Title
Caption: Closed Captioning Glasses

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CAPTION:
CLOSED CAPTIONING GLASSES

By

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A capstone project submitted for
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University Honors
University of California, Riverside

APPROVED

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Abstract

As we age, we become more prone to hearing disabilities. It is forecasted that by the age of 60, one in every four Americans will become hard of hearing. This affliction hinders daily communication and makes social interaction difficult. Our device, Caption, seeks to provide assistance to those who suffer from hard of hearing by using speech to text technology. In conjunction with the Vufine and Raspberry Pi, we have created a device that is able to convert speech into text in real time for one to read. Caption provides benefits that conventional hearing aids and sign language cannot, including a faster means of communication (speech vs ASL) and lower costs. Rather than teaching those who become hard of hearing American Sign Language, we designed a device that uses their existing skills to aid them in their disability. With low cost and easy-to-work technology, we believe that Caption will aid those who are hard of hearing.

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Problem

By the age of 60, approximately 25% or 10 million people in the US population are hard of hearing and 1 million people are functionally deaf. There is a direct correlation between adults in the US who experience hearing impairment and depression.[Y] In a multistage probability sampling of the US population of approximately eighteen thousand adults over the age of 18, it was reported that a majority of the people who experienced a hearing impairment usually reported having higher levels of depression and having specific health conditions (eg. hypertension, diabetes, cardiovascular disease, etc.). There also is a greater correlation between older women who reported to a hearing impairment and depression. This is taking into account several lifestyle factors such as living alone, BMI, smoking and drinking. A hearing impairment is an invisible handicap which leads to social and economic burden on families. People who are hard of hearing can become isolated even from their own families because they are unable to communicate and participate in social activities. The overall well-being of these individual begins to disintegrate when they are not able to communicate with their support group. There is a reduction in the symptoms of depression and an improved lifestyle that was reported from adults who wore hearing aids. Improved communication between family members and people who experience hearing impairments can lead to better relationships and improved confidence.

The cost of hearing aids cost typically around $1500 to $3500 per ear, and most medical insurances do not help cover the cost of this ‘invisible’ disability. A typical private insurance will only cover the cost of an exam to test for hearing loss, but will not provide assistance in purchasing the device. There are only four states in the US (Arkansas, Connecticut, New Hampshire, and Rhode Island) who are required to provide hearing coverage for both adults and children. Only 20% of older Americans who need hearing aids have access to them, and only

50% of the users reported to feelings of satisfaction with the device. Most adults end up accepting their hearing loss as a new way of life, since they are unaware of their hearing loss or are in denial of having it.

The device, Caption, seeks to allow people who are hard of hearing to be able to communicate and interact with the people around them. By using skills that they already have, the user will be able to properly use this device without the additional need of having to learn a skill set. The technology is quite easy to use, allowing the user to have a smooth transition when interacting with the device. The idea is that it will eventually be used as a device that is inconspicuous to people around the user, also, to provide the user with a sense of discretion towards their hearing impairment disability.

Project Objective Statement

The main goal of the project is to be able to translate speech to text in real time, and to be able to display this into a wearable display. There already exist applications that require translation of speech into text to use of the application. One main example being the use of advanced machine learning technology of ‘Siri’ in iPhone devices to communicate within the whole device. It uses voice recognition from the user to make commands in the system and obtain different information or open new apps within the device. This type of speech recognition is very fast and is used by most iPhone users to make their day to day life easier.

Closed captioning is also available while watching videos or movies online. However, the closed captioning lines are written from a pre-written script, and are displayed for everyone to see. There are some movie theaters that offer a separate screen that displays closed captioning, but it is only offered in some locations and it is tedious to look at the screen showing the movie and the screen showing the closed captioning. Building off of an open source code and Web

Speech API using HTML5, Speech Recognition, the Caption device uses this to be able to translate speech to text in real time. Caption is unique in the sense that it is an all inclusive device that builds upon the idea of using speech to text to help people who are hard of hearing communicate in real time to follow conversation with the people around them.

