Speech-based Data Exploration for Diabetes Management among Older Adults

Vedangi Bhavsar*
Pune Institute of Computer Technology
University of Pune

Utkarsha Nehe†
Pune Institute of Computer Technology
University of Pune

Aditya Mandke‡
Pune Institute of Computer Technology
University of Pune

Srushti Sardeshmukh§
Pune Institute of Computer Technology
University of Pune

Alark Joshi¶
Visualization and Graphics Lab
University of San Francisco

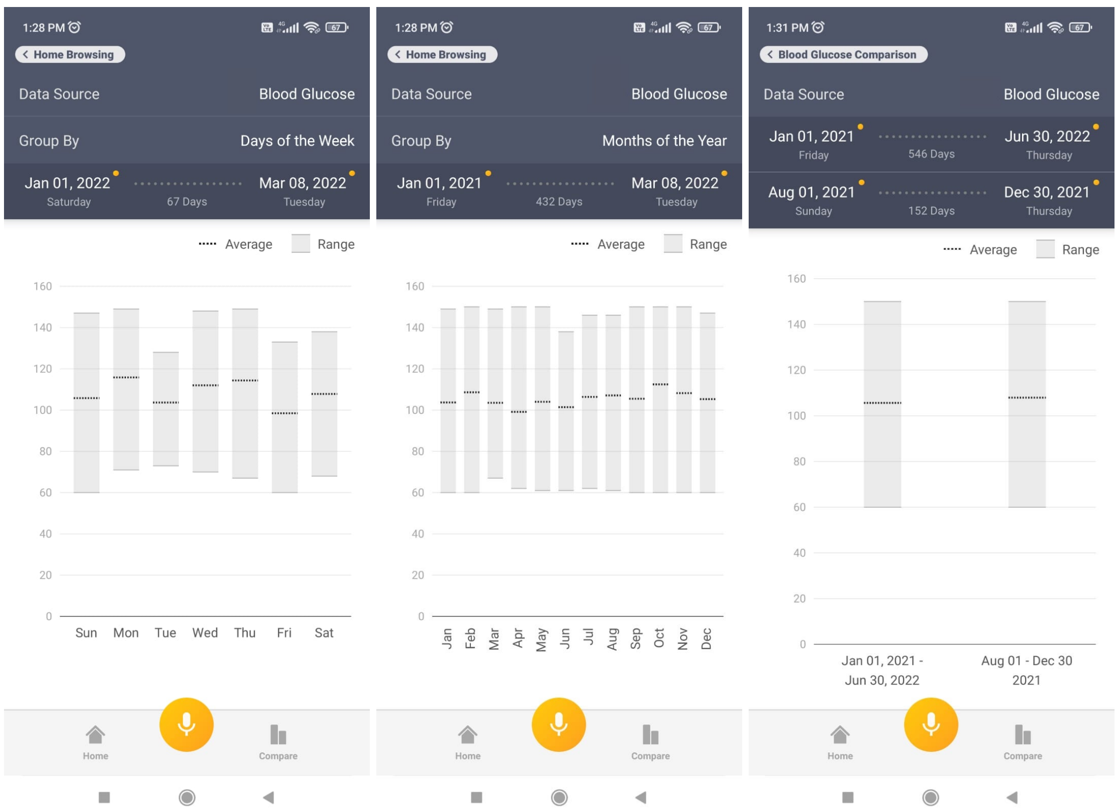

Figure 1: This figure shows the average including range over a user specified time period. The leftmost figure shows the data aggregated based on days of the week, the middle figure shows the average and ranges for each month, whereas the rightmost figure shows the ability to compare the blood glucose levels for user-specified time ranges.

Abstract

Diabetes management is particularly challenging for older adults due the various factors that affect the blood glucose of a patient. Based on a requirements analysis, we developed a prototype that will allow older adults to interact with their own blood glucose data using speech. Through self-reflection and contextual clues, we aim to increase the awareness of the factors that may lead to instability in blood glucose levels among patients.

