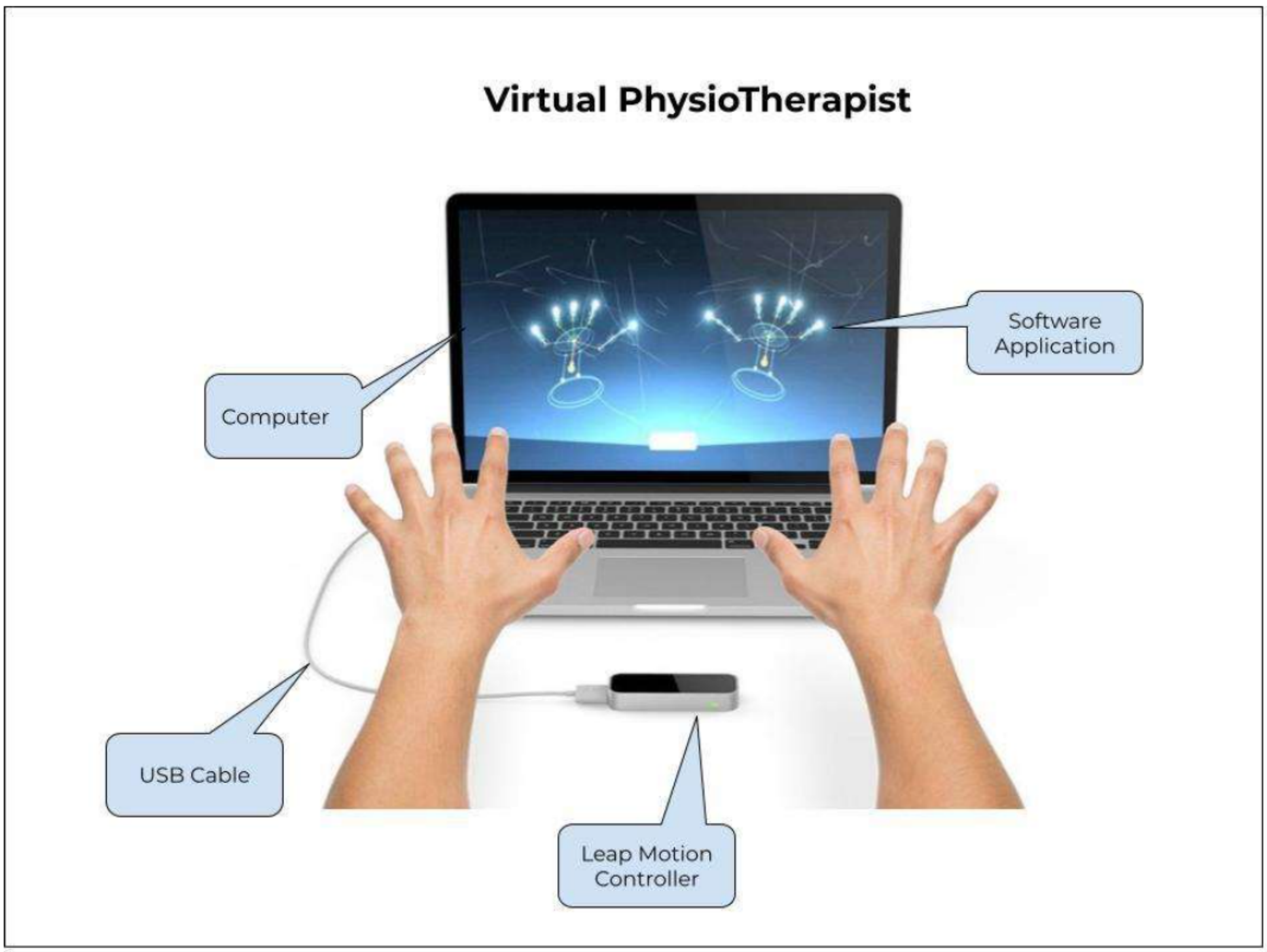
- We had to keep our solution under $250. This restricted us because we had to make our solution as simple as possible while sufficiently solving the problem. We managed to do this by trying to find the cheapest and most-effective parts.
- We also only had 8 months to fully complete our project, which heavily limited us because we weren't able to fully test all the possible forms of arthritis.
- Due to the COVID-19 global pandemic, our state was in lockdown mode for several months during this season. Therefore, we set an additional constraint for our solution to be remotely developed and tested in various locations without us having to get together as a team.
- Our solution also had to be usable and efficient. Another major constraint was that the solution has to be easy to set up with minimal instructions to follow.
- Our solution has to be lightweight so that it can be hand carried by arthritis patients and can connect seamlessly with their existing computers, laptop or a desktop via USB.



Based on your criteria and constraints, what is your proposed solution to the problem you chose? Explain what it will look like and how it will work. If you can, include a detailed, labeled drawing:

Our Solution

Our solution's main purpose was to create a virtual physical therapy experience for patients with arthritis cost-effectively and reliably to allow them to perform their daily exercise routines in the comfort of their own homes. We took on an additional goal to also connect patients with physical therapists online via a web portal. We also graded each of the ten hand exercise performances to maintain and publish daily, weekly, monthly statistics for patients, shareable with their respective families and physical therapists. Based on our research and expert interviews no other similar solution is available on the market, especially at below $250 price point.



High-Level Test plan

Users are expected to perform a total of 10 hand exercises, 3 times each, for a 5 second duration.

Total number of Hand Exercises = 10
Total number of iterations per hand exercise = 3
Duration of each iteration in seconds = 5

For a couple of age groups, we test for the following conditions -

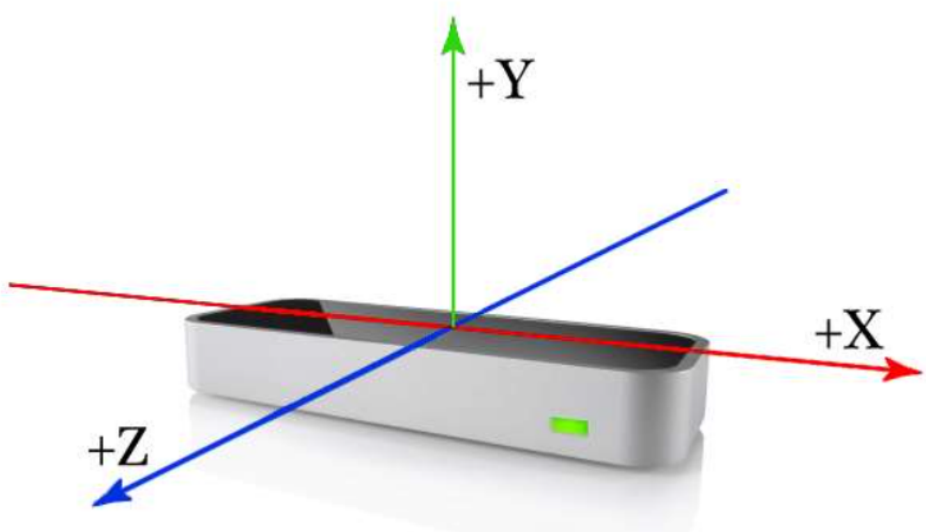
1) Record XYZ coordinates for Stretched hand
    a) Record variation in XYZ coordinates for 5 seconds
    b) Determine the error margin (goal: within 20% variation)

2) For each of ten hand exercises, one exercise at a time
    a) For each iteration of ten total iterations
        i) Record variation in XYZ coordinates for 5 seconds
        ii) Determine the error margin (goal: within 20% variation)
        iii) Update Rewards
            (1) If the error rate is within 20%: Assign 1 point
            (2) If the error rate is within 30%: Assign 0.5 point
            (3) If the error rate is >30%: Assign 0 point
        iv) Summarize total score for 3 iterations
    b) Summarize total score for 10 exercises

Leap Motion Coordinates

The Leap Motion Controller provides coordinates in units of real world millimeters within the Leap Motion frame of reference. That is, if a finger tip's position is given as `(x, y, z) = [100, 100, -100]`, those numbers are millimeters – or, x = +10cm, y = 10cm, z = -10cm.

The Leap Controller hardware itself is the center of this frame of reference. The origin is located at the top, center of the hardware. That is if you touch the middle of the Leap Motion controller (and were able to get data) the coordinates of your finger tip would be [0, 0, 0].



VIRTUAL PHYSIOTHERAPIST ALGORITHM

Setup & Calibration

Record XYZ coordinates for Stretched hand

Record variation in XYZ coordinates for 5 seconds

Determine the error margin (goal: within 20% variation)

Rewards = 0

Total-Rewards = 0

For 1 thru 10 hand-exercises

Total-Rewards = Total-Rewards + Rewards

For 1 thru 3 tries of each exercise

Reset Rewards

Record variation in XYZ coordinates for 5 seconds

Determine the error margin (goal: within 20% variation)

Update Rewards

If the error rate is within 20%: Assign 1 point

If the error rate is within 30%: Assign 0.5 point

If the error rate is >30%: Assign 0 point

Reward = Reward + Points

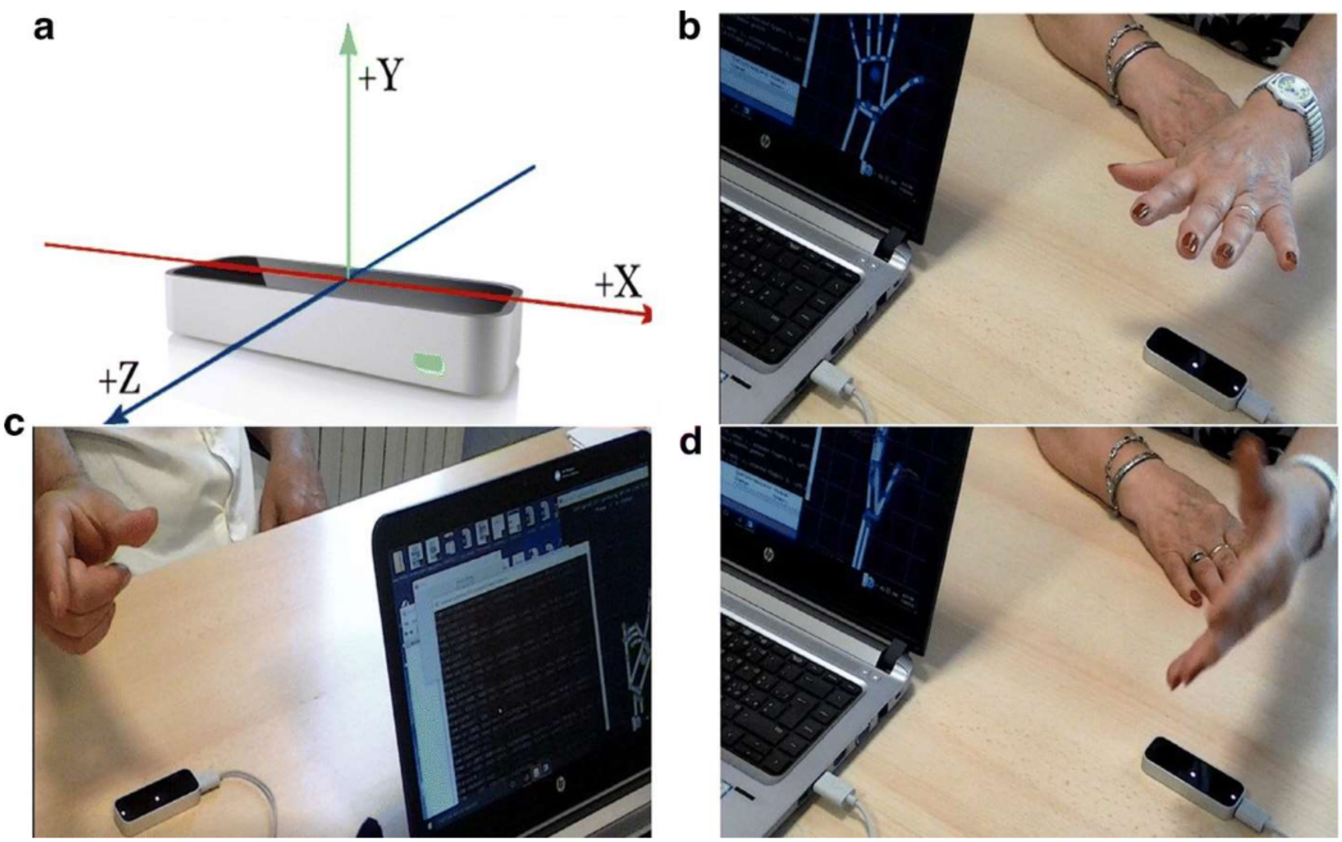
End-For (each-exercise-Trial)

End-For (each-exercise)

Prototype

Using the Leap Motion device, connected to a computer (windows/mac) our "**Virtual Physiotherapist**" solution monitors the X,Y,Z coordinates for each range of motion and the ten hand exercise routines. We used machine learning algorithms to analyze the Leap Motion data and graded the patients performance for ideal expectations. For example, the patient should make a fist for 5 seconds, and repeat this exercise for 10 times, to get the full 10 points. Similarly, for the remaining 9 exercise routines, they will need to do the same to get a full 100 points for each time they exercise virtually at their own homes.

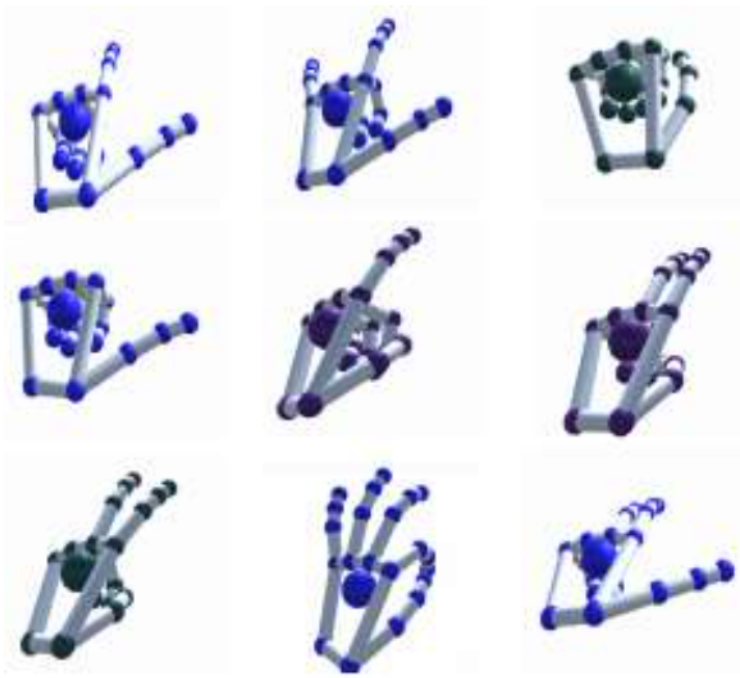
We maintain and publish a log of each exercise and share it with patients, their loved ones (depending on patient's consent) and their respective physical therapists for regular analysis.



Virtual PhysioTherapist Solution

Using the Leap Motion Controller, our Virtual PhysioTherapists solution monitors various hand exercise routines effectively, safely and reliably. The below figure displays screen captures of various movements across multiple age groups.

During the testing we made sure the Leap Motion controller device was placed in a flat surface on the table, and there was sufficient distance between the user's hand and the computer screen as a safety precaution.



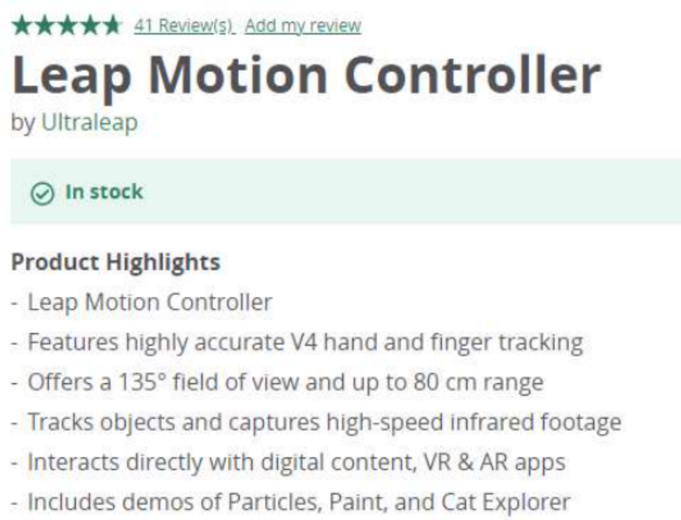
Our prototype has the following 7 components.