Build on previous technology:

- Vufine glasses to display our text
- Open source code & Web Speech API
- Idea from closed captioning glasses from movie theaters

Objective

Prototype of Final Design

One of the main components of the device is the lapel microphone which is used to take input from the user and use it to run in the program.

- Lapel Microphone → to obtain the audio (speech)
- SD card → to put on our program that changes speech to text

Design Documentation

There are two main goals of our project, to be able to translate speech to text, and to be able to display it on the glasses. The first design iteration was based on the concept behind Google Glass which used a mini projector and a clear prism to project an image onto the retina of the eye. The speech to text API would be run using Arduino UNO as an open source microcontroller board. To input audio into our device, we would use a mini USB microphone because it is small and easy to fit into our device. One of the main reasons why it was decided to not use the prism to display information is because it was dangerous to create our own prism and test it using real test subjects. For one, it would take a lot of experimental data to test the optimal refractive angle which would be safe for a user to wear for an extended period of time. When there is a light shining at the eye it is possible to cause degradation at specific parts of the eye. The Arduino was not used because we believed that a quad-cortex Raspberry Pi 3B would be able to run the code more efficiently.

For the second iteration of the project, the components of the product changed to include a 32 GB SD card, a Raspberry Pi 3B, Vufine Wearable Display, Mini USB microphone, and batteries. The program to translate speech to text was tested using a laptop, and the computer microphone while the microphone arrived. Looking more closely at different ideas on ways to display text on to glasses, we found that the Vufine Wearable Display was a cheaper and effective way to be able to process the image into the field of view of the user without needing to test the part extensively at the risk of damaging someone's eyesight. The first microphone that was tested was a Mini USB microphone that is designed specifically for Raspberry Pi. However, one of the problems when testing this part was that there was a lot of interference when testing it through the Raspberry Pi 3b terminal. The reason that a Raspberry Pi 3b is being used is because it has wifi access, quad core CPU, HDMI and USB ports. Also, it was decided that using batteries to power the device would not be very friendly for older generations because it would not last very long.

In the final design iteration, it was decided that the final components would consist of a *Raspberry Pi 3b,* Vufine Wearable Display, 32GB SD card, lapel microphone, and a Juicebox. The lapel microphone was tested and obtained a higher quality of audio, allowing for an improvement of voice recognition by the speech to text program. The Juicebox has a battery life of approximately 4 hours which will power the Raspberry Pi.

However, when testing the functionality of the device we ran into a big problem: the microphone wasn't working. While the microphone would work when running a script directly on the raspberry pi, the microphone would not be able to record during on Chromium. Further research revealed that this was due to chromium and the ARM board architecture not being compatible with running some of the code of HTML5. Put simply, our raspberry pi was unable to utilize the microphone of an HTML on chromium. Thus we needed to find an alternative microcomputer with an x86 architecture in order to run our HTML5 API. Ultimately, the UDOO Advanced board was chosen due to its x86 architecture, thus enabling us to run the microphone on the HTML coding.

Final Component Specs

	Weight	**Battery Life**	**Dimensions**	**Screen Brightness**	**Refresh Rate**
Vufine Wearable Display	26 g	~ 90 minutes	96 x 20 x 14 mm	220 cd/m^2	60 Hz

	Weight	**Sensitivity**	**Dimensions**	**Polar Pattern**
Lapel Microphone	5.3 g	7 mV/Pa	19 x 8.5 mm	Omnidirectional

	Weight	CPU	RAM	Ports
Raspberry Pi 3B	42g	4 x ARM Cortex-A53	1GB	HDMI, ethernet, DSI

	Architecture	CPU	RAM	Dimensions
UDOO Advanced	x86	Intel Celeron N3160 2.24 Ghz	4GB	4.72" x 3.35"

Patentability

While some of our components, including the Vufine Wearable display, already hold patents, we believe that there is potential to patent the device's application and functionality as novel. We would be patenting the entire device, stating that the specifications and tweaks created specifically for those with hearing disabilities makes our device unique and patentable.

