Thwarting Carpal Tunnel Syndrome (CTS) Progression via an Accessible CTS Detection App and CTS Self-Reflection Form

Karthik Raj

University of California, San Diego, kraj@ucsd.edu

Although there is no distinctive header, this is the abstract. This submission template allows authors to submit their papers for review to an ACM Conference or Journal without any output design specifications incorporated at this point in the process. The ACM manuscript template is a single column document that allows authors to type their content into the pre-existing set of paragraph formatting styles applied to the sample placeholder text here. Throughout the document you will find further instructions on how to format your text. If your conference's review process will be double-blind: The submitted document should not include author information and should not include acknowledgments, citations or discussion of related work that would make the authorship apparent. Submissions containing author identifying information may be subject to rejection without review. Upon acceptance, the author and affiliation information must be added to your paper.

CCS CONCEPTS • Insert your first CCS term here • Insert your second CCS term here • Insert your third CCS term here

Additional Keywords and Phrases: Insert comma delimited author-supplied keyword list, Keyword number 2, Keyword number 3, Keyword number 4

ACM Reference Format:

First Author's Name, Initials, and Last Name, Second Author's Name, Initials, and Last Name, and Third Author's Name, Initials, and Last Name. 2018. The Title of the Paper: ACM Conference Proceedings Manuscript Submission Template: This is the subtitle of the paper, this document both explains and embodies the submission format for authors using Word. In Woodstock '18: ACM Symposium on Neural Gaze Detection, June 03–05, 2018, Woodstock, NY. ACM, New York, NY, USA, 10 pages. NOTE: This block will be automatically generated when manuscripts are processed after acceptance.

1 INTRODUCTION

Carpal Tunnel Syndrome (CTS) is a condition where there is pressure exerted on the median nerve, which is enclosed in the carpal tunnel. There are two typical mechanisms by this pressure is induced. The first method involves the carpal tunnel shrinking in width on its own [1]. The second method is when the tissues surrounding the external flexor tendons swell in size, forcing the carpal tunnel to collapse on the median nerve [1].

The typical age population afflicted with carpal tunnel syndrome are people aged from 30 to 60 years old. It is much more common in women than men [2]. The symptoms of carpal tunnel syndrome include weakness when gripping objects; "pins and needles" feeling in the fingers; burning or tingling especially in the thumb, index, and middle fingers; etc. [3]. These symptoms grow in duration as the severity of carpal tunnel syndrome increases. Thus, it is important to treat carpal tunnel syndrome as early as possible.

2 MOTIVATION

Unfortunately, Carpal Tunnel Syndrome (CTS) does not have an at-home means of detection and the only means of verifying whether an individual has CTS resides in clinics. At the clinics, the doctor may conduct a physical exam or tests such as an EMG or nerve conduction velocity tests [3]. The EMG allows for the doctor to visually see whether the median nerve is compressed. The nerve conduction velocity test measures how fast an electrical impulse travel through the median nerve and abnormal speeds indicate compression on the median nerve. Both are highly accurate tests for identifying whether an individual has CTS, but they require the individual to travel to the clinic to take these tests. Because of this prerequisite, individuals concerned with having CTS must initially resort to online websites like WebMD and MayoClinic and check whether they have most of the symptoms associated with CTS. An at-home means of detecting CTS would provide concerned individuals with an immediate verification of the presence of CTS and more time for them to act with this information. An earlier diagnosis would also hinder CTS progression and prevent the patient from being forced to resort to extreme treatment options like surgery.

Along with the older population, CTS is a common condition amongst people in the workforce and deprives them of the ability to maintain a sustainable income. In a report compiled by the Orthopedic Center of Arlington, "According to the compiled information from the Bureau of Labor and Statistics and the National Institute for Occupational Safety and Health (NIOSH), Carpal Tunnel surgery is the second most common type of surgery, with well over 230,000 procedures performed annually [4]. Although surgery is a highly effective operation with around a 90% success rate, there is a potential for complications to arise and the length of the recovery period varies based on CTS severity [6]. Also, according to the industry watchdog Cost Helper Health, the typical cost for carpal tunnel surgery in 2020 was $6,928 per hand without insurance. But with insurance, the copayment (including aftercare, therapy, and rehab) was approximately $1,000 [5]. Thus, surgery is an expensive course of action, but is relied upon when the patient's CTS is too severe for conservative treatment options to make a difference. However, if a more accessible means of detecting CTS was possible, there is a greater likelihood for people to be diagnosed earlier and more time for people who test positive to explore affordable, non-invasive CTS treatment options. This would greatly benefit people in the workforce whose job makes them prone to developing CTS and cannot afford expensive and risky options like surgery.