1) Leap Motion Controller that connects to a computer (PC/Mac)
2) USB cable to connect the device to computer
3) Unity software to develop Virtual Physiotherapist application
4) Stumptown Virtual Physiotherapists website to connect patients with therapists
5) Machine learning algorithms to analyze hand exercise routines
6) Logging capability to share daily, weekly, monthly statistics
7) Friendly daily reminder to patients to perform their exercise routines

Bill of Materials

#	Material	Unit Cost
1	Leap Motion Controller	$89.99
2	3D Printed Enclosure	$5.00
3	USB Cable to connect to PC/Mac	$0.00
4	Virtual PhysioTherapist Software	$0.00
5	Windows PC or Mac Computer	Required
6	Shipping and Handling Cost	$10.00
	TOTAL COST OF SOLUTION	**$104.99**

Materials


★★★★★ 41 Review(s) Add my review

Leap Motion Controller

by Ultraleap

In stock

Product Highlights

- Leap Motion Controller
- Features highly accurate V4 hand and finger tracking
- Offers a 135° field of view and up to 80 cm range
- Tracks objects and captures high-speed infrared footage
- Interacts directly with digital content, VR & AR apps
- Includes demos of Particles, Paint, and Cat Explorer

Software used

Operating System Windows 10+
Unity Software: https://unity3d.com/get-unity/download
Leap Motion Software Development Kit: https://developer.leapmotion.com/

Windows DOWNLOAD 4.1.0 ›

Mac DOWNLOAD 2.3.1 ›

Linux DOWNLOAD 2.3.1 ›

Testing Solution

How will you test your solution? The BEST way to test your solution is to build a working model or a prototype that you can actually use. Or you can guess how your solution will work BASED ON your research. Which method will you use and why?:

After we built the prototype, we decided to test the accuracy of each hand exercise routine as well as accuracy of the leap motion device in various lighting conditions. For the total 10 exercise types, each requiring 3 iterations, and each iteration for 5 seconds, we developed a healthy dataset which we were able to analyze further for patterns.

```
VIRTUAL PHYSIOTHERAPIST ALGORITHM
Setup & Calibration
Record XYZ coordinates for Stretched hand
        Record variation in XYZ coordinates for 5 seconds
        Determine the error margin (goal: within 20% variation)
Rewards = 0
Total-Rewards = 0

For 1 thru 10 hand-exercises
        Total-Rewards = Total-Rewards + Rewards
        For 1 thru 3 tries of each exercise
            Reset Rewards
            Record variation in XYZ coordinates for 5 seconds
            Determine the error margin (goal: within 20% variation)
            Update Rewards
                If the error rate is within 20%: Assign 1 point
                If the error rate is within 30%: Assign 0.5 point
                If the error rate is >30%: Assign 0 point
            Reward = Reward + Points
        End-For (each-exercise-Trial)
End-For (each-exercise)
```

Test Case Scenarios

We developed the following test plan to comprehend both the hardware and software aspects of our solution. In addition, we have developed a test plan for the web connection with the device at home to move, store and process the collected data for recommendations.

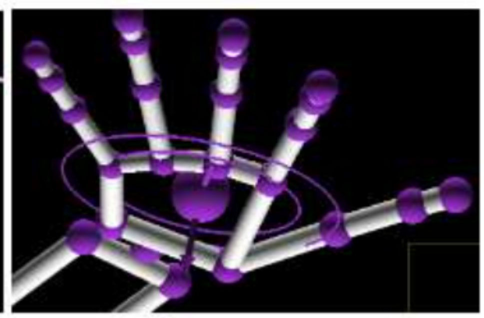
Setup & Calibration

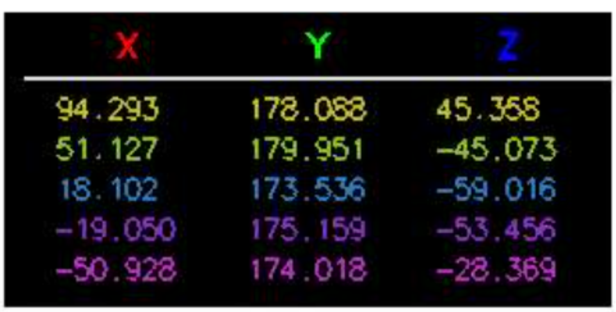
Install the compiled VPT (Virtual Physiotherapist) application on Windows PC without any errors.

Data Collection (Age: 46) - Patient-1

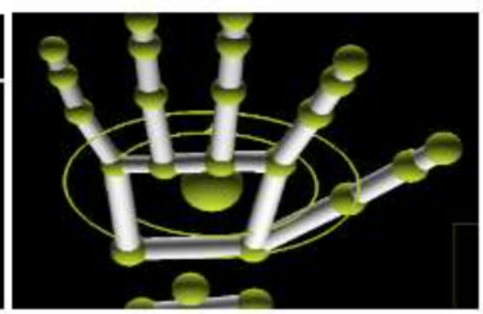
1) **Stretched hand**

X	Y	Z
92.392	176.892	35.273
57.196	210.064	-62.382
33.304	211.507	-80.849
-4.410	217.354	-79.488
-49.788	210.369	-59.237

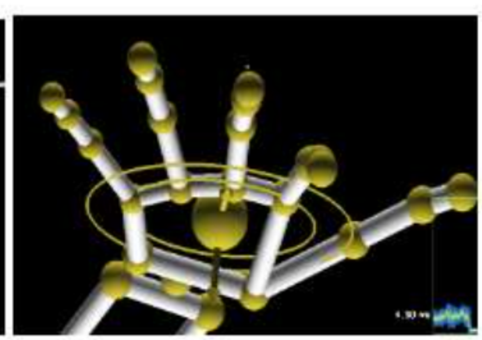




X	Y	Z
94.293	178.088	45.358
51.127	179.951	-45.073
18.102	173.536	-59.016
-19.050	175.159	-53.456
-50.928	174.018	-28.369

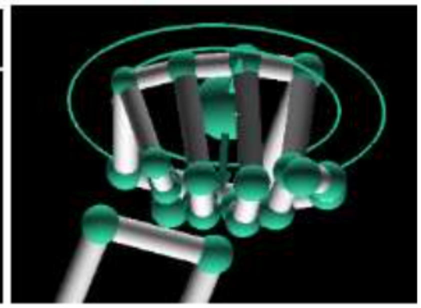


X	Y	Z
94.088	167.810	44.570
52.707	171.833	-45.744
17.630	168.515	-59.961
-21.053	177.189	-56.261
-54.842	172.942	-30.299

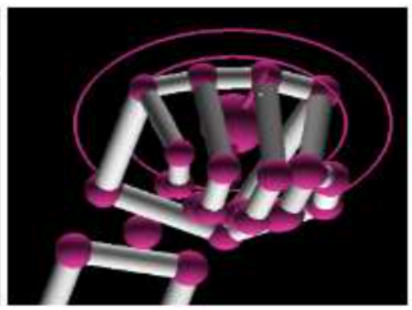


2) Make a Fist

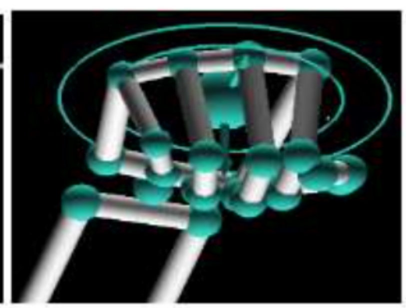
X	Y	Z
49.589	155.606	-5.469
24.834	111.399	17.682
13.376	109.380	20.012
-1.174	109.202	20.779
-14.630	113.911	15.209



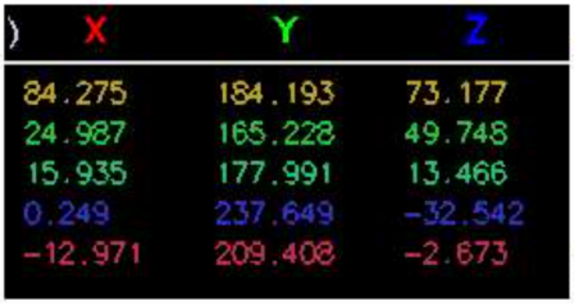
X	Y	Z
51.146	139.413	-26.373
36.613	128.265	14.469
22.578	125.407	14.648
10.350	123.765	13.848
-1.568	127.948	5.847



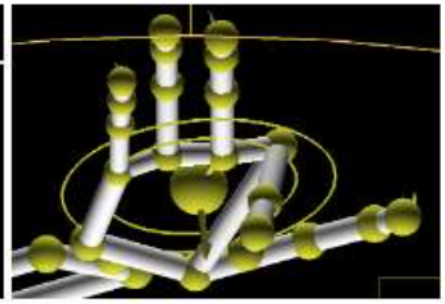
X	Y	Z
56.528	169.317	12.396
23.331	119.945	42.461
12.865	123.961	47.452
-1.472	124.102	49.736
-13.970	128.681	44.239



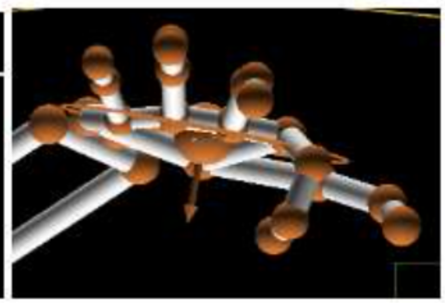
3) Finger Bend

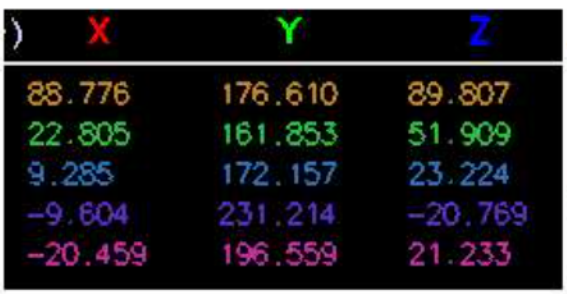


X	Y	Z
84.275	184.193	73.177
24.987	165.228	49.748
15.935	177.991	13.466
0.249	237.649	-32.542
-12.971	209.408	-2.673

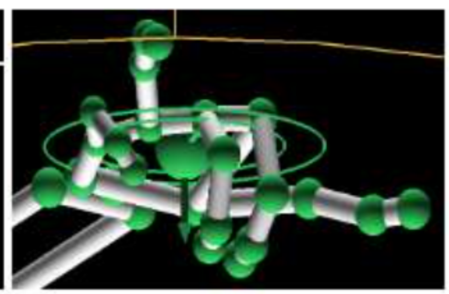


X	Y	Z
94.881	181.884	93.582
30.681	172.220	62.926
25.016	210.152	-0.287
-0.256	253.475	-14.364
-13.682	227.522	9.544



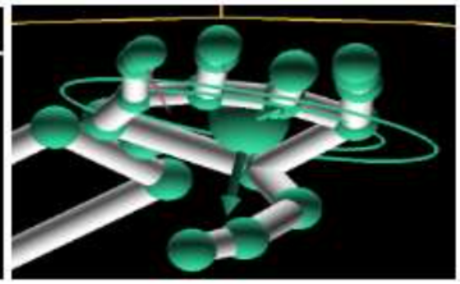


X	Y	Z
88.776	176.610	89.807
22.805	161.853	51.909
9.285	172.157	23.224
-9.604	231.214	-20.769
-20.459	196.559	21.233

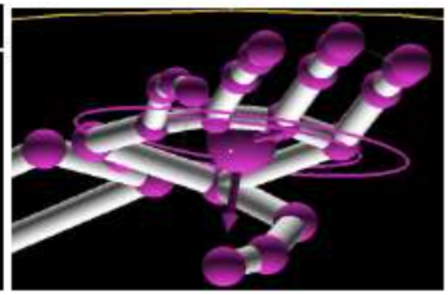


4) Thumb Bend

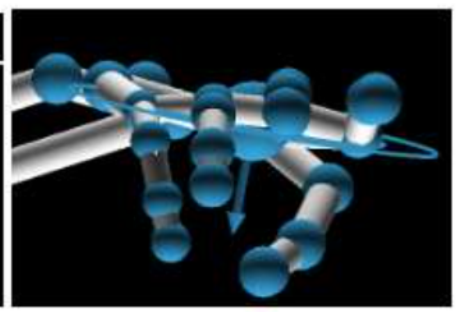
X	Y	Z
27.055	158.115	57.458
55.950	225.918	-15.085
44.425	225.688	-31.338
29.685	219.444	-26.025
8.150	212.157	-6.869



X	Y	Z
25.724	160.689	58.142
55.622	203.322	-18.563
32.057	203.638	-34.323
9.036	191.133	-26.021
-6.495	177.697	6.206

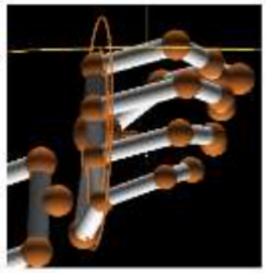


X	Y	Z
27.644	146.581	67.422
58.939	188.407	-4.907
36.565	189.967	-20.046
13.285	179.345	-12.157
-2.100	164.520	19.151

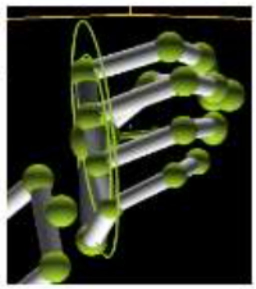


5) Make an 'O'

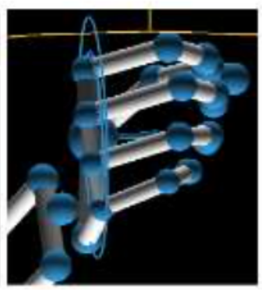
X	Y	Z
44.662	243.941	50.630
31.216	259.365	51.599
36.606	244.854	54.819
36.014	227.899	50.657
27.582	212.785	43.819



X	Y	Z
49.895	214.454	42.946
41.027	225.069	38.859
44.288	208.803	43.156
42.492	191.045	39.691
33.541	176.223	33.419

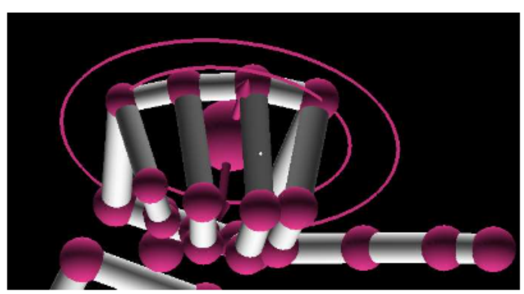


X	Y	Z
44.182	223.321	26.192
34.802	227.490	16.023
36.567	208.035	24.142
32.748	189.567	22.893
22.854	175.225	17.283

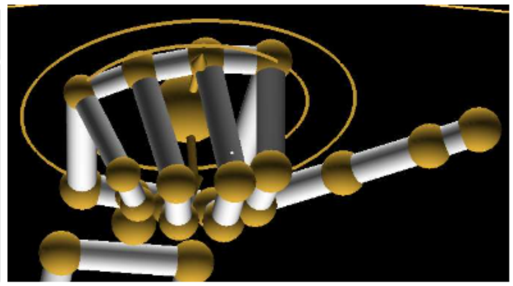


6) Table Bend

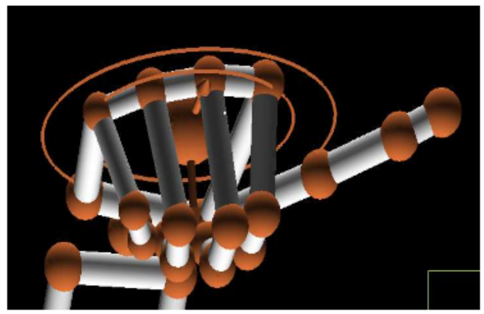
X	Y	Z
82.393	220.072	60.439
4.986	176.993	29.657
-4.617	171.456	31.263
-18.623	170.156	33.928
-31.984	174.020	29.769