The patent on Google Glasses would be the primary adversary to our patent. They already have a patent on the wearable display performing assisted display functions similar to our device. However, we have distinguished ourselves by creating our functionality and design solely for users attempting to alleviate their hearing disability complications. We have implemented specific changes and designs, such as only having a speech to text functionality and having the application open in order to provide an intuitive experience for users. Additionally, we wanted to provide ease of use due to our device being market towards senior people with growing hearing disabilities. Additionally, our device has software specifications made purposefully for aiding those that are hard of hearing, all aspects lacking in the Google Glasses design.

Additionally, future directions would allow us to create a custom wearable display tuned specifically for our device's use which would then be patentable as a product. This would give our product complete autonomy, allowing it to be created and sold by our brand However, in its current state, we would utilize our patent to create a partnership between our brand and the brands of the products we are utilizing in order to sell our product.

Our product would be under a Class 1 Medical Device, due to it non-invasive use. We would not need FDA clearance for our device, making the transition into a marketable device much easier. However, it would still be required that we list our product and establishment with the FDA.

Market Potential

There are two markets that we would be targeting with our product. The first group is the hearing aid market. The hearing aid industry is a $9.78 billion industry which has been steadily growing by 7% annually. There is potential to capture some of the customers of this market segment, as it has been reported by the National Institute of Deafness and Other Communication Disabilities that 50% of those using hearing aids are not satisfied with the hearing aids performance in some way. We also see potential to market this product towards those who are hearing aid adverse, as only 20-30% of those who could benefit from the use of hearing aids actually purchase one.

The user would be any one with a hearing disability. Our main goal is to have this product covered by Medicare. This would be beneficial as subsidizing the cost through Medicare would further reduce the purchase price for users allowing almost anyone for afford our product regardless of financial standing. To qualify for Medicare coverage, it is necessary to undergo rigorous testing in order to ensure that our product is beneficial to the users.

Our product would be under a Class 1 Medical Device, due to it non-invasive use. We would not need FDA clearance for our device, making the transition into a marketable device much easier. However, it would still be required that we list our product and establishment with the FDA.

The budget for the prototype device is as follows:

Item	**Cost**
Vufine	$100
UDOO Advanced	$174
Microphone	$15
Battery/ Juicebox	$55
microSD Card	$8
Total Cost per Unit	**$352**
Retail Price	**$599**
Profit/Margin	**$248/40%**

Startups have margins of 30-80%. Due to the Typically, the margin of products in a medical device company is 20-30%. With mass production manufacturing, estimated retail cost would drastically decrease.

One of the objectives of pricing this product was to produce a better alternative to hearing aids, eliminating the parts that consumers disliked about them. One of the main reasons consumers were dissuaded from purchasing a hearing aid was their expensive pricing. Starting at $1500 per hearing aid, this price is just not affordable or justifiable in many people's eyes. This has resulted in only 20-30% of people who could benefit from hearing aids actually purchasing hearing aids.

Impact upon implementation

The user would be the one to benefit the most from using this device. People who are hard of hearing often feel disconnected from their friends and families due to the fact that they are unable to keep up in conversation. By using this device, the user will be able to maintain close friendships and communicate with their community. As people who are hard of hearing are able to integrate themselves into their society, they are more likely to become more active within their social circle, helping them improve mental health. Most importantly, the user will never feel left out of any conversation ever again. In comparison to using hearing aids, the user will be able to live their days worry-free of taking special care of a hearing device. There will no longer be a requirement to receive ear appointments to ensure that the hearing aid device is still functioning at the optimal range for the hearing disability. Also, this is a cheaper alternative to those who do not have the necessary funds to afford expensive hearing aids.