3 RELATED WORK

In September 2019, Fujita et al. created a tablet-based CTS screening app [7]. This app utilizes a support vector machine algorithm based on thumb movement speeds from CTS and non-CTS patients to classify both groups with 93% sensitivity and 73% specificity. The app is used while tablet is lying flat on a table and a black holder is used to hold all fingers except the thumb. There are 2 circles on the screen with the smaller orange circle is where the user's thumb lies, and it controls a thumb icon in the larger green circle. The app is essentially a game where the user manipulates the thumb icon to collect animal characters appearing randomly in 12 clock-like directions as quickly as possible. These animal characters appear 2x in each clock-like position and shift to a different position if not caught in time. The speed and time of the thumb movements in all 12 directions was collected from both CTS and non-CTS patients to construct the screening algorithm.

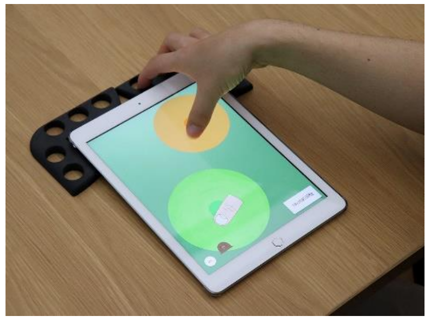

Figure 1: Image of Tablet-based CTS detection app taken from https://mhealth.jmir.org/2019/9/e14172/

Some limitations of this approach are that due to the large screen size of a tablet, the user can directly manipulate the thumb icon and instead needs to rely on indirect manipulation. This approach complicates the process, but was still incorporated well within the app. More importantly, this detection algorithm relies on data from both multiple populations: CTS and non-CTS patients. It would be ideal if the algorithm only needed data from one population to function as this greatly simplifies the data collection process. Regardless, this is a great first attempt that can be built upon in future iterations based upon this approach.

In March of 2021, Koyama et al. built upon the work conducted in the previous paper and created a CTS screening smartphone app [8]. This app utilizes an anomaly detection algorithm based on healthy (non-CTS) patients' data to determine whether an individual has CTS with 94% sensitivity and 67% specificity. The app begins with the user placing all fingers except their thumb in a 3D-printed finger guide attached to the back of the phone. In the app, the user controls a rabbit character with his/her thumb and collects vegetables located in different regions of the screening area. The vegetables appear in 1 of 12 random clock-like positions and if not collected in 5 seconds, the vegetable shifts to a different spot. The game ends after all vegetables have been collected in all potential orientations twice. The position of the thumb and capture times of the vegetables were recorded. From my understanding, the screening model is constructed via the use of a convolutional neural network approach: anomaly detection applied to the reconstruction errors of the autoencoder. The reconstruction error is noted to be larger for users with CTS than without CTS.

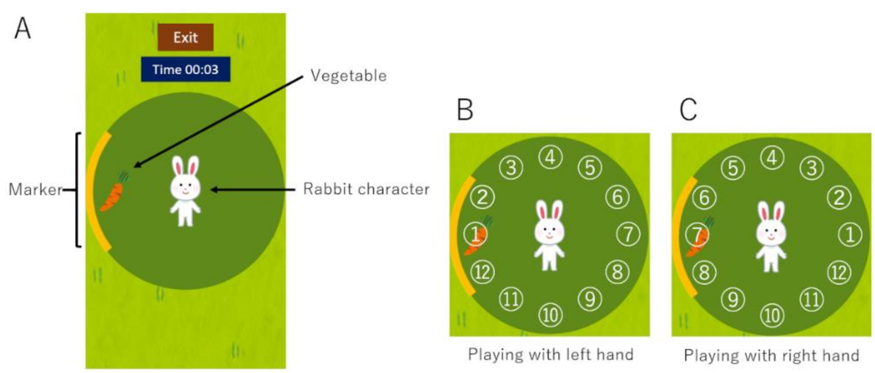

Figure 2: Image of Smartphone based CTS detection app taken from https://mhealth.jmir.org/2021/3/e26320/