X	Y	Z
81.719	193.261	43.810
1.294	168.483	33.568
-9.837	166.693	35.900
-23.922	168.861	39.552
-36.495	174.080	35.146

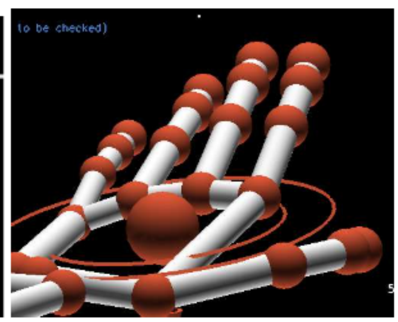


X	Y	Z
81.041	171.537	35.828
6.176	145.469	28.659
-4.989	144.964	31.904
-19.281	148.505	34.697
-30.547	154.946	29.042

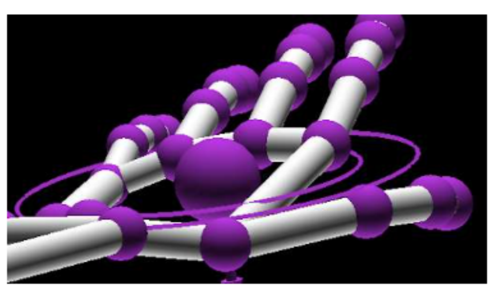


7) Finger-Lift

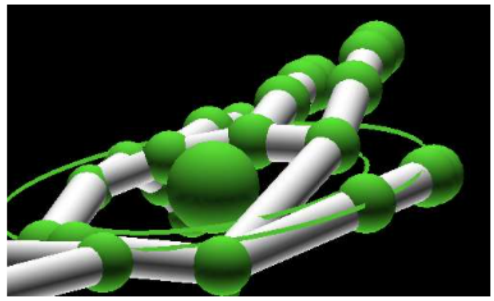
X	Y	Z
52.406	103.556	68.887
35.893	144.055	-11.576
25.983	134.818	-28.838
10.407	126.588	-26.095
-12.475	122.050	-11.799



X	Y	Z
49.742	106.700	51.307
39.352	157.739	-26.286
25.948	158.060	-46.303
6.018	155.801	-44.631
-19.506	147.514	-29.080

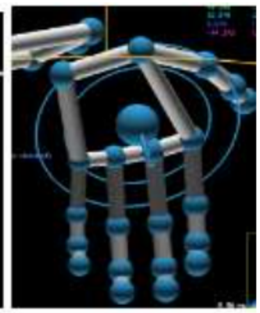


X	Y	Z
51.730	129.229	38.884
20.567	164.845	-44.745
-6.789	153.703	-59.500
-25.727	138.415	-48.473
-44.144	140.673	-30.350

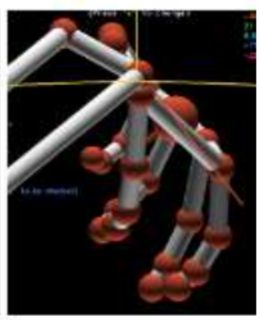


8) Wrist Stretch

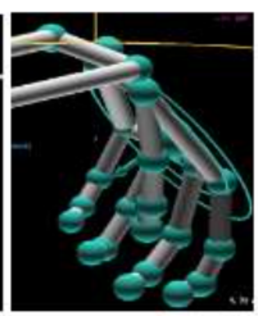
X	Y	Z
56.746	215.607	-3.331
26.178	131.462	-2.476
6.066	117.739	-4.565
-14.431	124.044	-3.574
-31.257	146.158	-0.439



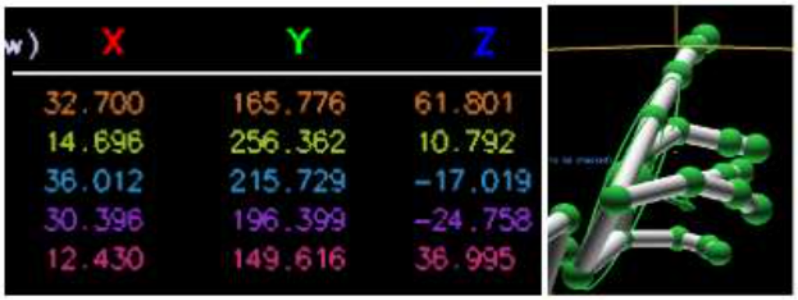
X	Y	Z
43.238	194.234	54.437
66.840	159.375	47.214
49.582	148.684	38.673
26.160	150.371	38.617
6.166	167.443	45.604



X	Y	Z
30.511	134.140	59.096
26.954	135.293	61.650
11.498	149.918	62.959
-0.556	165.091	58.264
-4.359	177.429	51.267

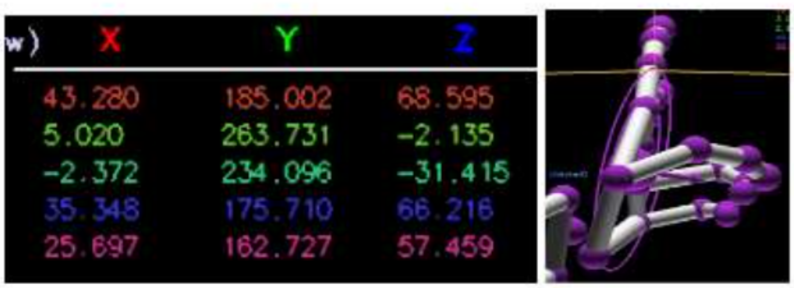


9) Finger Touch



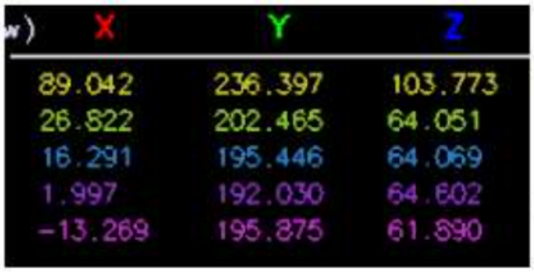
w)	X	Y	Z
	32.700	165.776	61.801
	14.696	256.362	10.792
	36.012	215.729	-17.019
	30.396	196.399	-24.758
	12.430	149.616	36.995

w)	X	Y	Z
	44.372	211.032	62.892
	-6.467	281.240	-13.085
	-4.827	250.832	-38.490
	31.161	201.799	61.385
	27.756	186.455	57.986

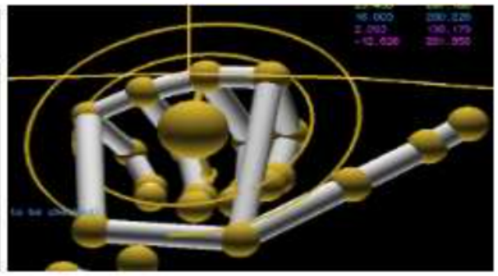


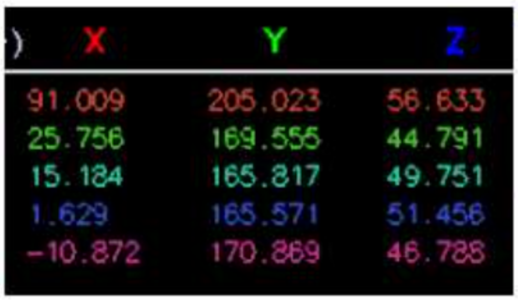
w)	X	Y	Z
	43.280	185.002	68.595
	5.020	263.731	-2.135
	-2.372	234.096	-31.415
	35.348	175.710	66.216
	25.697	162.727	57.459

10)Knuckle Bend

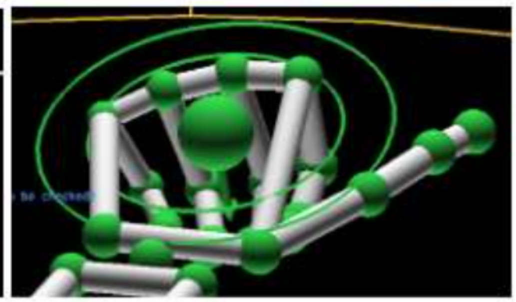


w)	X	Y	Z
	89.042	236.397	103.773
	26.822	202.465	64.051
	16.291	195.446	64.069
	1.997	192.030	64.602
	-13.269	195.875	61.890

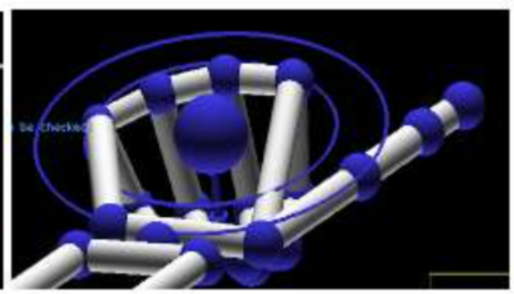




)	X	Y	Z
	91.009	205.023	56.633
	25.756	169.555	44.791
	15.184	165.817	49.751
	1.629	165.571	51.456
	-10.872	170.869	46.788

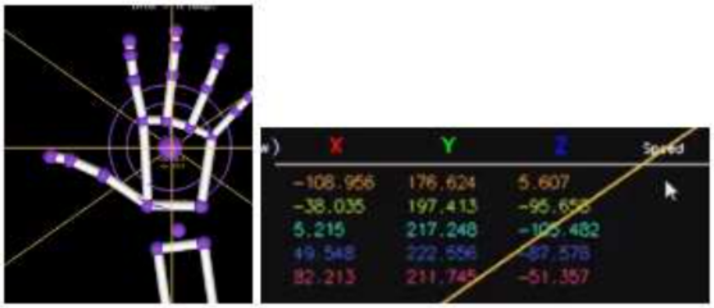


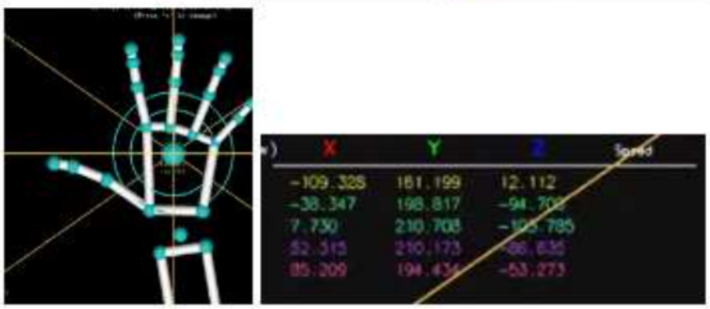
w)	X	Y	Z
	83.597	157.868	33.296
	20.141	106.455	34.880
	10.068	105.617	40.018
	-3.388	106.498	42.655
	-15.340	110.975	38.529