As more and more people continue to purchase the wearable display, more people will become aware of the existing problem that people who are hard of hearing experience:

- Provide people with a novel approach to dealing with hearing loss
    - Alternative to hearing aids
- Help reconnect those who have been socially isolated due to their hearing disability
- Offer a cheaper alternative to hearing aids

Appendices

Appendix A: Test Figures

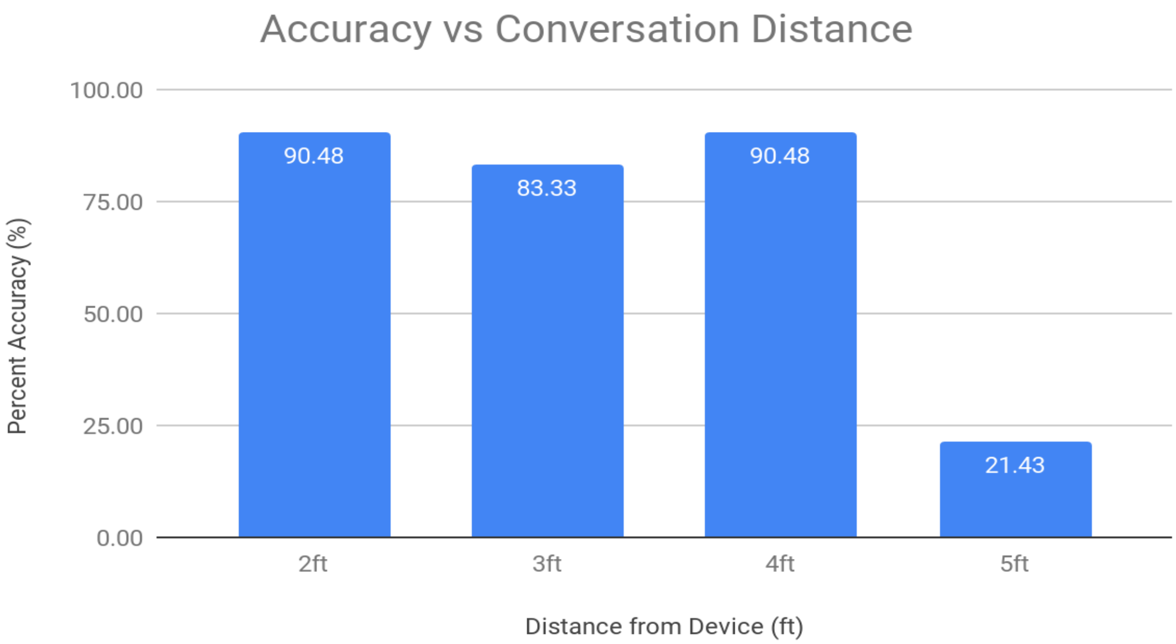

FIgure A: Accuracy With Changes in Distance. The test was conducted with two people. One with the microphone (device) and the other some distance (2, 3, 4, or 5 ft) away. The microphone was about 4 inches away from the user. The user had an accuracy around 97%, while the user had around an 88% accuracy within 5 ft.