One of the prominent limitations of this approach, acknowledged by the authors, is the fixed screening circle radius. There is potential for misclassification of healthy people with small thumbs since they may be unable to reach the vegetables in a smooth manner. Also, with the growing disparities in phone sizes, the current size of the screening circle may not function well in some phones, but there is no ability for a dynamic adjustment. However, their approach gives hope for a widely accepted, at-home detection of CTS with accuracies comparable to clinical standards.

4 PROJECT AIM

The aim for this project is to create an app, via React Native, with the same ideology used in the JMIR Health App. Given the limited time remaining for the quarter, this app will not have all the features of the JMIR Health app, but at least be able to record thumb position and the time required to capture a carrot placed in one of the 12 clock directions. These features were chosen because they are the required measurements used to create the machine learning model for classifying CTS and non-CTS users. React Native is used because it has cross-platform functionality (works on Android and IOS) and can be made via a software known as Expo CLI, which greatly simplifies the app development process.

Another aim for this project is to create a CTS self-reflection form via Google Forms. The purpose of this form is to allow users who test positive for CTS to identify his/her activities, which fit the criteria for progressing CTS. With this knowledge, the user can hinder the growth in their condition by either eliminating these activities from his/her lifestyle or using alternate ways of completing these activities without worsening their condition. The hope is that this immediate lifestyle shift will allow treatments like physical therapy to be more effective rather than being forced to commit to surgery as a last resort. Surgery is a highly effective operation with around a 90% success rate, but there is a potential for complications to arise and there is a recovery period whose length varies based on CTS severity. Also, according to the industry watchdog Cost Helper Health, the typical cost for carpal tunnel surgery in 2020 was $6,928 per hand without insurance. But with insurance, the copayment (including aftercare, therapy, and rehab) was approximately $1,000. Thus, surgery is an expensive course of action, which should be utilized as a last resort if all other options fail.

With these aims in mind, the project timeline is as follows. Since React Native requires knowledge of React concepts and JavaScript, the first 2 weeks will be devoted to learning these concepts and how to code in JavaScript. The remaining 2 weeks will be focused on constructing this app with the desired functionality using the knowledge gained in the previous weeks. Lastly, the final week will be devoted to constructing the CTS self-reflection form. The timeline is flexible in terms of time allocated for each goal, but the goals should be achieved by the final presentation.

5 METHODOLOGY

5.1 CTS Self-Reflection Form Design Approach

Initially, this form was envisioned to allow for the user to list out any activities that he/she believes fit the criteria of activities that can progress CTS and the time allotted for each activity. Upon completion of the form, the user will receive charts encapsulating all the provided activities and their respective times spent on these activities. However, from a use-case perspective, this approach seemed unlikely to yield sufficient results because the user essentially needs to run through their evolving lifestyle to find activities that met the requirements. Thus, an alternate approach was used where the user essentially notes down the various settings and time in which he/she engages in CTS-progressing activities. Unlike the previous method which is equivalent to searching an entire house for a small toy, this new approach is equivalent to searching for that same toy within different rooms of the house. By systematically engaging in smaller, but more direct pursuits of this toy, the person is more likely to find the toy in a shorter amount of time than engaging in a massive endeavor with no clear direction. The added efficiency and guidance of this approach made this new format a superior option to the initial idea.