*e-mail: vedangibhavsar123@gmail.com
†e-mail: utkarshanehe@gmail.com
‡e-mail: adeetya.m@gmail.com
§e-mail: srushti.sardeshmukh@gmail.com
¶e-mail: apjoshi@usfca.edu

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1 Introduction

Diabetes is a life style disease that affects millions of people all over the world. Unfortunately, it affects older adults much more than the youth. As smartphones have become more popular, people are getting more comfortable with using them for communication and entertainment. Older adults frequently have trouble interacting with the user interface components on smartphones due to challenges with multi-screen navigation [6] and the fat finger problem [19] among other things. The quantified self movement [13] is great for improving fitness levels, but it has excluded a large number of older adults due to the need for interaction with the devices and related apps.

In this paper, we share the work that was conducted with older adults in Pune, India to collect the requirements for an app that would

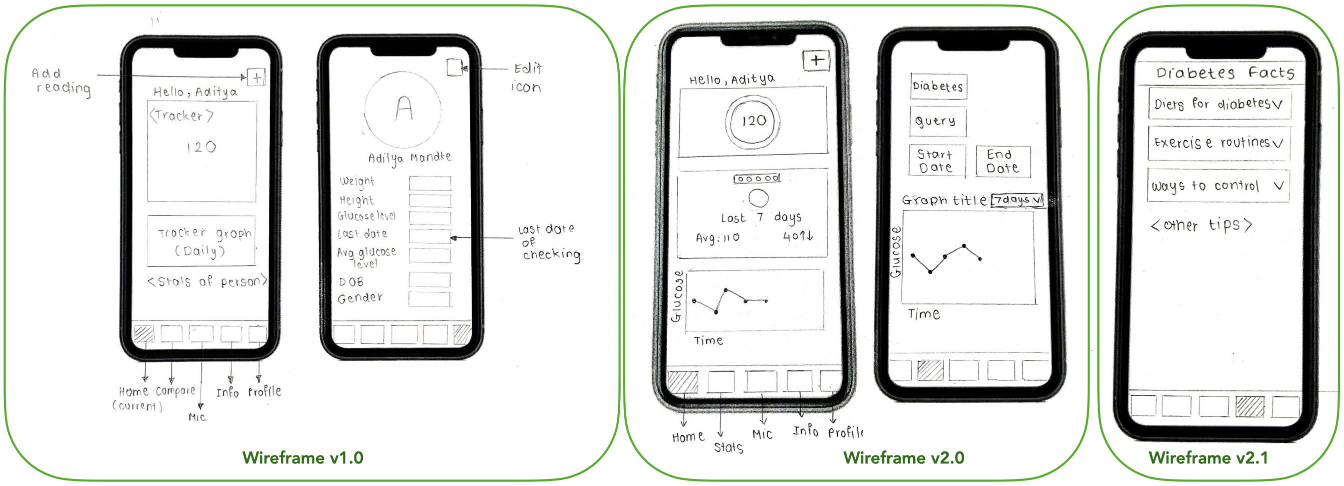

Figure 2: This shows the various wireframe prototype that the team iterated through as the app was being designed with input from older adults. The last wireframe (version 2.1) includes all the designs from the previous version (2.0), but also includes tips for Diabetes patients to better manage their blood glucose levels.

satisfy their needs and would allow them to get a better understanding of their blood glucose levels through natural language interaction with their data rather than tapping and navigating multiple screens.

Towards that end, we built an app (based on the Data @ Hand [9] framework), that allows individuals to ask questions about their data and get visual representations that let them explore their historic blood glucose levels, compare certain time intervals, and examine averages at the week and month level to see any trends in the data.

2 Related Work

2.1 Speech-based interaction

Speech-based interfaces are becoming increasingly common for interacting with data. Kassel and Rohs [7] introduced Valletto - a system that uses multimodal interaction (speech and touch) to allow users a conversational experience with data. Orko [21] and InChorus [20] are examples of similar systems where the user is allowed seamless interaction with data using speech, touch, and keyboard/mouse as needed.