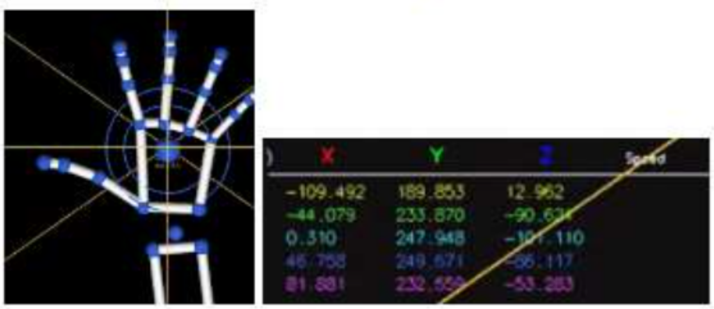


Data Collection (Age: 44) - Patient-2

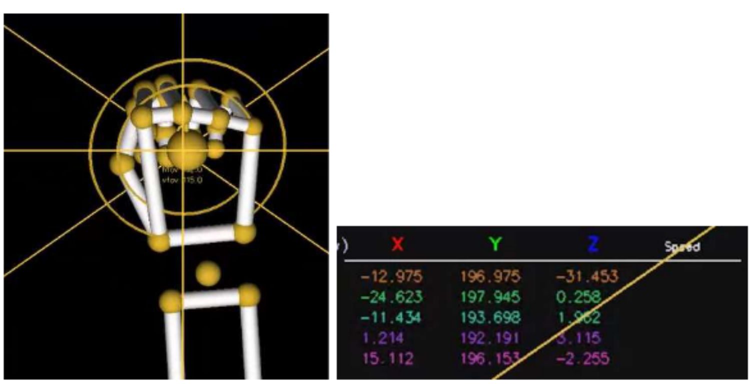
1. **Stretched Hand**

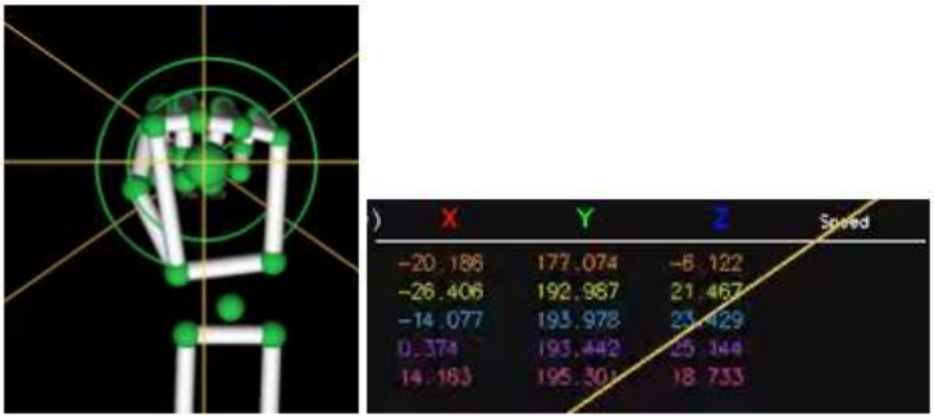


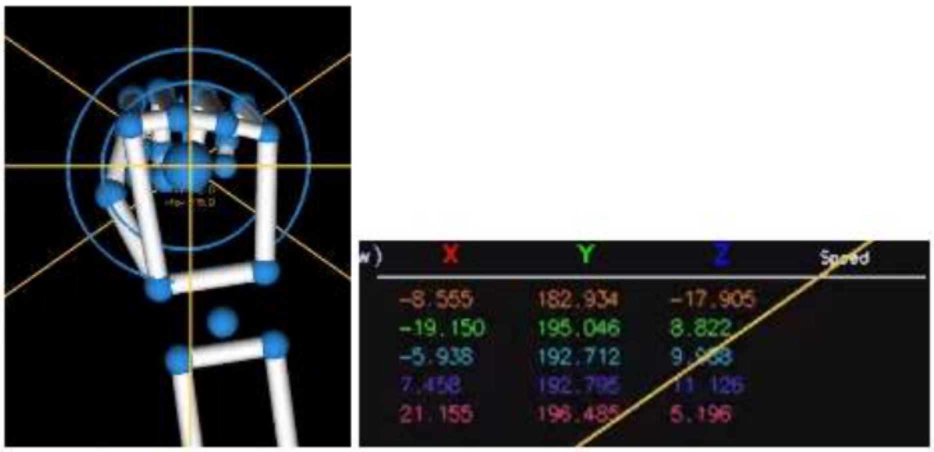




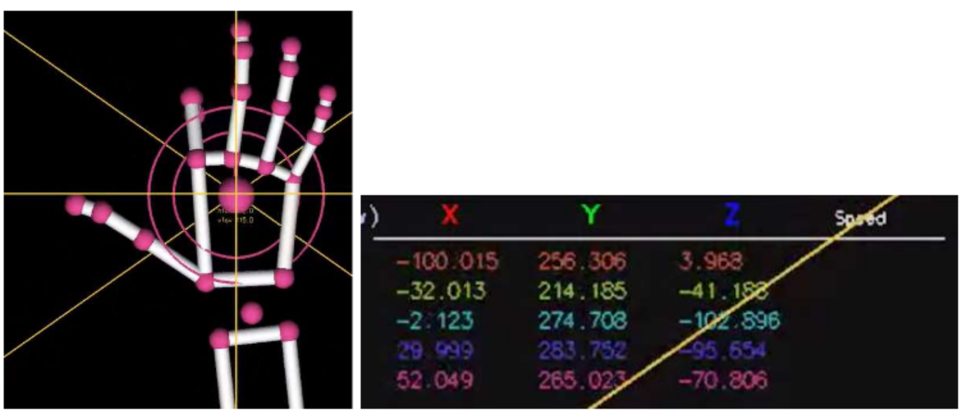
2. **Make a Fist**

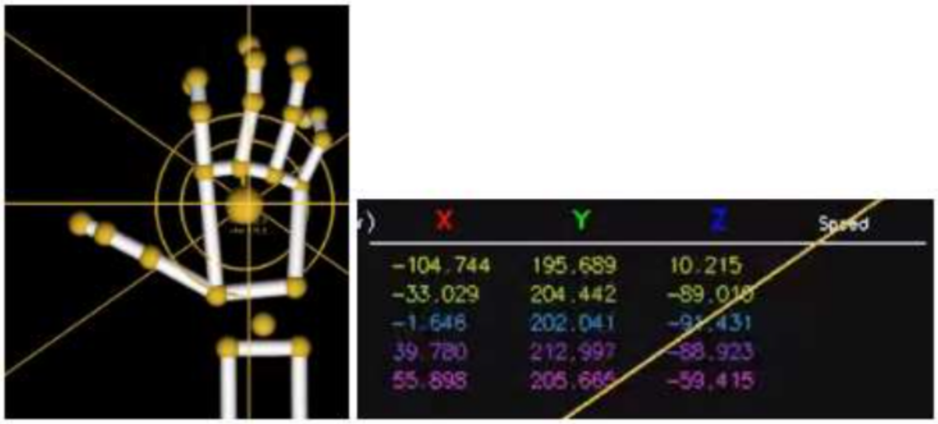


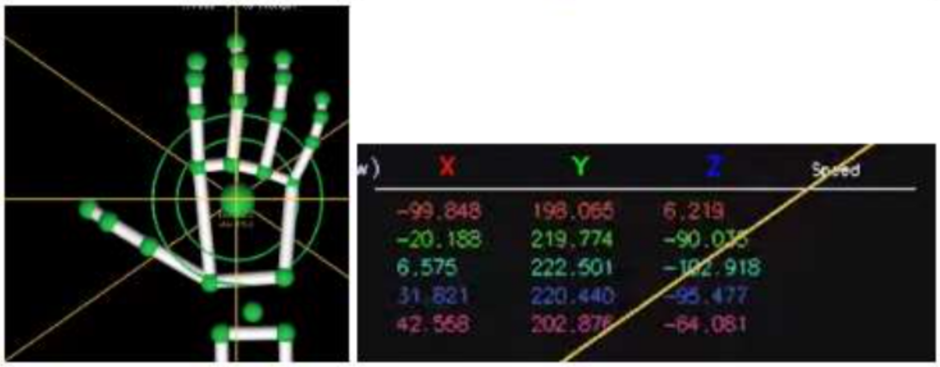




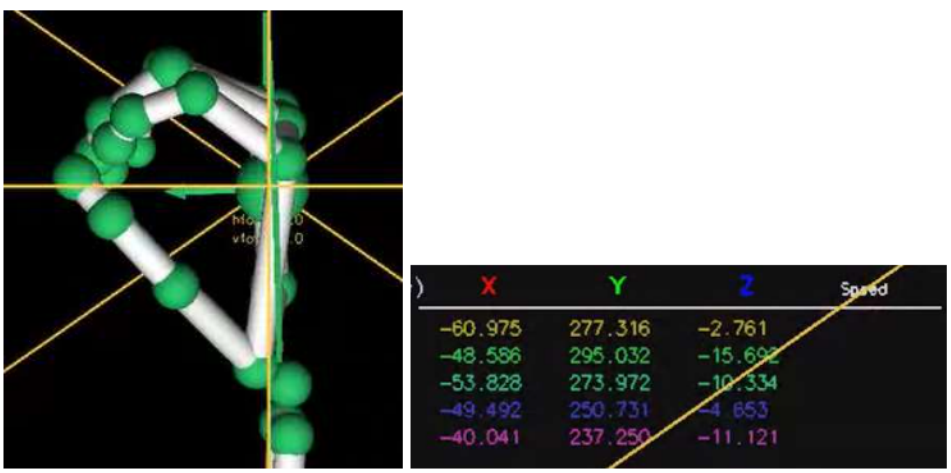
3. Finger Bend

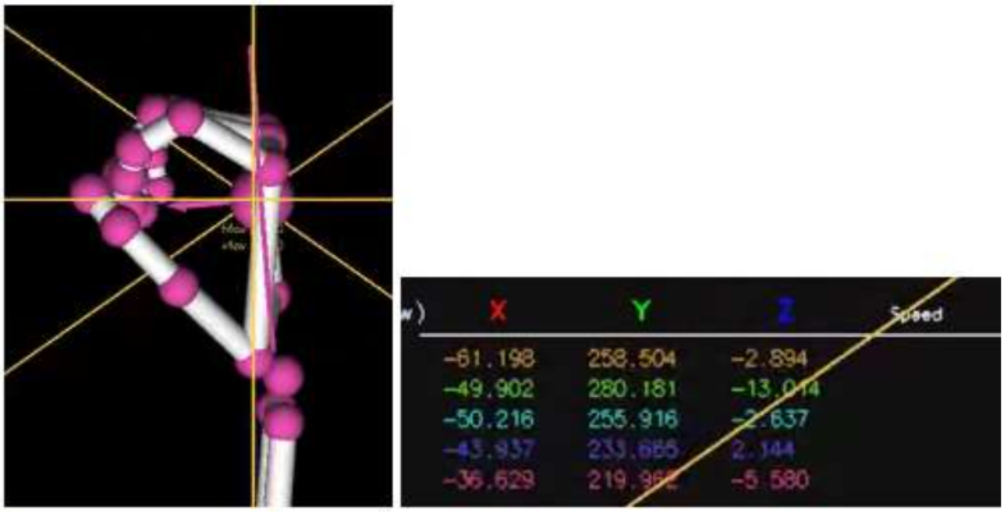


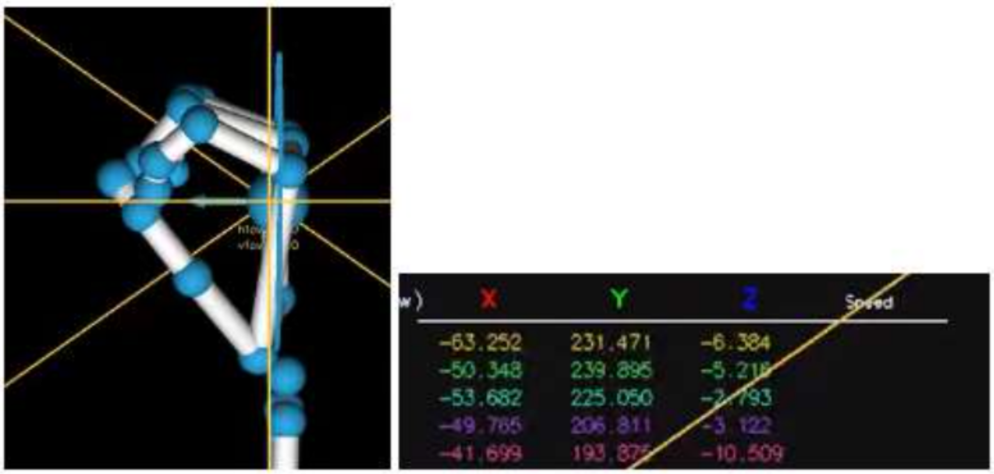

X Y Z Speed
-104.744 195.689 10.215
-33.029 204.442
-1.646 202.041
39.780 212.997 -88.923
55.898 -59.415


X Y Z Speed
-99.848 198.065 6.219
-20.188 219.774
6.575 222.501
31.821 220.440 -95.477
42.568 -64.081

4. **Make an 'O'**

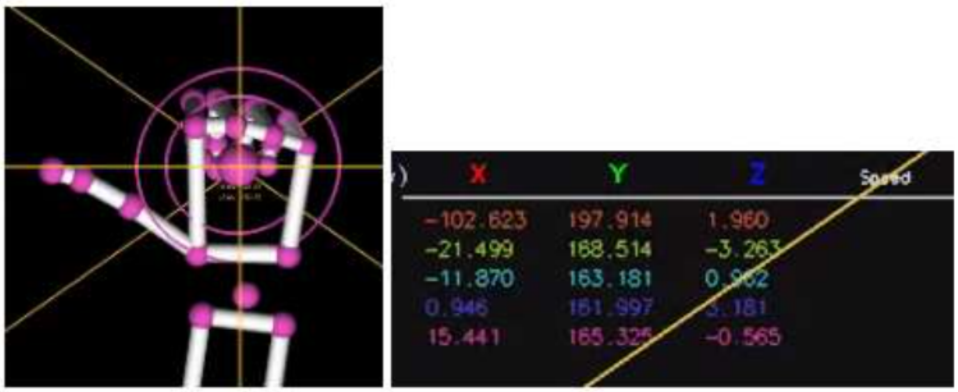

X Y Z Speed
-60.975 277.316 -2.761
-48.586 295.032
-53.828 273.972 -10.334
-49.492 250.731 -4.653
-40.041 237.250 -11.121


X Y Z Speed
-61.198 258.504 -2.894
-49.902 280.181 -13.014
-50.216 255.916 -2.637
-43.937 233.665 2.144
-36.629 219.962 -5.580

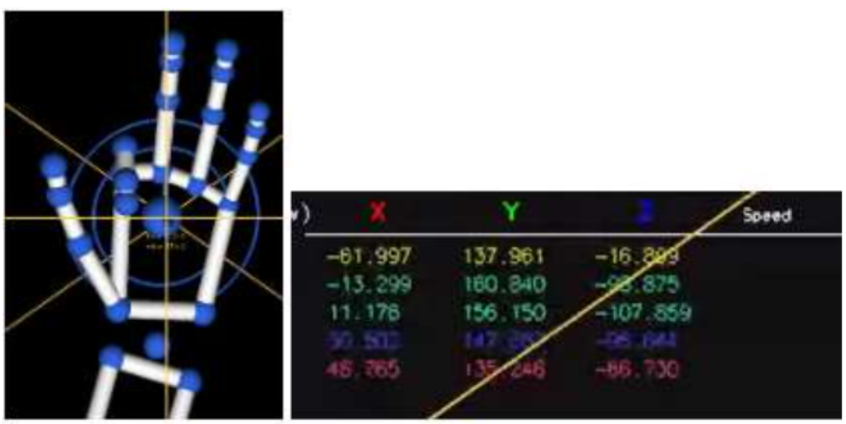

X Y Z Speed
-63.252 231.471 -6.384
-50.348 239.895 -5.218
-53.682 225.050 -2.793
-49.765 206.811 -3.122
-41.699 193.875 -10.509

5. Table Bend


X Y Z Speed
-100.735 153.293 5.946
-14.175 140.524 -5.069
-3.850 135.784 -1.681
8.996 138.391 1.138
22.235 145.208 -2.024

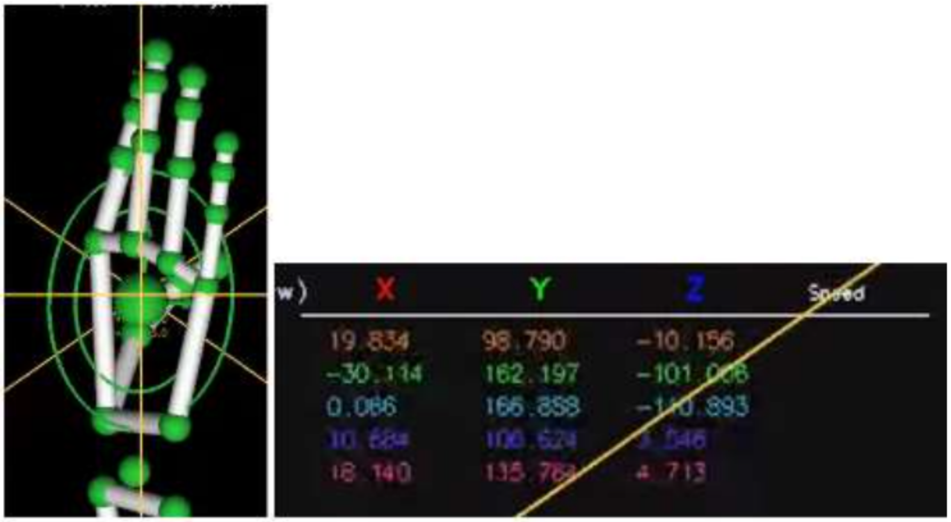


6. Finger Lift

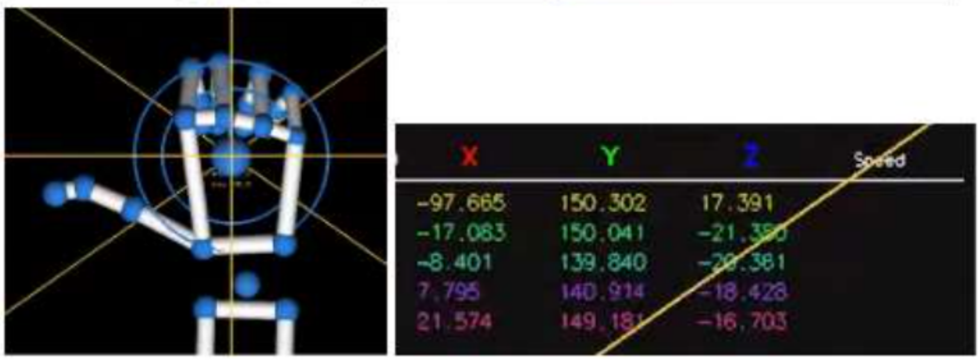


7. **Wrist Stretch**

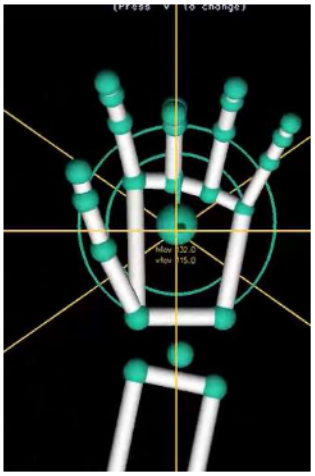
8. **Fingertip Touch**

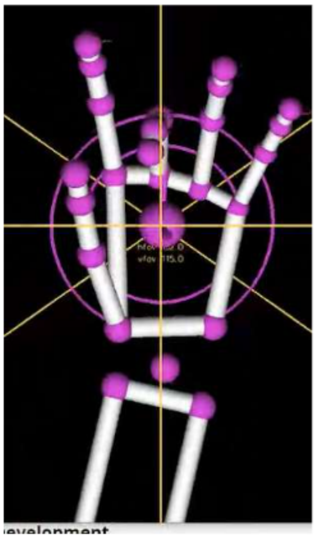


9. **Knuckle Bend**



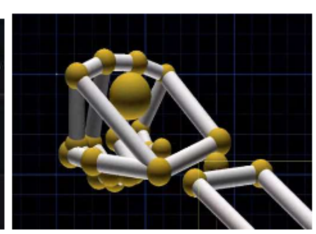
10. Finger Walk



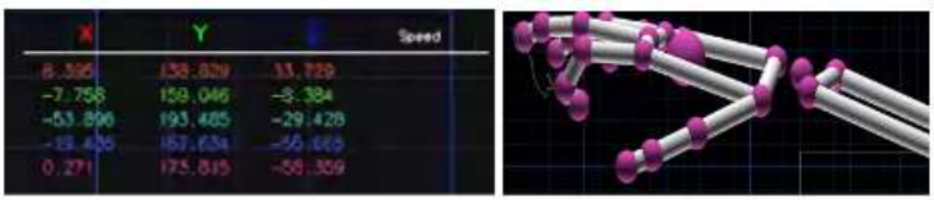


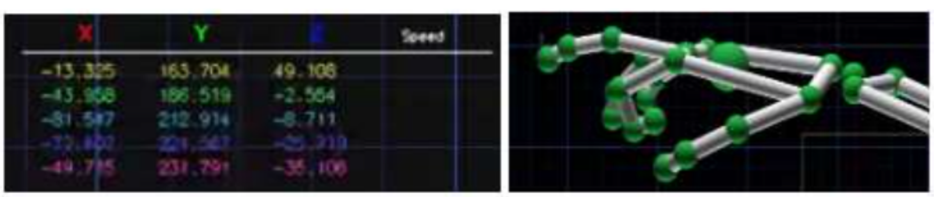
Data Collection (Age: 13)