At the beginning of the form, there is an introductory page documenting the purpose of the form and asks for the user's email address. This email address is necessary for the respondent to receive a copy of his/her responses to the form, which should be used to create lifestyle shifts that hinder the progression of CTS. Next, the form asks: does the user engage in activities that require frequent, repetitive, grasping movements with hands? If the user answers no, the next question is posed: does the user engage in activities that require frequent, repetitive, small movements with hands? However, if the user answers yes, they are led to a multiple-choice grid where different lifestyle settings are noted on the left-most column and time ranges culminating to a maximum of 12 hours span the top-most row. Each setting allows only one answer or no response if the user believes the setting is not applicable. This setup was chosen because it is an intuitive layout that allows for quick responses and most importantly, the same time option can be selected for different settings. Other question formats did not grant this ability resulting in the multiple-choice grid being the best option that fits my needs.

This question format is also the result if the user answers yes to the next question: does the user engage in activities that require frequent, repetitive, small movements with hands? However, if the user responds no, they will arrive at the ending page. This section reaffirms the goal of this form and attempts to persuade the user to shift their lifestyle by highlighting the negative aspects of surgery: high cost, risk for complications, and potentially long recovery period. This section also accounts for the possibility of neither of these activities being applicable but asks the respondent to check with his/her clinician for potential non-invasive treatment options. There is also a word of caution to not engage in the kinds of activities asked in the form for risk of CTS severity increase.