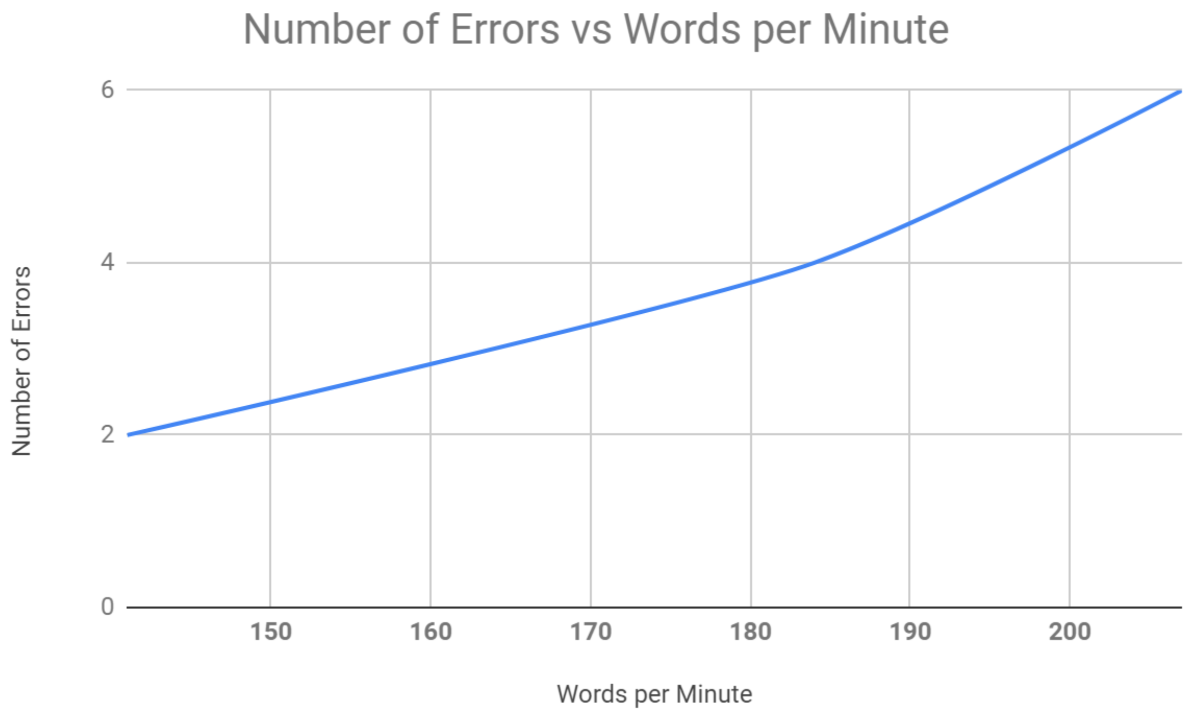

Figure B: Accuracy With Varying Words Per Minute. A person speaks around 120 - 150 words per minute in an average conversation. Looking at the graph, our program has an accuracy around for an average conversation a person has a good accuracy

Appendix B: Program Code

CODE 1: HTML

```
<!DOCTYPE html>
    <head>
              <!--  -->
        <meta charset="utf-8">
        <meta http-equiv="X-UA-Compatible" content="IE=edge">
        <title>Closed Captioning App</title>
        <meta name="description" content="">
        <meta name="viewport" content="width=device-width, initial-
scale=1">

        <link rel="stylesheet"
href="https://cdnjs.cloudflare.com/ajax/libs/shoelace-css/1.0.0-
beta16/shoelace.css">
        <link rel="stylesheet" href="styles.css">

    </head>
    <body>
        <div class="container">
                <div class="input-single">
                    <textarea id="note-textarea" placeholder="Starting
voice recognition..." rows="6"></textarea>
                    <!--  <textarea id="note-textarea"
placeholder="Starting voice recognition..." rows="6"></textarea> -->
                </div>
              </div>
        <script
src="https://cdnjs.cloudflare.com/ajax/libs/jquery/3.2.1/jquery.min.js"></
script>
        <script src="script.js"></script>

    </body>
</html>
```