Choe et al. [2] present the idea of using speech to interact with personal data such as that obtained from fitness trackers, sleep trackers, and so on. They posit that lay users would be better able to gain an understanding of their data using speech on their mobile phones rather than using clunky desktop applications. They also mention the concept of context capturing and how a mobile device can help with ease the burden such as “completed a workout” can be deduced by using the location and activity levels.

Kim et al. [9] introduced the ‘Data @ Hand’ system that allows fitness enthusiasts to interact with their data verbally by asking questions of their Fitbit data. patients were shown their Fitbit data in their system and were able to ask questions about the maximum number of steps taken in the last week/month, compare their activity across two user specified time ranges, and more.

2.2 Diabetes management and self-reflection

Self-reflection in the personal health space has been proven to lead to an improved understanding of data. Choe et al. [3] found that self-reflection of data from fitness trackers (Fitbit, Runkeeper) led to “self-trackers [13]” gain insights into their own data.

Diabetes management is a widely researched topic and there have been many interventions designed to help patients better understand and manage their blood glucose levels [5]. Mamykina et al. [16] conducted a study with a GlucoWater G2 Biographer in 2006 and found that while it helped patients better understand their blood glucose levels, they are eager to generate their own hypothesese rather than take suggestions from physicians. Their group also examined the effects of self-reflection in MAHI [14, 15] and found that their health monitoring application helped individuals develop an ‘Internal Locus of Control,’ which often leads to improved patient outcomes for self-care.

2.3 Health visualization for older adults

Le et al. [12] conducted a study evaluating the perceived usability of visualizations to communicate health-related data to older adults. They found that reducing metaphoric comparison within a visualization, limiting differences in color gradient, and reducing the number of visual cues led to better outcomes for older adults. In a follow up study, Le et al. [11] compared bar plots, radial plots, and a light ball metaphor (“changes in brightness with differences in score”) to convey health-related information and found that patients preferred bar charts and radial plots, but were unsure about the light ball metaphor. They also found that data sharing was an important task when working with health data. The data should be accessible on paper as well and that users should be able to take printouts of it for doctors and family members. Overall, their suggestions for the visualizations were (i) reduce clutter, (ii) have clear contrast, (iii) use discriminatory colors, and (iv) limit complexity.

3 Approach

3.1 Requirements Gathering through Interviews

To better understand the needs of older adults, we conducted interviews with 7 older adults (age 62-79). All of them had Type-2 Diabetes and had varying levels of challenges with the disease. 5 of the 7 patients mentioned that they would be comfortable with using English as the language for verbal interaction with an app that showed them their Diabetes data. The glucose monitoring of the patients was variable between every day to once every 3 months. 3 of the 7 patients owned a glucometer. All of them had an Android device and would therefore be able to use only an Android app. 5 of the 7 patients regularly exercised in the form of walking. One of them mentioned that they would like the app to also provide tips related to diet, exercise, sleep as they related to Diabetes management.

3.2 Wireframing

Based on the requirements analysis and features that were planned for the project, we built wireframe prototypes to get quick feedback on designs. Figure 2 shows the various iterations of the prototypes.

In the first prototype, we included all the components that we added all the features to the app based on the requirements gathering and our internal discussions. That included visualizations, buttons to open the microphone, navigate to the user profile, and to go back to the home screen. We realized after getting feedback for version 1.0 that quick summaries of data in the form of data visualizations should be shown on the landing page of the app, rather than on a secondary/tertiary page after multiple clicks and swipes.

Version 2.0 and 2.1 of the wireframe included fewer screens and less navigation with clear representations and less clutter ([10]). In Version 2.1, we also added tips related to Diabetes management as suggested by one of the interviewees.

3.3 Visual Representations of Blood Glucose Data

To provide an overview of the blood glucose data for a patient, we created multiple visualizations to help with increased awareness and self reflection. The aim was to allow patients to see quick visual summaries of their data that would enable self-reflection.

The first visualization technique used was to show patients the average and range of values aggregated based on the days of the week as well as the months of a year. We chose this technique due to the fact that older adults can easily read and understand averages and ranges (minimum and maximum values) [10].