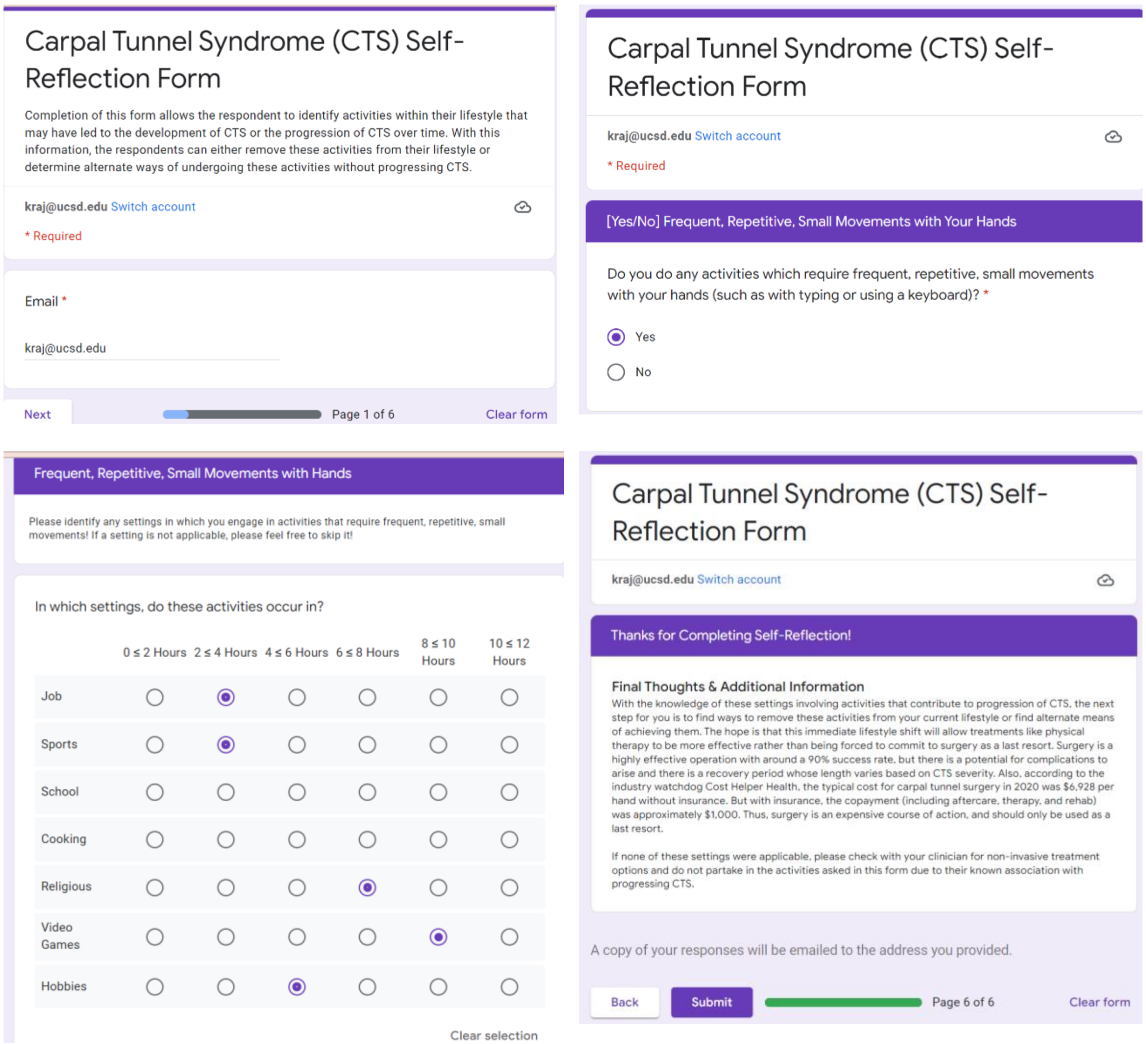

Figure 3: Unique Pages of the CTS Self-Reflection Form displayed in order from left to right. Font may be illegible, but purpose is to illustrate the form’s appearance and general user interface.

5.2 CTS Screening App Design Approach

5.2.1 Steps for Rendering App Layout

The app begins with obtaining the dimensions of the usable space (area excluding the top notification bar) of the phone. At the very top of the page, there is the title of the app followed by two separate text sections denoting the position of the circle and the time value for tagging the black circle. Using the dimensions obtained at the very beginning of the app, the largest circle defining the area for which the CTS screening will take place is rendered on the screen. The CTS screening area circle is dynamically positioned to be near the bottom of the screen and originate from the middle of the screen. However, the radius of this circle is fixed and was calibrated based on the screen width of the Samsung Galaxy S9. The black circle or the target circle can go in 12 different clock-like positions close to the edge of the CTS screening area circle. Each position is defined by the angle of its position with respect to the center of the CTS screening area circle and horizontal axis of the CTS screening area circle. The red circle or start circle is fixed at the center of the CTS screening area circle and is used to indicate where the user will start the drag.

ALGORITHM 1: Rendering the App Layout (Smaller Font Saves Space & Improves Format)

```
<View style={styles.container}>
 <Svg height="100%" width="100%">
      <View style={styles.textc}>
      <Text style = {{fontSize: 40, fontWeight: 'bold', color: 'pink'}}> CTS Detection App </Text>
      <Text style = {{fontSize: 30, fontWeight: 'bold', color: 'orange', marginTop: 30}}> Circle Position: {cpos}  </Text>

 <Text style = {{fontSize: 30, fontWeight: 'bold', color: 'cyan', marginTop: 5}}> Time Value: {timer} seconds   </Text>
  </View>
  <Circle cx= {width/2} cy= {height * (2/3)} r="152" stroke="green" strokeWidth="2.5" fill="" />
  <Circle cx= {width/2} cy= {height * (2/3)} r="20" stroke="red" strokeWidth="2.5" fill="" onPress = {midStart}  />
  <Circle cx={width/2 + (120*Math.cos((pos*Math.PI)))} cy= {(height *(2/3)) - (120*Math.sin((pos*Math.PI)))} r="20"
stroke = 'black' onPress= {clickHandler} onLongPress = {reset_time_pos} />
</Svg>
</View>
const styles = StyleSheet.create({
 container: {
  flex: 1,
  alignItems: 'center',
  justifyContent: 'space-between',
  backgroundColor: 'black',
 },
 textc: {
  alignItems: 'center',
  justifyContent: 'flex-start',
  alignSelf: 'center',
  top: 40,
 },
  }
);
```

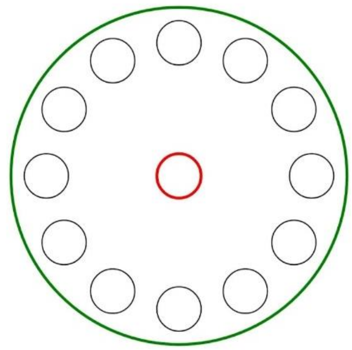

Figure 4: Image of CTS Screening Area Layout with all potential positions of the black target circle and the red start circle

5.2.2 Animatable Elements

The animatable elements of the app are only possible by utilizing useState variables. A useState variable is a special type of variable that forces the screen to render when variable's value changes. There are three useState variables. These variables represent tag time, target circle position, and the text of the target circle position. The tag time, target circle position, and the text of the target circle position all initialize as 0.