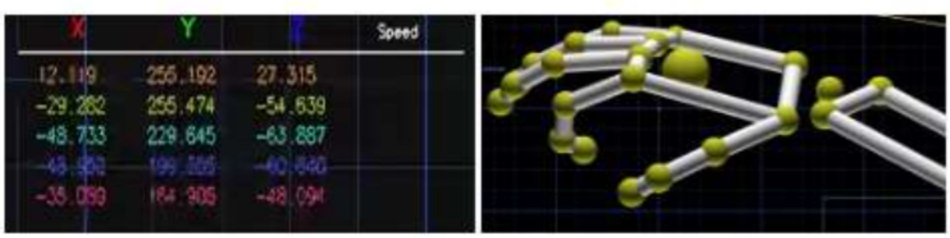
1. **Make a Fist**



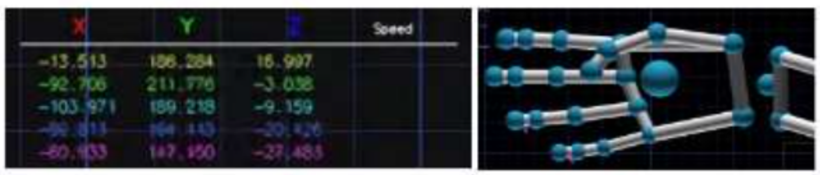
2. Finger Bend





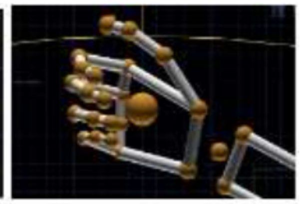


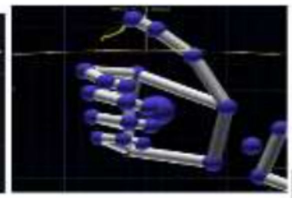
3. Thumb Bend

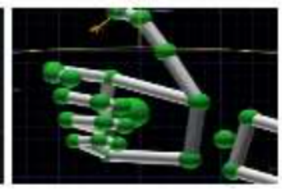


4. Make an 'O'

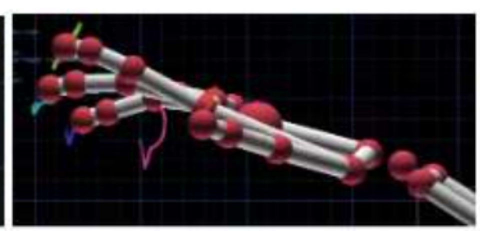
5. Table Bend

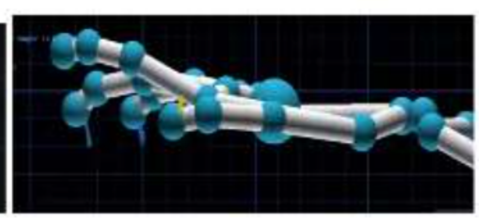






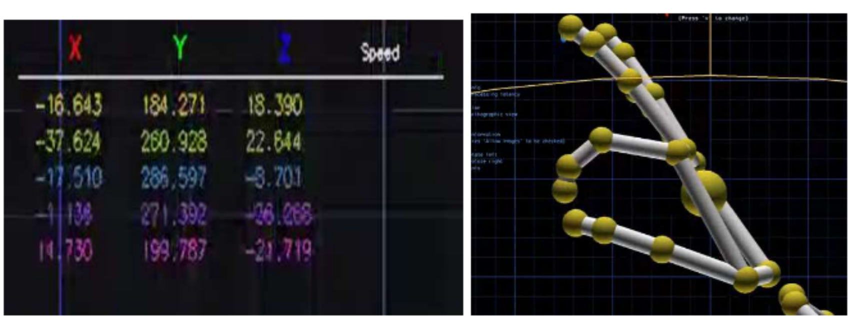
6. Finger-Lift

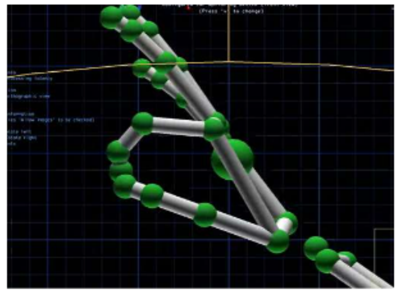


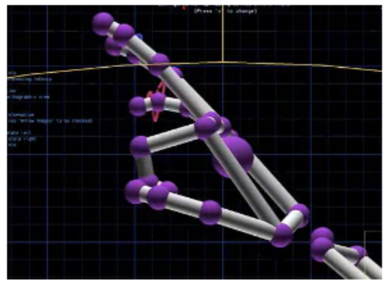


7. Wrist Stretch

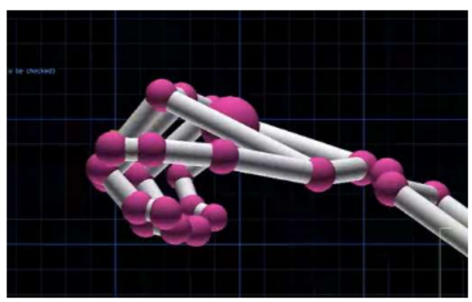
8. Finger Touch



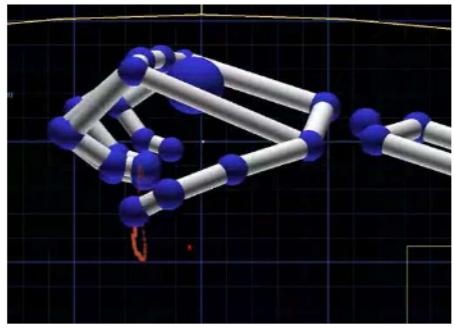




9. Knuckle Bend



X	Y	Z	Speed
38.344	253.600	72.867	
-2.686	213.139	30.724	
-9.963	191.665	27.322	
-3.947	168.491	33.725	
13.210	146.989	46.997	



Unity Program Software

```
* This program tracks hand movements and displays XYZ coordinates relative to center of the palm

using UnityEngine;
using System.Collections;
using Leap;

namespace Leap.Unity{

 public abstract class HandModel : HandModelBase {

  [SerializeField]
  private Chirality handedness;
  public override Chirality Handedness {
   get { return handedness; }
   set { handedness = value; }
  }

  private ModelType handModelType;
  public override abstract ModelType HandModelType {
   get;
  }

  /** The number of fingers on a hand.*/
  public const int NUM_FINGERS = 5;
```

```
/** The model width of the hand in meters. This value is used with the measured value
* of the user's hand to scale the model proportionally.
*/
public float handModelPalmWidth = 0.085f;
/** The array of finger objects for this hand. The array is ordered from thumb (element 0) to pinky
(element 4).*/
public FingerModel[] fingers = new FingerModel[NUM_FINGERS];

// Unity references
/** Transform object for the palm object of this hand. */
public Transform palm;
/** Transform object for the forearm object of this hand. */
public Transform forearm;
/** Transform object for the wrist joint of this hand. */
public Transform wristJoint;
/** Transform object for the elbow joint of this hand. */
public Transform elbowJoint;

// Leap references
/** The Leap Hand object this hand model represents. */
protected Hand hand_;

/** Calculates the position of the palm in global coordinates.
* @returns A Vector3 containing the Unity coordinates of the palm position.
*/
public Vector3 GetPalmPosition() {
  return hand_.PalmPosition.ToVector3();
}

/** Calculates the rotation of the hand in global coordinates.
* @returns A Quaternion representing the rotation of the hand.
*/
public Quaternion GetPalmRotation() {
  if (hand_ != null) {
```

```
    // The hand Basis vectors are calculated explicitly.  This requires using Basis.CalculateRotation()
    // instead of Basis.quaternion.
    return hand_.Basis.CalculateRotation();
  }
  if (palm) {
    return palm.rotation;
  }
  return Quaternion.identity;
}

/** Calculates the direction vector of the hand in global coordinates.
* @returns A Vector3 representing the direction of the hand.
*/
public Vector3 GetPalmDirection() {
  if (hand_ != null) {
    return hand_.Direction.ToVector3();
  }
  if (palm) {
    return palm.forward;
  }
  return Vector3.forward;
}

/** Calculates the normal vector projecting from the hand in global coordinates.
* @returns A Vector3 representing the vector perpendicular to the palm.
*/
public Vector3 GetPalmNormal() {
  if (hand_ != null) {
    return hand_.PalmNormal.ToVector3();
  }
  if (palm) {
    return -palm.up;
  }
  return -Vector3.up;
}
```

```
/** Calculates the direction vector of the forearm in global coordinates.
* @returns A Vector3 representing the direction of the forearm (pointing from elbow to wrist).
*/
public Vector3 GetArmDirection() {
 if (hand_ != null) {
  return hand_.Arm.Direction.ToVector3();
 }
 if (forearm) {
  return forearm.forward;
 }
 return Vector3.forward;
}

/** Calculates the center of the forearm in global coordinates.
* @returns A Vector3 containing the Unity coordinates of the center of the forearm.
*/
public Vector3 GetArmCenter() {
 if (hand_ != null) {
  Vector leap_center = 0.5f * (hand_.Arm.WristPosition + hand_.Arm.ElbowPosition);
  return leap_center.ToVector3();
 }
 if (forearm) {
  return forearm.position;
 }
 return Vector3.zero;
}

/** Returns the measured length of the forearm in meters.*/
public float GetArmLength() {
 return (hand_.Arm.WristPosition - hand_.Arm.ElbowPosition).Magnitude;
}

/** Returns the measured width of the forearm in meters.*/
public float GetArmWidth() {
```

```
  return hand_.Arm.Width;
}

/** Calculates the position of the elbow in global coordinates.
* @returns A Vector3 containing the Unity coordinates of the elbow.
*/
public Vector3 GetElbowPosition() {
  if (hand_ != null) {
    Vector3 local_position = hand_.Arm.ElbowPosition.ToVector3();
    return local_position;
  }
  if (elbowJoint) {
    return elbowJoint.position;
  }
  return Vector3.zero;
}

/** Calculates the position of the wrist in global coordinates.
* @returns A Vector3 containing the Unity coordinates of the wrist.
*/
public Vector3 GetWristPosition() {
  if (hand_ != null) {
    Vector3 local_position = hand_.Arm.WristPosition.ToVector3();
    return local_position;
  }
  if (wristJoint) {
    return wristJoint.position;
  }
  return Vector3.zero;
}

/** Calculates the rotation of the forearm in global coordinates.
* @returns A Quaternion representing the rotation of the arm.
*/
public Quaternion GetArmRotation() {
```

```
  if (hand_ != null) {
    Quaternion local_rotation = hand_.Arm.Rotation.ToQuaternion();
    return local_rotation;
  }
  if (forearm) {
    return forearm.rotation;
  }
  return Quaternion.identity;
}

/**
* Returns the Leap Hand object represented by this HandModel.
* Note that any physical quantities and directions obtained from the
* Leap Hand object are relative to the Leap Motion coordinate system,
* which uses right-handed axes and units of millimeters.
*/
public override Hand GetLeapHand() {
  return hand_;
}

/**
* Assigns a Leap Hand object to this hand model.
* Note that the Leap Hand objects are recreated every frame. The parent
* HandController calls this method to set or update the underlying hand.
*/
public override void SetLeapHand(Hand hand) {
  hand_ = hand;
  for (int i = 0; i < fingers.Length; ++i) {
    if (fingers[i] != null) {
      fingers[i].SetLeapHand(hand_);
    }
  }
}

/**
```

```
 * Implement this function to initialise this hand after it is created.
 * This function is called by the HandController during the Unity Update() phase when a new hand is
detected
 * by the Leap Motion device.
 */
 public override void InitHand() {
  for (int f = 0; f < fingers.Length; ++f) {
   if (fingers[f] != null) {
    fingers[f].fingerType = (Finger.FingerType)f;
    fingers[f].InitFinger();
   }
  }
 }

 /**
  * Returns the ID associated with the hand in the Leap API.
  * This ID is guaranteed to be unique among all hands in a frame,
  * and is invariant for the lifetime of the hand model.   */
 public int LeapID() {
  if (hand_ != null) {
   return hand_.Id;
  }
  return -1;
 }
 public override abstract void UpdateHand();
}
}
```

Testing Criteria

Explain how you tested your prototype or model. Be sure to include every step of your testing including all safety precautions that were taken. If not stated it will be assumed no safety precautions were taken. If you are using research to guess how your solution will work, explain step-by-step how it will work and why:

We tested every single component in our prototype for specific criteria. For the ten hand exercise routines, we followed procedures carefully using safety precautions. In the below sections we explain our testing criteria and constraints. In the section below we will comprehend our test procedures and observations for each step.


Patient Name:

Statistics

Monthly Weekly Daily

Daily Stats

Hand Exercise	# of Times	Duration	Status	Points
1	10	5s		10
2	10	5s		10
3	10	5s		10
4	10	5s		10
5	10	5s		7
6	10	5s		10
7	10	5s		10
8	10	5s		6
9	10	5s		9
10	10	5s		3

85

Data & Error Analysis

Exercise-1 (Stretch Hand)

Iteration		x value	y value	z value	x-error	y-error	z-error
1	finger 1	92.392	176.892	35.273	-1.28%	1.71%	-15.48%
	finger 2	57.196	210.064	-62.382	6.56%	12.16%	22.16%

	finger 3	33.304	211.507	-80.849	44.72%	14.63%	203.55%
	finger 4	-4.41	217.354	-79.488	-70.28%	14.46%	26.03%
	finger 5	-49.788	210.369	-59.237	-3.98%	13.24%	50.72%
2	finger 1	94.293	178.088	45.358	0.75%	2.40%	8.68%
	finger 2	51.127	179.951	-45.073	-4.75%	-3.91%	-11.74%
	finger 3	18.102	173.536	-59.016	-21.34%	-5.95%	121.58%
	finger 4	-19.05	175.159	-53.456	28.39%	-7.76%	-15.24%
	finger 5	-50.928	174.018	-28.369	-1.78%	-6.33%	-27.82%
3	finger 1	94.088	166.781	44.57	0.53%	-4.10%	6.80%
	finger 2	52.707	171.833	-45.744	-1.81%	-8.25%	-10.42%
	finger 3	17.63	168.515	59.961	-23.39%	-8.67%	-325.12%
	finger 4	-21.053	177.189	-56.261	41.89%	-6.69%	-10.79%
	finger 5	-54.842	172.942	-30.299	5.77%	-6.91%	-22.91%
average	finger 1	93.591	173.920	41.734			
	finger 2	53.677	187.283	-51.066			
	finger 3	23.012	184.519	-26.635			
	finger 4	-14.838	189.901	-63.068			
	finger 5	-51.853	185.776	-39.302			

Exercise-2 (Make a Fist)

Iteration		x value	y value	z value	x-error	y-error	z-error
1	finger 1	49.589	155.606	-5.468	-5.40%	0.53%	-15.64%
	finger 2	24.8324	111.399	17.682	-12.13%	-7.07%	-28.90%
	finger 3	13.376	109.38	20.012	-17.80%	-8.53%	-26.89%
	finger 4	-1.174	109.202	20.779	-145.72%	-8.25%	-26.11%
	finger 5	-14.63	113.911	15.209	45.49%	-7.77%	-30.12%
2	finger 1	51.146	139.413	-26.373	-2.43%	-9.93%	306.89%
	finger 2	36.613	128.265	14.469	29.56%	7.00%	-41.82%
	finger 3	22.578	125.407	14.648	38.75%	4.87%	-46.48%
	finger 4	10.35	123.765	13.848	303.04%	3.98%	-50.76%
	finger 5	-1.568	127.948	5.847	-84.41%	3.59%	-73.14%
3	finger 1	56.528	169.317	12.396	7.83%	9.39%	-291.25%
	finger 2	23.331	119.945	42.461	-17.44%	0.06%	70.73%
	finger 3	12.865	123.961	47.452	-20.94%	3.66%	73.37%
	finger 4	-1.472	124.102	49.736	-157.32%	4.27%	76.86%
	finger 5	-13.97	128.681	44.239	38.92%	4.18%	103.26%
average	finger 1	52.421	154.779	-6.482			
	finger 2	28.259	119.870	24.871			
	finger 3	16.273	119.583	27.371			
	finger 4	2.568	119.023	28.121			
	finger 5	-10.056	123.513	21.765			