The leftmost figure in Figure 1 shows a patient's blood glucose data aggregated over 67 days based on the days of the week. Based on the visualization, we can see that on average the patient's blood glucose levels were the highest on Mondays. Similarly, we can also represent the monthly averages and range of the blood glucose level, as shown in the middle figure in Figure 1. The rightmost figure in Figure 1 allows a user to compare their blood glucose levels across two ranges of time that can be specified by the user. Here the user would like to compare their blood glucose levels between January 1st, 2021-June 30th, 2021 with the range from August 1st, 2021-December 30th, 2021. The average is slightly higher in the second time span as compared the first time span.

The second visualization technique that we chose was a line chart, again due its simplicity and easy of understanding [10]. Figure 3 shows the blood glucose level for a single week. We also added a historic average blood glucose level value (shown as a dotted line) for patients to know when they are below or above the "normal" levels.

Note: The data used for *all* the screenshots of the app is simulated.

3.4 Data Entry

One of the major problems with compliance when using such systems is entering blood glucose level data for patients. Patients may forget to enter their data for a past date even though they may have taken readings on their glucometer. To enable patients to enter their data for the current data or a past date, we provide a textbox that allows patients to submit their data for today's date or for a previous date, as shown in Figure 4. In the future, we plan to integrate speech-based or a nudge-based interaction [18] for easier data entry. The idea would be to send the user a nudge on WhatsApp (popular social media communication app used widely internationally) to remind them to record and enter their blood glucose level by just replying to a WhatsApp message. The nudge could be sent earlier in the day for fasting glucose levels and one after lunch time for postprandial glucose to help patients enter data seamlessly into the app.

3.5 Spoken Interaction

To facilitate seamless interaction with data, we allowed patients to ask questions of their data. Simple "retrieve value [1]" tasks to

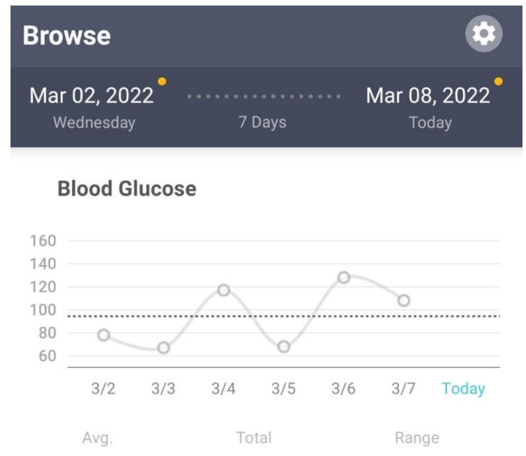

Figure 3: This figure shows a line chart representing the blood glucose data of a patient for a week. The dotted line conveys the average value of the patient based on all the data in the app so far (not just for that week).

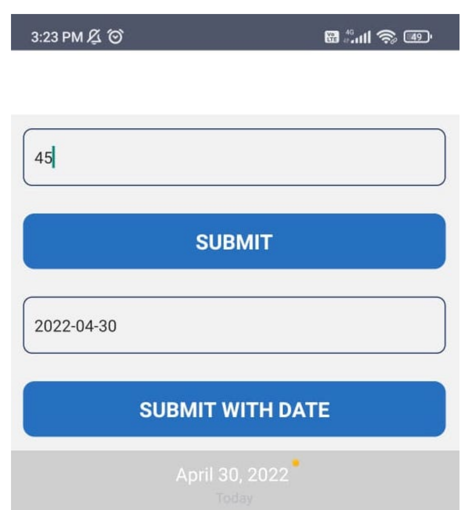

Figure 4: This figure shows how the patient could enter their blood glucose data for the current date or for a past date.