The timer is a function, which increments a variable denoted as a counter by one for each tenth of a second that passes. Google searches revealed alternative ways of creating a timer, but these methods were unnecessarily complicated due to the authors' intentions for these techniques to be used in an app whose sole function is a timer. Given the other components of this app, I decided to go with the simple method, but this technique has limitations that will be discussed later.

ALGORITHM 2: Initializing required Variables, Obtaining Dimensions & Defining Timer Function

```
const {height, width} = Dimensions.get('window') // Returns usable window size for Phone
 var counter = 0; // Value used in timer function
 const [pos, setPos] = useState(0); // Holds Circle Position
 const [cpos, setCpos] = useState(0); // Holds text of Circle Position
 const [timer, setTimer] = useState(0); // Holds timer value that is displayed on the screen

// Timer Function
 const midStart = () => {
  setInterval(() => counter += 1, 100);
 }
```

The red start circle and the black target circle have different capabilities as well depending on the amount of time the user presses either of these components. The red start circle is associated with a function that starts the timer upon contact by the user's finger. Upon contact by the user, the black target circle will stop and reset the timer, and display the timer result. This contact also results in an updated circle position where the angle defined by the target circle's center, start circle's center, and the horizontal axis of the start circle is increased by 30 degrees. To clarify, the target circle shifts its position counterclockwise. Lastly, the text of the target circle position is updated to indicate the position of the circle whose timer result was just obtained. If the target circle is pressed for at least 0.5 seconds, then the text of the circle position and the timer value reset to 0.

ALGORITHM 3: Functions Utilized onPress of Start or Target Circle

```
// Timer Function is activated upon press of the Red Start Circle
const midStart = () => {
  setInterval(() => counter += 1, 100);
 }
// Displaying Updated Target Circle Position Text, Target Circle Position, Timer Value & Resetting Timer. All
achieved upon press of black target circle.
 const clickHandler = () => {
  setCpos(cpos + 1); // cpos + 1
  setPos(pos + 1/6); // pos + 1/6
  setTimer((counter)/10)
  counter = 0;
  }
// Setting Displayed Timer Value and Circle Position Text to 0 upon longpress of black target circle
 const reset_time_pos = () => {
   setCpos(0);
   setTimer(0);
  };
```

A user interested in using this app for CTS screening will initiate the process by pressing the red start circle with his/her thumb. Then, he/she will simulate a drag by dragging his/her thumb to the black target circle and press the black target circle. Upon contact, the timer will stop and reset, and its value along with the updated circle position associated with that time will be displayed on the screen. The black target circle will also move to the next counterclockwise position. This process repeats for the remaining 11 potential target circle positions. When the times for the remaining positions have been obtained, the test concludes by long pressing the black target circle to reset the timer and circle position text. The circle position and the associated tag time for each position are two key measurements that can be used for the generation of a CTS screening model.

6 RESULTS

This project resulted in the development of an app that can record target circle position and its associated tag time with the precision of a tenth of a second. The process for collecting these measurements does require the user to drag along the screen without any visual feedback. However, this approach does not affect the accuracy of the collected data because a drag is still required to take place. This app allows for repeated trials and the procedure can be restarted upon the user's command. These measurements: tag time and target circle position can be used in the development of a machine learning algorithm for classifying CTS and non-CTS patients.

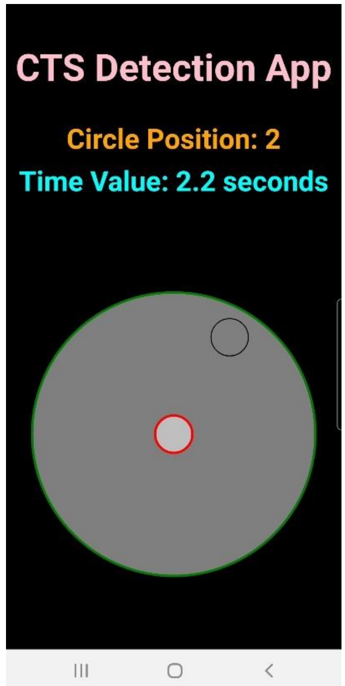

Figure 4: Screenshot of CTS Screening App in action. Required Information for Machine Learning Algorithm displayed below title.