Exercise-3 (Finger Bend)

Iteration		x value	y value	z value	x-error	y-error	z-error
1	finger 1	84.275	184.193	73.177	-5.64%	1.82%	-14.43%
	finger 2	24.987	165.228	49.748	-4.48%	-0.72%	-9.32%
	finger 3	15.935	177.991	13.466	-4.84%	-4.70%	10.97%
	finger 4	0.249	237.649	-32.542	-107.77%	-1.30%	44.26%
	finger 5	-12.971	209.408	-2.673	-17.40%	-0.83%	-128.53%
2	finger 1	94.881	181.884	93.582	6.24%	0.55%	9.42%
	finger 2	30.681	172.22	62.926	17.29%	3.48%	14.70%
	finger 3	25.016	210.152	-0.287	49.39%	12.52%	-102.37%
	finger 4	-0.256	253.475	-14.364	-92.01%	5.27%	-36.33%
	finger 5	-13.682	227.522	9.544	-12.88%	7.75%	1.88%
3	finger 1	88.776	176.61	89.807	-0.60%	-2.37%	5.01%
	finger 2	22.805	161.853	51.909	-12.82%	-2.75%	-5.38%
	finger 3	9.285	172.157	23.224	-44.55%	-7.82%	91.39%
	finger 4	-9.604	231.214	-20.769	199.78%	-3.97%	-7.93%
	finger 5	-20.459	196.559	21.233	30.28%	-6.92%	126.65%
average	finger 1	89.311	180.896	85.522			
	finger 2	26.158	166.434	54.861			
	finger 3	16.745	186.767	12.134			
	finger 4	-3.204	240.779	-22.558			
	finger 5	-15.704	211.163	9.368			

Exercise-4 (Thumb Bend)

Iteration		x value	y value	z value	x-error	y-error	z-error
1	finger 1	27.055	158.115	57.458	0.92%	1.93%	-5.82%
	finger 2	55.95	225.918	-15.085	-1.56%	9.73%	17.38%
	finger 3	44.425	225.688	-31.338	17.89%	9.33%	9.69%
	finger 4	29.685	219.444	-26.025	71.24%	11.60%	21.61%
	finger 5	8.15	212.157	-6.869	-5594.38%	14.81%	-211.47%
2	finger 1	25.724	160.689	58.142	-4.04%	3.58%	-4.70%
	finger 2	55.622	203.322	-18.563	-2.14%	-1.24%	44.44%
	finger 3	32.057	203.638	-34.323	-14.93%	-1.35%	20.14%
	finger 4	9.035	191.133	-26.021	-47.88%	-2.80%	21.59%
	finger 5	-6.495	177.697	6.205	4278.65%	-3.84%	0.69%
3	finger 1	27.644	146.581	67.422	3.12%	-5.51%	10.51%
	finger 2	58.939	188.407	-4.907	3.70%	-8.49%	-61.82%
	finger 3	36.565	189.967	-20.046	-2.97%	-7.98%	-29.83%
	finger 4	13.285	179.345	-12.157	-23.36%	-8.80%	-43.19%
	finger 5	-2.1	164.52	19.151	1315.73%	-10.97%	210.78%
average	finger 1	26.808	155.128	61.007			
	finger 2	56.837	205.882	-12.852			
	finger 3	37.682	206.431	-28.569			
	finger 4	17.335	196.641	-21.401			
	finger 5	-0.148	184.791	6.162			

Exercise-5 (Make an 'O')

Iteration		x value	y value	z value	x-error	y-error	z-error
1	finger 1	44.662	243.941	50.63	-3.43%	7.35%	26.82%
	finger 2	31.216	259.365	51.599	-12.52%	9.29%	45.38%
	finger 3	36.606	244.854	54.819	-6.50%	11.01%	34.67%
	finger 4	36.014	227.899	50.657	-2.89%	12.36%	34.20%
	finger 5	27.582	212.785	43.819	-1.47%	13.14%	39.08%
2	finger 1	49.895	214.454	42.946	7.89%	-5.63%	7.57%
	finger 2	41.027	225.069	38.859	14.98%	-5.16%	9.48%
	finger 3	44.288	208.803	43.156	13.12%	-5.33%	6.02%
	finger 4	42.492	191.045	39.691	14.58%	-5.81%	5.15%
	finger 5	33.541	176.223	33.419	19.82%	-6.30%	6.07%
3	finger 1	44.182	223.321	26.192	-4.46%	-1.72%	-34.39%
	finger 2	34.802	227.49	16.023	-2.47%	-4.14%	-54.86%
	finger 3	36.557	208.035	24.142	-6.62%	-5.68%	-40.69%
	finger 4	32.748	189.567	22.893	-11.69%	-6.54%	-39.35%
	finger 5	22.854	175.225	17.283	-18.36%	-6.83%	-45.15%
average	finger 1	46.246	227.239	39.923			
	finger 2	35.682	237.308	35.494			
	finger 3	39.150	220.564	40.706			
	finger 4	37.085	202.837	37.747			
	finger 5	27.992	188.078	31.507			

Exercise-6 (Table Bend)

Iteration		x value	y value	z value	x-error	y-error	z-error
1	finger 1	82.393	220.072	60.439	0.83%	12.88%	29.44%
	finger 2	4.986	176.993	29.657	14.31%	8.15%	-3.17%
	finger 3	-4.617	171.456	31.263	-28.76%	6.47%	-5.33%
	finger 4	-18.623	170.155	33.928	-9.64%	4.71%	-5.91%
	finger 5	-31.984	174.02	29.769	-3.10%	3.78%	-4.95%
2	finger 1	81.719	193.261	43.81	0.00%	-0.87%	-6.17%
	finger 2	1.924	168.483	33.568	-55.89%	2.95%	9.60%
	finger 3	-9.837	166.693	35.9	51.78%	3.51%	8.71%
	finger 4	-23.922	168.861	39.552	16.08%	3.91%	9.69%
	finger 5	-36.495	174.08	35.146	10.56%	3.82%	12.22%
3	finger 1	81.041	171.537	35.828	-0.83%	-12.01%	-23.27%
	finger 2	6.176	145.469	28.659	41.59%	-11.11%	-6.43%
	finger 3	-4.989	144.964	31.904	-23.02%	-9.98%	-3.39%
	finger 4	-19.281	148.505	34.697	-6.44%	-8.62%	-3.78%
	finger 5	-30.547	154.946	29.042	-7.46%	-7.60%	-7.27%
average	finger 1	81.718	194.957	46.692			
	finger 2	4.362	163.648	30.628			
	finger 3	-6.481	161.038	33.022			
	finger 4	-20.609	162.507	36.059			
	finger 5	-33.009	167.682	31.319			

Exercise-7 (Finger Lift)

Iteration		x value	y value	z value	x-error	y-error	z-error
1	finger 1	52.406	103.556	68.887	2.17%	-8.49%	29.91%
	finger 2	35.893	144.055	-11.576	12.39%	-7.39%	-57.96%
	finger 3	25.983	134.818	-28.838	72.68%	-9.43%	-35.74%
	finger 4	10.407	126.588	-26.095	-435.64%	-9.75%	-34.32%
	finger 5	-12.475	122.05	-11.799	-50.83%	-10.75%	-50.31%
2	finger 1	49.742	106.7	51.307	-3.02%	-5.71%	-3.24%
	finger 2	39.352	157.739	-26.286	23.22%	1.41%	-4.54%
	finger 3	25.948	158.06	-46.303	72.44%	6.18%	3.17%
	finger 4	6.018	155.801	-44.631	-294.09%	11.07%	12.33%
	finger 5	-19.506	147.514	-29.08	-23.13%	7.87%	22.48%
3	finger 1	51.73	129.229	38.884	0.85%	14.20%	-26.67%
	finger 2	20.567	164.845	-44.745	-35.60%	5.98%	62.50%
	finger 3	-6.789	153.703	-59.5	-145.12%	3.25%	32.57%
	finger 4	-25.727	138.415	-48.473	729.72%	-1.32%	22.00%
	finger 5	-44.14	140.673	-30.35	73.96%	2.87%	27.83%
average	finger 1	51.293	113.162	53.026			
	finger 2	31.937	155.546	-27.536			
	finger 3	15.047	148.860	-44.880			
	finger 4	-3.101	140.268	-39.733			
	finger 5	-25.374	136.746	-23.743			

Exercise-8 (Wrist Stretch)

Iteration		x value	y value	z value	x error	y error	z errorr
1	finger 1	56.746	215.607	-3.331	30.46%	18.91%	-109.07%
	finger 2	26.178	131.462	-2.476	-34.54%	-7.44%	-106.98%
	finger 3	6.066	117.739	-4.565	-72.90%	-15.16%	-114.11%
	finger 4	-14.431	124.044	-3.574	-487.48%	-15.33%	-111.49%
	finger 5	-31.257	146.158	-0.439	218.41%	-10.70%	-101.37%
2	finger 1	43.238	194.234	54.437	-0.60%	7.12%	48.19%
	finger 2	66.84	159.375	47.214	67.14%	12.22%	33.14%
	finger 3	49.582	148.684	38.673	121.53%	7.14%	19.52%
	finger 4	26.16	150.371	38.617	602.41%	2.64%	24.16%
	finger 5	6.166	167.443	45.604	-162.81%	2.30%	41.87%
3	finger 1	30.511	134.14	59.096	-29.86%	-26.02%	60.88%
	finger 2	26.954	135.239	61.65	-32.60%	-4.78%	73.84%
	finger 3	11.498	149.918	62.959	-48.63%	8.03%	94.58%
	finger 4	-0.556	165.091	58.264	-114.93%	12.69%	87.33%
	finger 5	-4.359	177.429	51.267	-55.60%	8.40%	59.49%
average	finger 1	43.498	181.327	36.734			
	finger 2	39.991	142.025	35.463			
	finger 3	22.382	138.780	32.356			
	finger 4	3.724	146.502	31.102			
	finger 5	-9.817	163.677	32.144			

Exercise-9 (FingerTip Touch)

Iteration		x value	y value	z value	x-error	y-error	z-error
1	finger 1	32.7	165.776	61.801	-18.49%	-11.48%	-1.16%
	finger 2	14.696	256.362	10.792	232.76%	-4.02%	-310.53%
	finger 3	36.012	215.729	-17.019	274.96%	-7.63%	-45.68%
	finger 4	30.396	196.399	-24.758	-5.90%	2.66%	-175.78%
	finger 5	12.43	149.616	36.995	-43.40%	-10.01%	-27.45%
2	finger 1	44.372	211.032	62.892	10.61%	12.69%	0.58%
	finger 2	-6.467	281.24	-13.085	-246.43%	5.29%	155.27%
	finger 3	-4.827	250.832	-38.49	-150.26%	7.40%	22.84%
	finger 4	31.161	201.799	61.385	-3.53%	5.49%	87.89%
	finger 5	27.756	186.455	57.986	26.39%	12.14%	13.72%
3	finger 1	43.28	185.002	62.892	7.88%	-1.21%	0.58%
	finger 2	5.02	263.731	-13.085	13.67%	-1.27%	155.27%
	finger 3	-2.372	234.096	-38.49	-124.70%	0.23%	22.84%
	finger 4	35.348	175.71	61.385	9.43%	-8.15%	87.89%
	finger 5	25.697	162.727	57.986	17.01%	-2.13%	13.72%
average	finger 1	40.117	187.270	62.528			
	finger 2	4.416	267.111	-5.126			
	finger 3	9.604	233.552	-31.333			
	finger 4	32.302	191.303	32.671			
	finger 5	21.961	166.266	50.989			

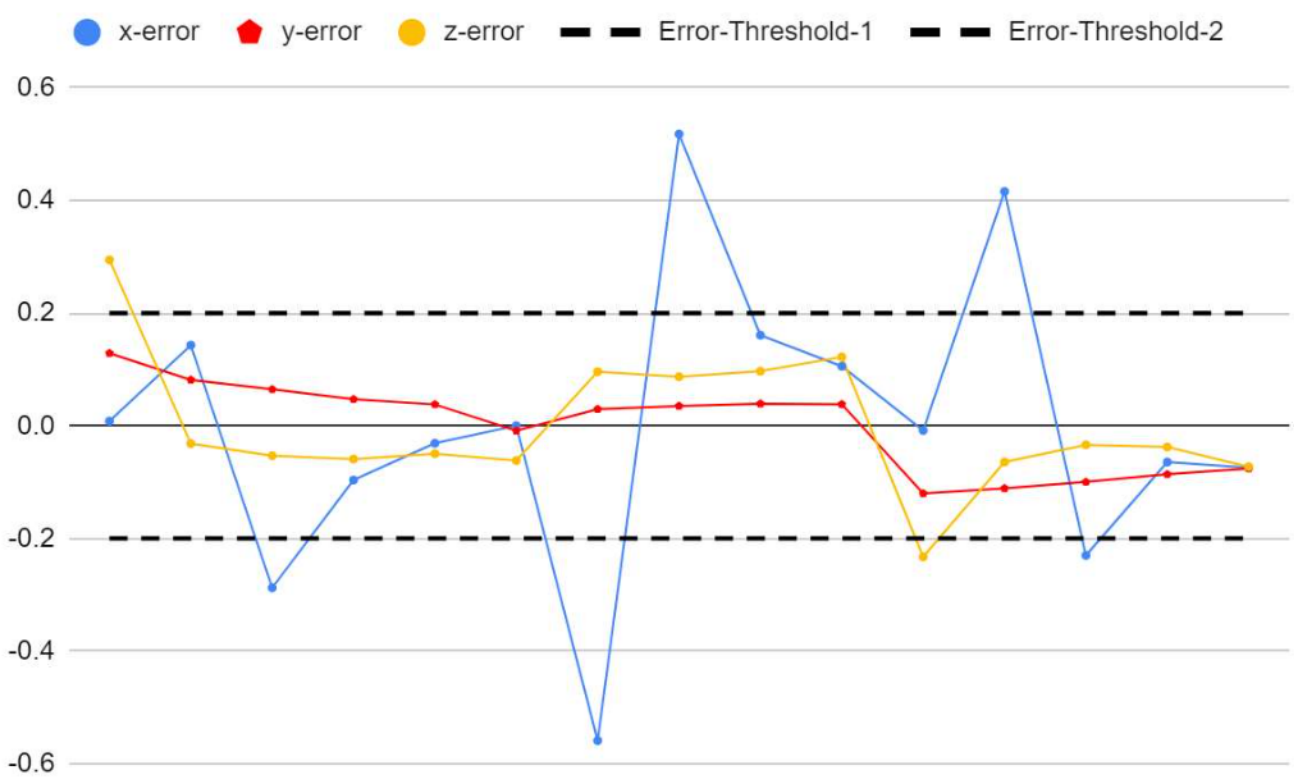
Exercise-10 (Knuckle Bend)