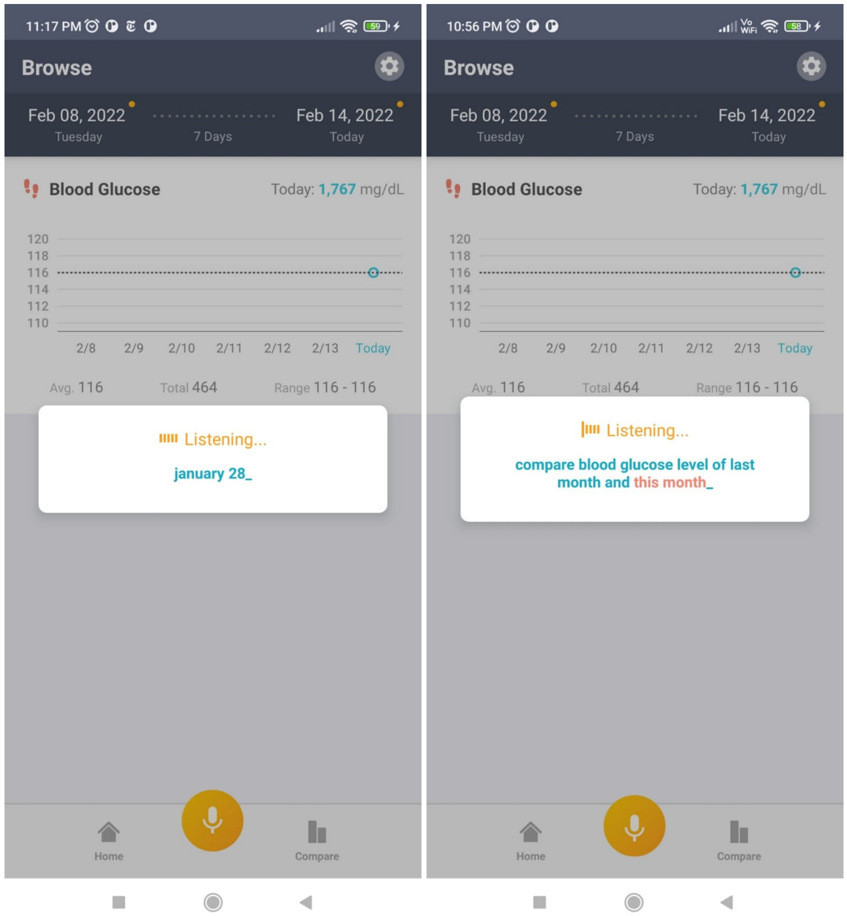

Figure 5: This figure shows a snapshot of user interaction with the data based on verbal cues provided by the user.

get the blood glucose value for a specific date was performed by specifying the date as shown in the left screenshot in Figure 5.

Self-reflection is possible if patients can compare their blood glucose levels based on good/bad eating habits, good/bad exercising habits, and so on. To facilitate this kind of comparison, patients could say “compared blood glucose level of last month and this month” as shown in the right screenshot of Figure 5.

If a patient was to specify the query of “2021 by months of the year,” our system would show the middle graph in Figure 1. For a user-specified query “show by blood glucose level data for the last week,” a line chart is shown as in Figure 3.

3.6 Implementation Details

We used the Data@Hand framework [9] as a starting point for our app. It is built using TypeScript on React Native and we stored our patient data locally on a SQLite database. For the speech-to-text recognizer, since we were only building an app for Android devices, we used the Microsoft Cognitive Services [4, 17]. The processing of the input text was performed using the Compromise Javascript library [8]. The interpreter then infers the user-specified operation by examining the tagged verbs and parameters.

4 Conclusion and Future Work

A challenge with speech-based data exploration is identifying accents and managing expectations [22] when interacting with an app using speech for data exploration. In this paper, we presented work that included discussing expectations and requirements of older adults for an app that allowed them to explore their blood glucose data using speech. While we were able to build the app, we have not yet evaluated it with our original group of participants that we interviewed for the requirements analysis.

In the future, we plan to add more functionality to the app such as managing a way to show missing values in the data, implementing more phrases that patients can use when interacting with the data, showing users dietary and exercise tips to manage the disease, integrating the database backend to work with WhatsApp (for easier data entry), and report generation for doctors and family members. That followed by a usability evaluation with a group of patients will provide us with insights into challenges with data exploration and the ability of our end users to understand and use the visualizations for self-reflection.

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