Another outcome of this project is the CTS self-reflection form created via Google Forms. The CTS self-reflection form is primarily intended for use by patients who have CTS. The form does not collect personal information aside from the respondent's email, which is used to send back a copy of the responses. This form introduces the respondent to the two kinds of activities that can progress CTS. Then, the respondent is pushed to recall in specific settings whether he/she engages in activities, which meet the criteria of the previously mentioned activities known to increase the severity of CTS. If so, then the respondent can indicate the hours spent conducting these behaviors. If not, the respondent is to leave that specific setting blank. Afterwards, the respondent receives a copy of their responses and an appeal to make lifestyle shifts, using the knowledge gained in the form, in hopes of increasing the effectiveness of conservative CTS treatments.

7 DISCUSSION

The CTS self-reflection form is a good attempt at pushing respondents to consider all potential behaviors that they engage in, which are associated with increasing CTS severity. However, adding in the ability to report specific activities conducted in the various settings would increase the effectiveness of this approach. This improvement would remove the current burden on the user to remember the different activities performed in the various settings. The other drawback of the current format is tied to the platform in which this form is built on. Google Forms is used with the purpose of collecting responses, but within this context, the collection of these responses is unnecessary and may dissuade respondents from divulging their information. In the current version, the obtained information lacks any value in the hands of a malicious individual because of the immense difficulty to hurt someone with only the contexts and time spent in these settings. Thus, the respondents should not be concerned with divulging this information. However, if the ability for the respondent to report specific activities is implemented, this information may prove harmful to the respondent if used malevolently. In this case and in the ideal version of this form, an alternate platform that does not intrinsically require the collection of the user's responses should be used.

Given the limited remaining in the quarter and initial steep learning curve, the current progress made on the CTS screening app is great, but there is room for improvement. The main issue with this current app is the lack of visual feedback for when the timer starts. The user is forced to assume the timer has begun upon contact with the red start circle. However, there are instances as encountered during testing where the timer has not started even though contact with the red circle was assumed to be made. There have been attempts at changing the timer text upon contact with the start circle to indicate the timer has begun, but these changes have unfortunately prevented the timer from beginning. Even though manipulating the text and starting the timer are two independent operations, there appears to be a bug preventing both these actions occurring together. Another issue is the app's lack of precision in the reported time, with the time ideally stated to a hundredth of a second. The current timer function is an incrementor, which increases the variable's value every tenth of a second. Thus, the final value of the variable is essentially the time span between timer start and end with the precision of a tenth of a second. However, increasing the frequency of this incrementor beyond this point results in immediate erroneous values. The assumption is that this approach places too much of a toll on the app, which results in an incorrect output. A timer function implemented in a different manner may achieve the desired precision and may even allow for visual feedback of the timer beginning.

The ability to create a CTS screening area circle with an adjustable radius should be implemented in a future iteration of this app. Currently, this circle's radius is fixed and is based upon calibrations of the Samsung Galaxy S9. However, newer phone models have vastly different screen sizes compared to the S9. More importantly, potential users of this app have different thumb sizes, which should be accounted for prior to screening. This is relevant because users with small thumbs are at risk to be misclassified as having CTS even though they simply were unable to reach the targets in a seamless manner. One simple method would be to ask for the length of the user's thumb prior to screening taking place. Then, the length would be converted into pixels and used as the radius for rendering the CTS screening area circle. A more complicated, but visually appealing method would be to begin with a screen with a draggable element located at the center of the CTS screening area. The user will be asked to place their hand in the same position that will be used for the CTS screening test and use his/her thumb to drag the element as far as possible. The drag distance stored from the center would be collected and used as a radius for the CTS screening area circle when it is rendered. Due to a hectic schedule, none of these approaches were implemented, but either one should resolve this issue.