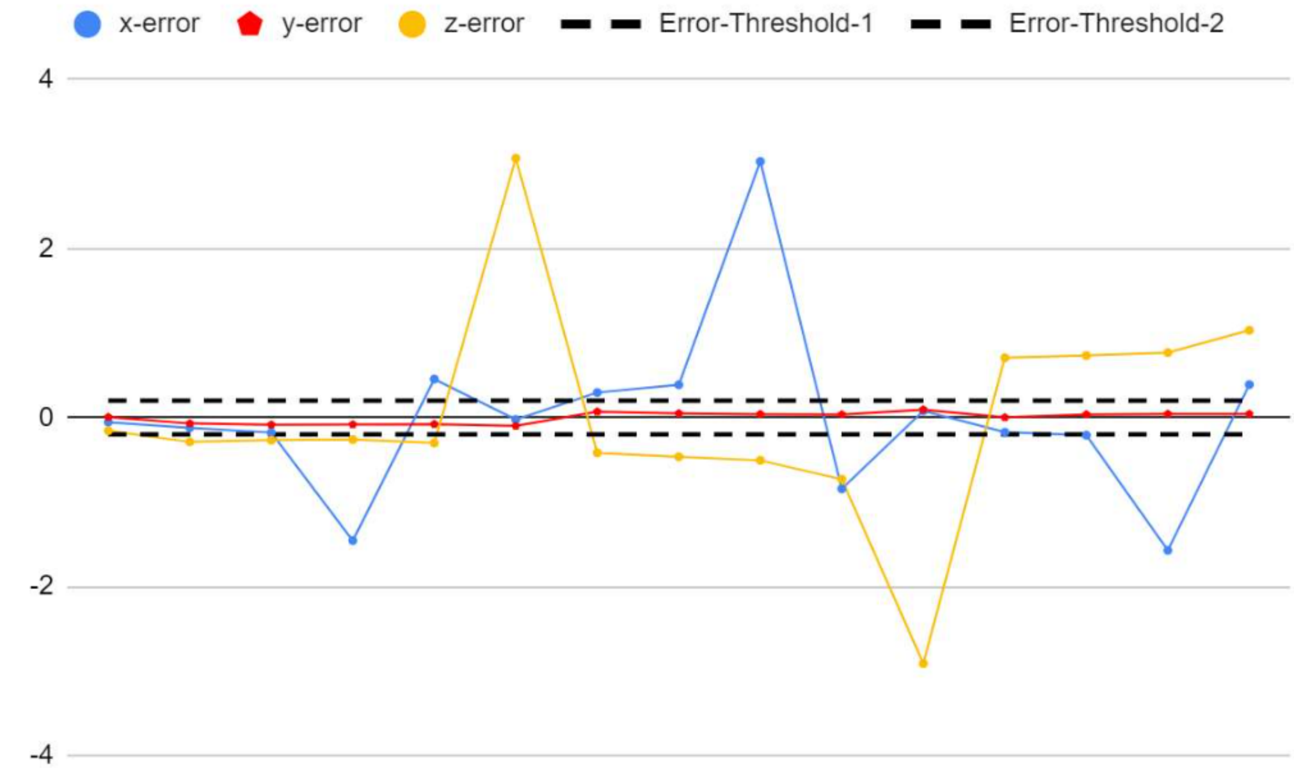
Iteration		x value	y value	z value	x-error	y-error	z-error
1	finger 1	89.042	236.397	103.773	1.32%	29.44%	60.72%
	finger 2	26.822	202.465	64.051	10.65%	27.17%	33.60%
	finger 3	16.291	195.446	64.069	17.64%	25.35%	24.94%
	finger 4	1.997	192.03	64.602	2396.25%	21.57%	22.11%
	finger 5	-13.269	195.875	61.89	0.83%	26.45%	26.13%
2	finger 1	91.009	205.023	56.633	3.56%	12.26%	-12.29%
	finger 2	25.756	169.555	44.791	6.26%	6.50%	-6.58%
	finger 3	15.184	165.817	49.751	9.65%	6.35%	-2.98%
	finger 4	1.629	170.869	51.456	1936.25%	8.17%	-2.74%
	finger 5	-10.872	157.868	46.788	-17.39%	1.91%	-4.65%
3	finger 1	83.597	106.455	33.296	-4.88%	-41.71%	-48.43%
	finger 2	20.141	105.617	34.99	-16.91%	-33.66%	-27.02%
	finger 3	10.068	106.498	40.018	-27.29%	-31.70%	-21.96%
	finger 4	-3.386	110.975	42.655	-4332.50%	-29.74%	-19.37%
	finger 5	-15.34	110.975	38.529	16.56%	-28.36%	-21.48%
average	finger 1	87.883	182.625	64.567			
	finger 2	24.240	159.212	47.944			
	finger 3	13.848	155.920	51.279			
	finger 4	0.080	157.958	52.904			
	finger 5	-13.160	154.906	49.069			

Charts

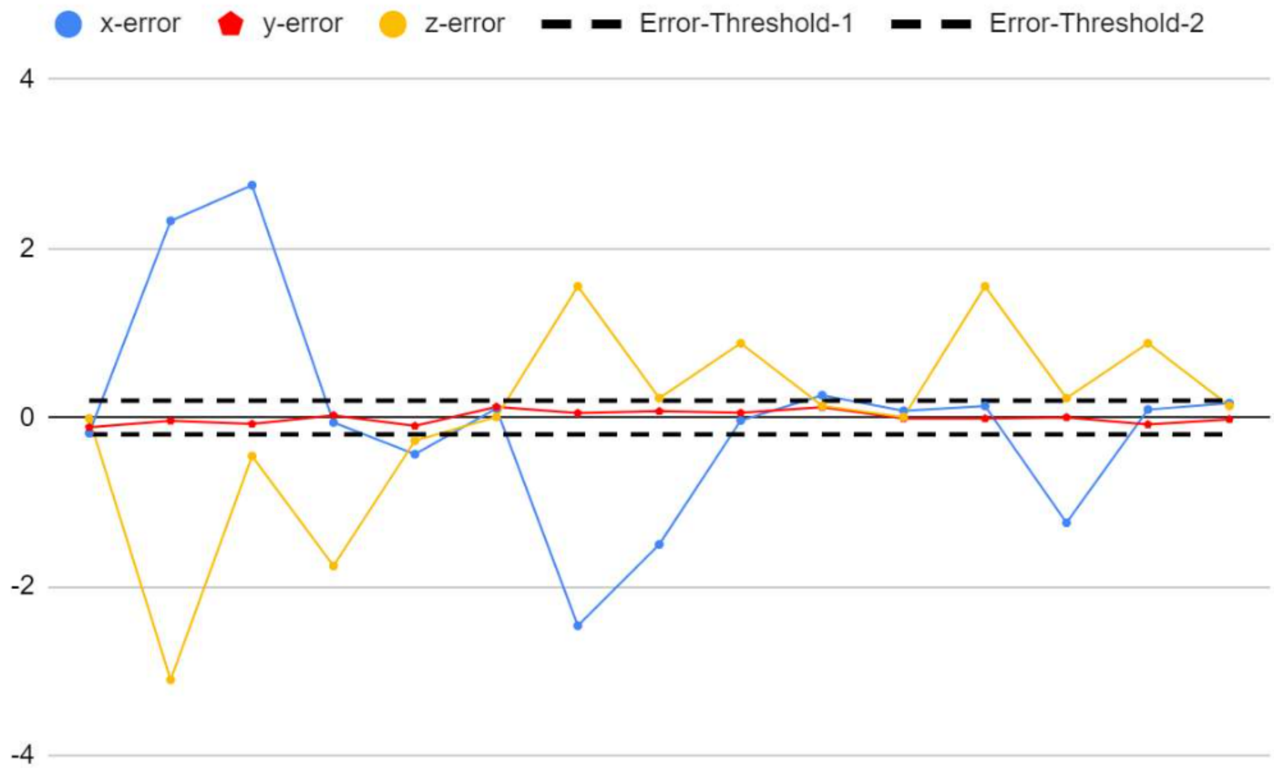
We set our error thresholds to -20% and +20% of the fingers XYZ coordinates variation between the three attempts for the ten hand exercise routines. Below charts show the exercise routines that exhibited higher variations in their XYZ values. We analyze the sources of error and explain how we addressed them to improve the accuracy of our overall solution.

Exercise-2 and Exercise-6 Error Analysis (Threshold -20% to +20%)





Exercise-5 & Exercise-9 Error Analysis (Threshold -20% to +20%)



Outlier Error Ranges

Exercise #	Error Margin Threshold Levels	Outlier Ranges (Best/Worst)
Exercise-1 (Stretch Hand)	-20% to +20%	-325% (z) +203% (z)
Exercise-2 (Make a Fist)	-20% to +20%	-291% (z) +306% (z)
Exercise-3 (Finger Bend)	-20% to +20%	-128.53% (z) +199.78% (x)
Exercise-4 (Thumb Bend)	-20% to +20%	-43% (z) 21.59% (z)
Exercise-5 (Make an 'O')	-20% to +20%	-54% (z) 39% (z)
Exercise-6 (Table Bend)	-20% to +20%	-55% (x) 51.78% (x)
Exercise-7 (Finger Lift)	-20% to +20%	-50.83% (z) 62.50% (z)
Exercise-8 (Wrist Stretch)	-20% to +20%	-59.60% (x) 59.49% (z)
Exercise-9 (FingerTip Touch)	-20% to +20%	-43.40% (x) 22.84% (z)
Exercise-10 (Knuckle Bend)	-20% to +20%	-41.71% (y) 29.44% (y)

Errors

What problems did you find with your solution? Be specific since you will need to redesign based on these problems:

Our solution displays X,Y,Z coordinates for all five fingers in each hand that we record to analyze hand positions for the ten hand exercise routines. We then analyzed consistency between those values across three attempts for each exercise. We set an error margin of -20% to +20% in XYZ values. We observed the following errors in both scenarios (age:46 and age:13) primarily in the Z axis with a few exceptions in y and x axes.

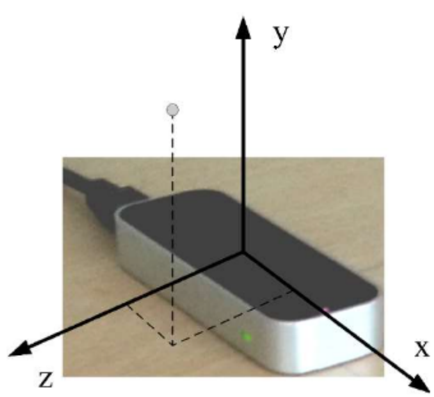
Z-axis variation in values is primarily because of two reasons:

1) Values are set as relative to the XYZ Grid versus relative to the center point of the hand, which caused variation based on the grid settings
2) Position of hand relative to the Leap Motion controller. Between the users based on their hand placement the Z axis value range exceeded error thresholds.

To minimize errors we redesigned the prototype.

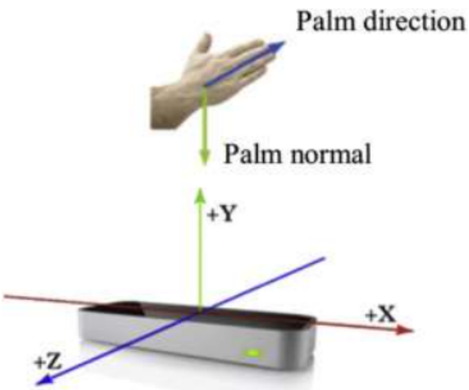
Describe all of the changes you made to your prototype or model (or proposed prototype) after your first test. Why will these changes improve your solution?:

Problem-1: Variation in Z values due to XYZ grid settings versus center of the hand



Solution-1: We fixed the XYZ grid settings to relative to the center of the hand

Problem-2: Position of hand relative to the Leap Motion Controller



Solution-2: Guide the patients visually to align the palm directions with the XYZ axes of the controller.

Problem-3: Error associated with lighting conditions in the room.

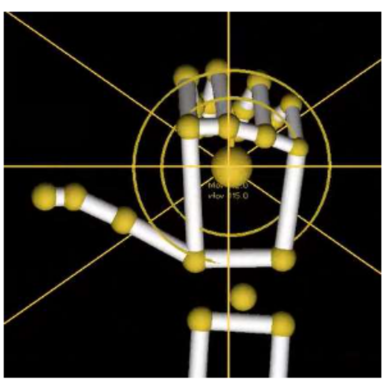
Solution-3: Recalibrate Lea Motion Controller one-time using the desktop or laptop screen as the lighting source reference to reset the device. Once this step is done, the XYZ values from the devices are consistent. We plan to update the solution documentation to guide the users.

Potential Sources of Error

What are your potential sources of error? Remember, this doesn't mean "Did everything work?", all tests have potential sources of error, so make sure you understand what that means. Explain how these sources of error could have affected your results:

We identified the following potential sources of errors.

- Position of the Leap Motion Controller device
    - When the device was not placed on a flat surface, the coordinates experienced significant variation.
    - The device must be placed on a flat surface, such as on the table. If not placed on a stable surface, the XYZ coordinates between exercise routines may vary thus skewing the data generated.
- Position of the hand
    - When the hand wasn't in a consistent position, the overall consistency of the data decreased.
    - Hand should be positioned within the permissible wide angle.
    - The device support nearly 180 degrees coverage for up to 24 inches
- Lighting condition
    - Without a consistent light source, the accuracy of the data set decreased.
    - Device uses several sensors to measure and report the XYZ values
    - If the device is not recalibrated for the room lighting conditions, it can cause deviation in the XYZ values
- Random Hand movements
    - Without stable hand movement it was more difficult to conclusively analyze the data set. In our data collection there were occasions of inaccurate and unstable movements were observed.

    - We changed our software application to display the XYZ axes to guide the hand placement, aligning the center of the palm to the dot shown on screen. This has substantially improved the accuracy of XYZ coordinate measurements to address random hand movements.

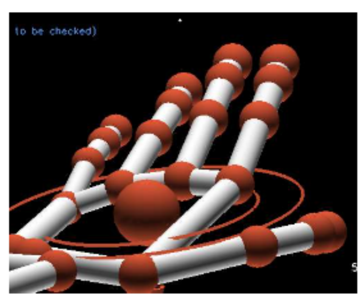
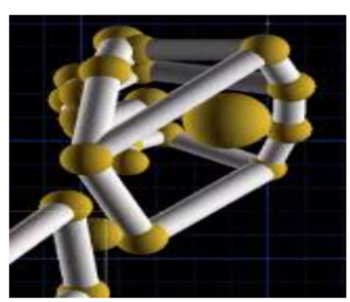
Conclusion

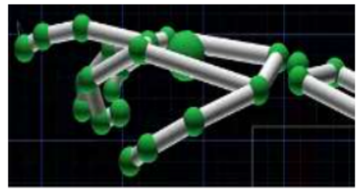
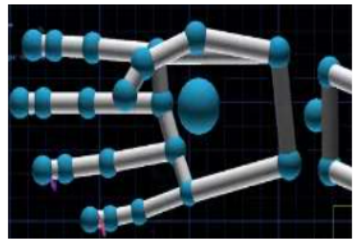
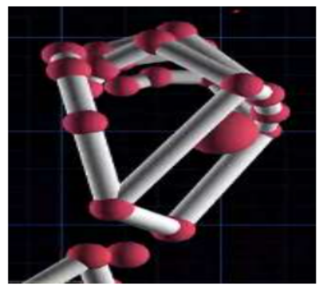
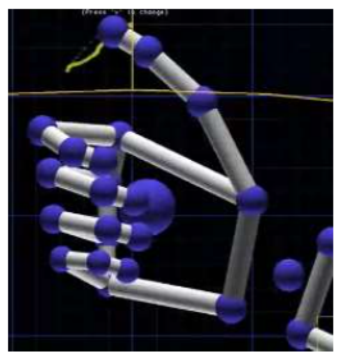
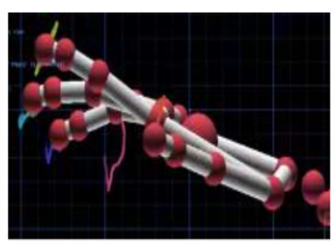
What conclusions can you draw based on the data you gathered during your tests?:

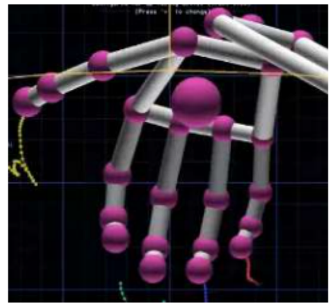
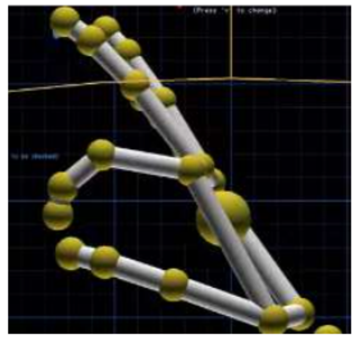
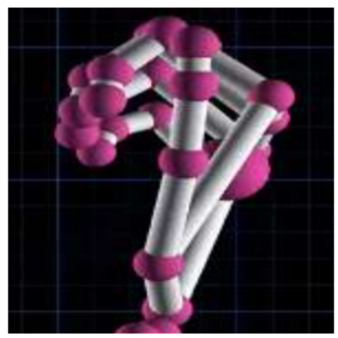
We set our hypothesis to prove or disprove, “can we offer a cost-effective and reliable virtual physiotherapy experience for people with arthritis''. We scoped our research to specifically hand exercises.