CODE 2: Java Script

```
try {
  var SpeechRecognition = window.SpeechRecognition ||
window.webkitSpeechRecognition;
  var recognition = new SpeechRecognition();
}
catch(e) {
  console.error(e);
  $('.no-browser-support').show();
  $('.app').hide();
}
```

```
var noteTextarea = $('#note-textarea');
var instructions = $('#recording-instructions');
var notesList = $('ul#notes');

var noteContent = '';

// Get all notes from previous sessions and display them.
var notes = getAllNotes();
// renderNotes(notes); // do we need to display previous notes?


/*-----------------------------
      Voice Recognition
------------------------------*/

// If false, the recording will stop after a few seconds of silence.
// When true, the silence period is longer (about 15 seconds),
// allowing us to keep recording even when the user pauses.
recognition.continuous = 1;
recognition.interimResults = 1;

recognition.start();

recognition.onend = function() {
       recognition.start();
}
var firstWord;
// This block is called every time the Speech APi captures a line.
recognition.onresult = function(event) {

  // event is a SpeechRecognitionEvent object.
  // It holds all the lines we have captured so far.
  // We only need the current one.

  var current = event.resultIndex;

  // Get a transcript of what was said.
  var transcript = event.results[current][0].transcript;


  // Add the current transcript to the contents of our Note.
  // There is a weird bug on mobile, where everything is repeated twice.
  // There is no official solution so far so we have to handle an edge
case.
  var mobileRepeatBug = (current == 1 && transcript ==
event.results[0][0].transcript);

  if(!mobileRepeatBug) {
       if (noteContent.split(/\r\n|\r|\n/).length > 3) {
              var lines = noteContent.split('\n');
              lines.splice(0,1);
              noteContent = lines.join('\n');
```

```
        }
        noteContent += transcript + '\n';
        noteTextarea.val(transcript);
  }
};

recognition.onstart = function() {
  instructions.text('Voice recognition activated. Try speaking into the
microphone.');
}

recognition.onspeechend = function() {
  instructions.text('You were quiet for a while so voice recognition
turned itself off.');
}

recognition.onerror = function(event) {
  if(event.error == 'no-speech') {
    instructions.text('No speech was detected. Try again.');
  };
}



/*-----------------------------
      App buttons and input
------------------------------*/


// Sync the text inside the text area with the noteContent variable.
noteTextarea.on('input', function() {
  noteContent = $(this).val();
})



notesList.on('click', function(e) {
  e.preventDefault();
  var target = $(e.target);

  // Listen to the selected note.
  if(target.hasClass('listen-note')) {
    var content = target.closest('.note').find('.content').text();
    readOutLoud(content);
  }

  // Delete note.
  if(target.hasClass('delete-note')) {
    var dateTime = target.siblings('.date').text();
    deleteNote(dateTime);
    target.closest('.note').remove();
  }
});
```

```
/*----------------------------
      Helper Functions
-----------------------------*/

function renderNotes(notes) {
  var html = '';
  if(notes.length) {
    notes.forEach(function(note) {
      html+= `<li class="note">
        <p class="header">
          <span class="date">${note.date}</span>
          <a href="#" class="listen-note" title="Listen to Note">Listen to
Note</a>
          <a href="#" class="delete-note" title="Delete">Delete</a>
        </p>
        <p class="content">${note.content}</p>
      </li>`;
    });
  }
  else {
    html = '<li><p class="content">You don\'t have any notes
yet.</p></li>';
  }
  notesList.html(html);
}



function getAllNotes() {
  var notes = [];
  var key;
  for (var i = 0; i < localStorage.length; i++) {
    key = localStorage.key(i);

    if(key.substring(0,5) == 'note-') {
      notes.push({
        date: key.replace('note-',''),
        content: localStorage.getItem(localStorage.key(i))
      });
    }
  }
  return notes;
}


function deleteNote(dateTime) {
  localStorage.removeItem('note-' + dateTime);
}
```

CODE 3: CSS

```
ul {
    list-style: none;
    padding: 0;
}

p {
    color: #444;
}

.container {
    max-width: 1500px;
    margin: 0 auto;
    text-align: center;
}

.container h1 {
    margin-bottom: 0px;
}

.page-description {
    font-size: 1.1rem;
    margin: 0 auto;
}

.tz-link {
    font-size: 1em;
    color: #1da7da;
    text-decoration: none;
}

.no-browser-support {
    display: none;
    font-size: 1.2rem;
    color: #e64427;
    margin-top: 0px;
}

.app {
    margin: 0px auto;
}

#note-textarea {
    margin: 0px 0;
        font-size: 5rem;
}

#recording-instructions {
    margin: 15px auto 60px;
}
```

```
#notes {
    padding-top: 0px;
}

.note .header {
    font-size: 0.9em;
    color: #888;
    margin-bottom: 10px;
}


.note .content {
    margin-bottom: 40px;

}

@media (max-width: 768px) {
    .container {
        padding: 50px 25px;
    }

}
```

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