8 CONCLUSION

The goal of this project is to illustrate how inaccessibility to well-established and highly accurate screening tests for carpal tunnel syndrome (CTS) can result in patients developing CTS and only acting when their condition is of noticeable impairment to their current lifestyle. This project attempts to tackle this issue by creating a version of the CTS screening app created by the Koyama et al that generates the required measurements designated for use in their machine learning algorithm. Smartphones are growing in use and being ubiquitous in modern society, so they were chosen to be a mechanism for screening patients concerned with having CTS. This project also attempts to empower individuals dealing with CTS by aiding them in recognizing the lifestyle activities that may be contributing to the progression of CTS. The hope is that this knowledge can result in immediate lifestyle changes that hinder the maturation of CTS and improve the effectiveness of affordable, non-invasive treatment options.

REFERENCES

[1] Carpal tunnel syndrome - symptoms and treatment - orthoinfo - AAOS. OrthoInfo. (n.d.). Retrieved January 24, 2022, from https://orthoinfo.aaos.org/en/diseases--conditions/carpal-tunnel-syndrome/#:~:text=Carpal%20tunnel%20syndrome%20is%20caused,and%20weakness%20in%20the%20hand.Sam Anzaroot and Andrew McCallum. 2013. UMass Citation Field Extraction Dataset. Retrieved May 27, 2019 from http://www.iesl.cs.umass.edu/data/data-umasscitationfield

[2] "Carpal Tunnel Syndrome." Mount Sinai Health System, https://www.mountsinai.org/health-library/diseases-conditions/carpal-tunnel-syndrome. Chelsea Finn. 2018. Learning to Learn with Gradients. PhD Thesis, EECS Department, University of Berkeley.

[3] "Carpal Tunnel Syndrome." *Johns Hopkins Medicine*, https://www.hopkinsmedicine.org/health/conditions-and-diseases/carpal-tunnel-syndrome.

[4] "11 Astounding Carpal Tunnel Statistics." Arlington, TX: Orthopedic Center of Arlington, https://www.orthoarlington.com/contents/patient-info/conditions-procedures/11-astounding-carpal-tunnel-statistics. James W. Demmel, Yozo Hida, William Kahan, Xiaoye S. Li, Soni Mukherjee, and Jason Riedy. 2005. Error Bounds from Extra Precise Iterative Refinement. Technical Report No. UCB/CSD-04-1344. University of California, Berkeley.

[5] "What's the Latest Cost for Carpal Tunnel Surgery?" What's the Latest Cost for Carpal Tunnel Surgery?, https://www.carpalrx.com/cost-for-carpal-tunnel-surgery#:~:text=According%20the%20industry%20watchdog%20Cost,and%20rehab)%20was%20approximately%20%241%2C000. Jason Jerald. 2015. The VR Book: Human-Centered Design for Virtual Reality. Association for Computing Machinery and Morgan & Claypool.

[6] "Carpal Tunnel Syndrome: Risk Factors, Symptoms & Treatment." Cleveland Clinic, https://my.clevelandclinic.org/health/diseases/4005-carpal-tunnel-syndrome#:~:text=Surgery%20for%20carpal%20tunnel%20syndrome,even%20up%20to%20three%20months. Fujita, Koji et al. "A Tablet-Based App for Carpal Tunnel Syndrome Screening: Diagnostic Case-Control Study." JMIR mHealth and uHealth vol. 7,9 e14172. 13 Sep. 2019, doi:10.2196/14172 Brian K. Reid. 1980. A high-level approach to computer document formatting. In Proceedings of the 7th Annual Symposium on Principles of Programming Languages. ACM, New York, 24–31. https://doi.org/10.1145/567446.567449

[7] Koyama, Takafumi et al. "A Screening Method Using Anomaly Detection on a Smartphone for Patients With Carpal Tunnel Syndrome: Diagnostic Case-Control Study." JMIR mHealth and uHealth vol. 9,3 e26320. 14 Mar. 2021, doi:10.2196/26320 TUG 2017. Institutional members of the LaTeX Users Group. Retrieved May 27, 2017 from http://wwtug.org/instmem.html