Using the Leap Motion controller which cost less than $100 and the software we developed using Unity/C++ running on a Windows or Mac computer (desktop/laptop) we proved that we can offer virtual physiotherapy experience to people with arthritis cost-effectively.

Through experiments we conducted we successfully concluded that for 9 out of 10 hand exercises, our solution is able to measure and report hand movements reliably. For the exercise-8 (Wrist Stretch), we are not able to successfully prove that the virtual physiotherapy experience can be comparable to real physiotherapy experience primarily because this routine requires users to use both hands and programmatically does not seem possible to separate left and right hand coordinates. However, for 9 out 10 exercises, we successfully proved that we can offer a reliable virtual physiotherapy experience for people with arthritis.

Exercise #	**Physical Therapy**	**Virtual Physiotherapy**	**Are the Physical and Virtual experiences comparable?**
Exercise-1 (Stretch Hand)			YES
Exercise-2 (Make a Fist)			YES

Exercise-3 (Finger Bend)			YES
Exercise-4 (Thumb Bend)			YES
Exercise-5 (Make an 'O')			YES
Exercise-6 (Table Bend)			YES
Exercise-7 (Finger Lift)			YES

Exercise-8 (Wrist Stretch)			NO
Exercise-9 (FingerTip Touch)			YES
Exercise-10 (Knuckle Bend)			YES

We have successfully proved that nine out of ten hand exercise routines can be supported reliably and cost-effectively using our "Virtual Physiotherapist" solution. As a next-step, we plan to increase our test coverage to multiple age groups and also invest more in our software application development to better guide the users. Subsequently, we plan to expand coverage to supporting exercise routines for other types of arthritis.

Community Benefits

Explain how investigating the problem your team chose will help the community. Be sure to include the impacts your research will have on individuals, businesses, organizations, and the environment in your community (if any). Make it very clear why solving this problem would help your community:

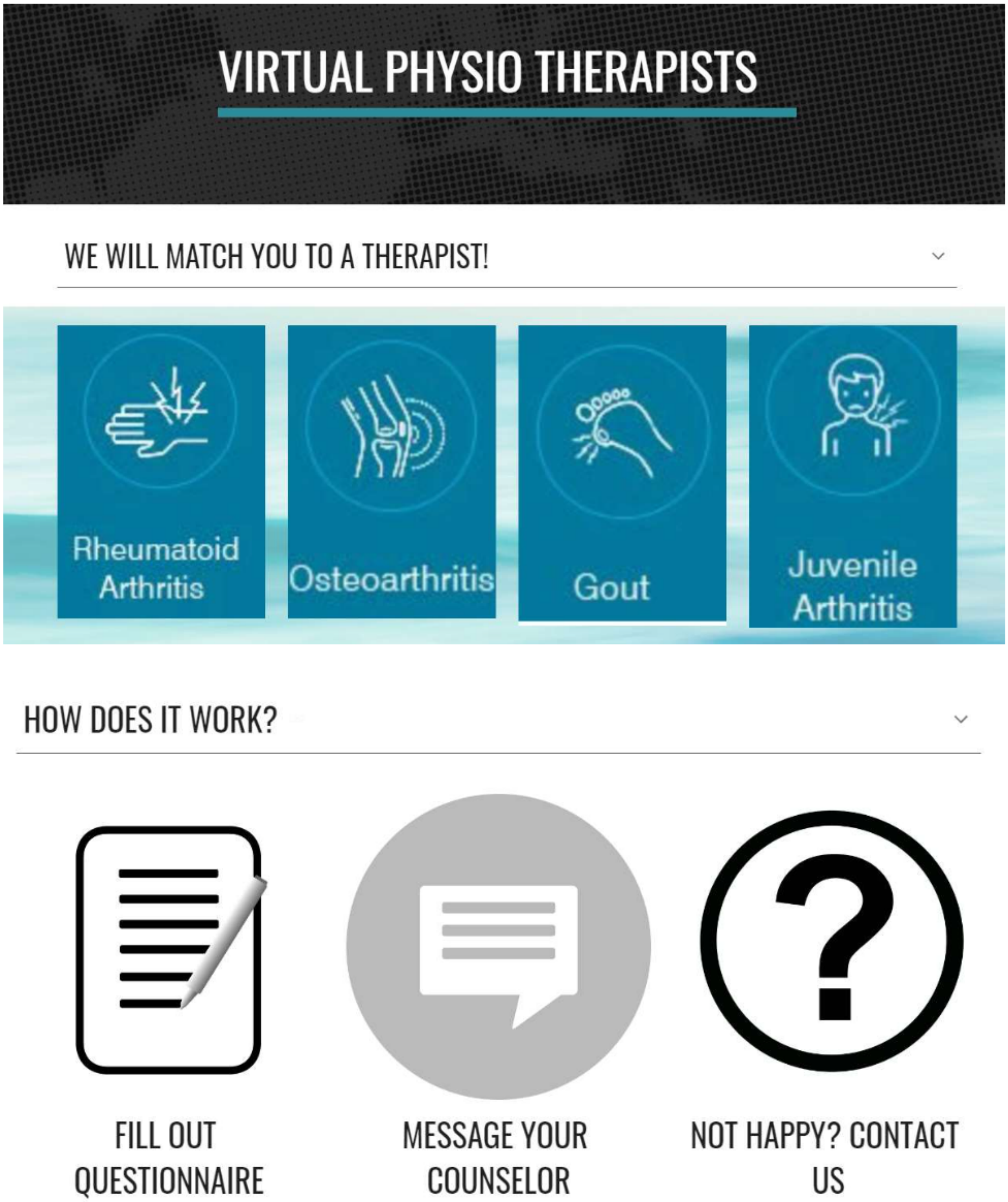
Cost: According to the arthritis Foundation, more than 54 million adults and almost 300,000 children have arthritis or another type of rheumatic disease, and by conservative estimates, this number is expected to increase 49% by 2040. Physiotherapy and Medication for people with arthritis costs nearly $200B annually, and requires patients to visit doctors multiple times weekly. Our Virtual Physiotherapy solution allows people with arthritis to exercise virtually anytime in comfort of their own homes for less than $100 and no recurring expenses.

Reduction in Travel Expenses/Exercises in comfort of your homes: Especially during COVID-19, global pandemic, as almost all of the states were in lockdown mode, and many of doctors and physiotherapists' offices were closed for extended period of time, many of our families and friends who have arthritis were not able to pursue their daily and weekly exercise routines successfully. Our solution allows them to perform their daily exercise routines in comfort of their own homes.

Historic data collection and analysis: Another major benefit of our solution is that it allows the patients, their families and doctors to monitor and analyze daily, weekly and monthly improvements in exercise accuracy levels. By monitoring and providing positive encouragement to patients we have the opportunity to improve their range of hand movements.

Reduction in medication expenses: According to the National arthritis Foundation, arthritis is the most common chronic condition among chronic users of opioids in the U.S. With our Virtual Physiotherapist solution, we have a way to keep therapists connected with the patients, remind them regularly of exercise routines, positively influence them to continue exercise routines, thus providing the opportunity to reduce their overall medical expenses.

Improving the Virtual Physiotherapy Experience: We have also developed a website prototype here to connect physiotherapists with the patients as needed, and provide both a therapist and patient views for data analysis. While most patients can do their exercise routines in comfort of their own homes, we believe, some patients can benefit from being coached or monitored by real physiotherapists while they exercise. We believe our Virtual Physiotherapist solution will serve both types of users as it allows the users to record their exercises, rates each of their routines as well as can store daily, weekly and monthly statistics for analysis using machine learning algorithms. Below are screens from the website we are in the process of publishing to connect patients with physiotherapists. https://sites.google.com/view/virtual-therapists/home



FOR THERAPISTS

Patient Name:

Statistics

Monthly | Weekly | Daily

Daily Stats

Exercise	# of Times	Duration	Status	Points
1	10	5s		10
2	10	5s		10
3	10	5s		10
4	10	5s		10
5	10	5s		7
6	10	5s		10
7	10	5s		10
8	10	5s		6
9	10	5s		9
10	10	5s		3

85

References

Research your problem. You must learn more about the problem you are trying to solve and also what possible solutions already exist. Find AT LEAST 10 different resources and list them here. They should include books, periodicals (magazines, journals, etc.), websites, experts, and any other resources you can think of. Be specific when listing them, and do not list your search engine (Google, etc.) as a resource:

1. "Amputee Statistics You Ought to Know." *Advanced Amputee Solutions LLC*, 2012, advancedamputees.com/amputee-statistics-you-ought-know#:~:text=The%20Amputee%20Coalition%20of%20America,year%202050%20to%203.6%20million.
2. "arthritis." *CDC*, Centers for Disease Control and Prevention (CDC), 2 Nov. 2020, www.cdc.gov/chronicdisease/resources/publications/factsheets/arthritis.htm#:~:text=Fast%20Facts,arthritis%20report%20severe%20joint%20pain.
3. "Common Challenges During Readjustment To Civilian Life." *US Veterans*, n.d., usveteransmagazine.com/2021/01/9-best-job-programs-veterans-separating-2021/.
4. "Hunger in Oregon." *Oregon Food Bank*, www.oregonfoodbank.org/our-work/hunger-in-oregon/ Accessed 6 Nov. 2020.
5. "Limb Loss Statistics ." *Amputee Coalition* , www.amputee-coalition.org/resources/limb-loss-statistics. Accessed 20 Dec. 2020.
6. "Mirror Therapy for arthritis Pain." *Mirror Therapy*, mirrortherapy.com/mirror-therapy-for-arthritis-pain/. Accessed 26 Jan. 2021.
7. "Policy." *Osteoarthritis Action Alliance*, 2020, oaaction.unc.edu/policy/.
8. "Prosthetic Limb Care in VA Facilities." *Healthcare Inspection*, 8 Mar. 2012, p. 77, www.va.gov/oig/pubs/VAOIG-11-02138-116.pdf
9. *arthritis By The Numbers*. Edited by Debbie Malone, arthritis Foundation, 2019, www.arthritis.org/getmedia/e1256607-fa87-4593-aa8a-8db4f291072a/2019-abtn-final-march-2019.pdf .

10. arthritis Foundation. "14 Ways to Work Out With arthritis ." *arthritis Foundation* , Jeremy S Cook, www.arthritis.org/health-wellness/healthy-living/physical-activity/other-activities/14-ways-to-work-out-with-arthritis . Accessed 17 Jan. 2021.
11. awareness." Advances in medical education and practice vol. 6 635-9. 1 Dec. 2015,
12. Baines, Wesley. "8 Health Problems Facing Veterans." *Beliefnet*, www.beliefnet.com/wellness/8-health-problems-veterans-face.aspx#:~:text=%208%20Health%20Problems%20Facin%20Veterans%20%201,the%20fact%20that%20the%20air%20was...%20More%20. Accessed 6 Nov. 2020.
13. Bauer, Janet. "Oregon Lags in Fighting Food Insecurity." *Oregon Center For Public Policy(OCPP)*, 17 May 2018, www.ocpp.org/2018/05/17/oregon-food-insecurity-lag/ .
14. Byra, Joanna, and Krzysztof Czernicki. "The Effectiveness of Virtual Reality Rehabilitation in Patients with Knee and Hip Osteoarthritis." *Clinical Medicine*, 14 Aug. 2020, p. 18, www.mdpi.com/2077-0383/9/8/2639/pdf.
15. Colgan, Alex. "How to Start Building Your VR Project." *Unity Core Assets 101*, Ultraleap, 2 Aug. 2016, blog.leapmotion.com/unity-core-assets-101-start-building-vr-project/.
16. Cook, Jeremy S. "How to Use the Leap Motion Controller: Setup & Tutorial." Arrow, Jeremy S Cook, 17 July 2020, www.arrow.com/en/research-and-events/articles/how-to-use-the-leap-motion-controller .
17. Cook, Jeremy S. "How to Use the Leap Motion Controller: Setup & Tutorial." *Arrow*, Jeremy S Cook, 17 July 2020, www.arrow.com/en/research-and-events/articles/how-to-use-the-leap-motion-controller.
    a. doi:10.2147/AMEP.S89479
18. F. Corona et al., "Serious Games for Wrist Rehabilitation in Juvenile Idiopathic arthritis," 2018 IEEE Games, Entertainment, Media Conference (GEM), Galway, 2018, pp. 35-42, doi: 10.1109/GEM.2018.8516458.

19. Faure, Charles, et al. "Fooling the Brain, Fooling the Pain: The Role of Mirror Therapy and Modern Uses in Virtual Reality." *Frontiers For Young Minds*, 3 July 2019, kids.frontiersin.org/article/10.3389/frym.2019.00091.
20. Flourish. "Virtual Reality and Pain." *Flourish*, arthritis Society, arthritis.ca/living-well/what-s-possible/research/virtual-reality-and-pain. Accessed 16 Dec. 2020.
21. Google VR. "Daydream Controller." *Google VR*, 11 Jan. 2019, developers.google.com/vr/discover.
22. *Introduction to VR in Unity - PART 1 : VR SETUP*. Valem, 8 Apr. 2020. *www.youtube.com*, uploaded by Valem, 8 Apr. 2020, www.youtube.com/watch?v=gGYtahQjmWQ .
23. Jia, Henry. "Leap Motion (Ultraleap)." *GitHub*, 10 May 2013, github.com/leapmotion.
24. *Leap Motion SDK*. CS50, 31 Oct. 2013. *Youtube*, uploaded by CS50, 31 Oct. 2013, www.youtube.com/watch?v=Fyk0F--43Cw .
25. Lundberg, Angela. "VR: A New Treatment for Chronic Pain?" *Rheumatoid arthritis*, 16 Jan. 2020, rheumatoidarthritis.net/living/virtual-reality-chronic-pain/.
26. McCarthy, Cathy. "You can now print out your own DIY controller for Google Cardboard." *Versions*, killscreen.com/versions/can-now-print-diy-controller-google-cardboard/. Accessed 20 Dec. 2020.
27. Mi, Ximin. "Leap Motion Controller." *VR / AR Resource Guide*, Georgia Tech Library, 27 Nov. 2019, libguides.gatech.edu/c.php?g=731374&p=6240622.
28. Olenick, Maria et al. "US veterans and their unique issues: enhancing health care professional
29. Tong X., Gromala D., Machuca F. (2019) LumaPath: An Immersive Virtual Reality Game for Encouraging Physical Activity for Senior arthritis Patients. In: Chen J., Fragomeni G. (eds) Virtual, Augmented and Mixed Reality. Applications and Case Studies. HCII 2019. Lecture Notes in Computer Science, vol 11575. Springer, Cham.

https://doi.org/10.1007/978-3-030-21565-1_2

30. Ultraleap. "How it Works: Tracking." *Ultraleap*, www.ultraleap.com/tracking/#how-it-works . Accessed 10 Jan. 2021.
31. Ultraleap. "Leap Motion Controller." *Ultraleap*, www.ultraleap.com/product/leap-motion-controller. Accessed 10 Jan. 2021.
32. Ultraleap. *Leap Motion Developer*. Developer.leapmotion.com . Accessed 10 Jan. 2021.
33. *Unity VR Tutorial - Player Movement/Interaction with Controller for Google Cardboard*. Xlaugts, 3 Dec. 2018. *www.youtube.com*, uploaded by Xlaugts, 3 Dec. 2018, www.youtube.com/watch?v=UBowqGbZ9a4 .
34. Wiederhold, Brenda K et al. "Virtual reality as a distraction technique in chronic pain patients." Cyberpsychology, behavior and social networking vol. 17,6 (2014): 346-52. doi:10.1089/cyber.2014.0207
35. HealthLine "Hand exercise routines for arthritis." https://www.healthline.com/health/osteoarthritis/arthritis-hand-exercises#treatments
36. Mayo Clinic. "Hand exercise routines for arthritis." https://www.mayoclinic.org/diseases-conditions/arthritis/multimedia/arthritis/sls-20076952?s=6
37. Shao, Lin. "Hand movement and gesture recognition using Leap Motion Controller", Stanford EE267 https://stanford.edu/class/ee267/Spring2016/report_lin.pdf