Web Visualization of Temporal and Spatial Health Data from Smartphone App in Smart and Connected Community (SCC)

Sharmin Afroz
Electrical and Computer Engineering, University of Memphis
Memphis, TN 38452 USA
safroz@memphis.edu

Bashir I. Morshed
Electrical and Computer Engineering, University of Memphis
Memphis, TN 38152 USA
bmorshed@memphis.edu

***Abstract*— This paper presents a strategy of graphical visualization of the community-based Smart and Connected Community (SCC) Health data through novel spatial and temporal plots. Temporal visualization consists of two plots: graph and flow; whereas spatial visualization can be static Google Map overlay or animation over selected timeframe. The visualization uses the disease severity (Events of Interest, EoI) through colors. An arbitrary grid is used with random area code where each grid is represented by rectangles defined by latitude and longitude of that area so that it is impossible to precisely localize the study participants. The major contribution of this work is to exhibit the continuous health status of the community through the cumulative and segmented animation on the spatial plots. To implement this, a web-based dynamic server is utilized. Front end of the server uses JavaScript JQuery and Ajax, whereas backend is managed by Hypertext Preprocessor, i.e. PHP. The phpMyAdmin (administration tool for MySQL) stores the JSON data from smartphone app. Survey result shows that 81.4% participants in pre-session and 84.75% participants in post-session provided positive feedback about the visualization. In this work, the visualization is implemented with mock data.**

Keywords— ***Google map API, health data, smartphone app, web-based visualization, smart and connected community.***

I. INTRODUCTION

Smartphones, wearables, body sensors, and Internet of Things (IoT) are becoming prevalent and they are integrated with intelligent technology for the welfare of human being and prosperity, leading rise to Smart and Connected Communities (SCC) initiatives. In addition, ubiquitous health monitoring and individual well-beings are growing issues these days. As many diseases can be monitored at home with these newer technologies that are capable to collect physiological signals, these can be efficiently utilized to improve individual as well as SCC health, which will lead to lower visits to hospitals for emergency care. In addition, many people with chronic disease might be able to reduce visit hospitals with effective everyday monitoring. However, it is difficult to track the disease conditions of various types and engage the participants to share their health data over time due to privacy concerns.

In order to reduce their hospital visits, some body sensor technology are already available. Sensor data can be collected through smartphones, and compute disease severity that can be sent to the server. Web server can be utilized to visualize these health data for the stakeholders. Furthermore, visualization can allow understanding of the conditions of diseases around their community.

In the literature, several applications of web-based visualization are reported. The spatial and temporal plot for web GIS platform are utilized in [1] to monitor and allocate the zero energy settlement in residential building in the district level. For the visualization of England Strategic health data, google map API, Google Earth KML (Keyhole Markup Language) version, and MSN Virtual Earth Map Control version have been exploited to introduce online mapping trends [2]. The work presented in [3] demonstrates a predictive modeling for patients events through web service by integrating a database of 31,855 ICU patients, where the patients are allowed to upload their data from web service and see the visualization of their events. Web visualization of clinical data based on pie charts and continuous calendar data to see the continuity of patients' data has been presented in [4]. To visualize the continuous data of stroke patients, a TimeSpan web visualization is presented in [5] as the data need a deep understanding of intervals time to save life. The work presented in [6] demonstrates a methodology to improve the health behavior of children through data visualization on the web. There are lot of research papers on spatial web visualization to show the vulnerability of climate change on human health [7][8][9]. Research work in [10] presents the spatial animation of ovarian cancer throughout the United States.

Our research group has been developing a smartphone app and a novel set of battery-less sensors to collect physiological data from users at home [11]. These data need a better visualization in both time and space (spatiotemporal) domains to be fully observable and utilizable to the end user and how the data are co-related with each other. Most of the health data web visualization tools have been introduced to meet the specific need of their own purpose. But in our work, we only take measure of the severity of person's health condition and provide the information to the overall community. It helps the person to be connected to the entire SCC. None of the previous work has been conducted for the betterment of the whole community by engaging the individual person. For this, the severity of person's health data are taken from the smartphone and then sent to SCC Health web server, and from the server, one can visualize how person's data are changed through some time interval by temporal plot and also the distribution of the disease in a several region through the spatial plot. The project specially considers privacy and anonymity of the participants. In the spatial plot, it can be visualized that one's environment is influenced by others. In the smart and connected community, it is not only the sole responsibility of individuals, but the whole community needs to be engaged to lead a healthier life [12].

This study is supported by the National Science Foundation under Grant No. 1637250.

II. METHOD

Physiological data are collected with sensors. These sensors send data to the scanner and the scanner sends data to smartphone via Bluetooth [11]. After that participants send smartphone data to the SCC Health server. From the server, the registered participants of the community can see the visualization of physiological data through temporal and spatial plot. Fig. 1 demonstrates the workflow from participants to SCC Health server.

In this paper, the visualization of the data is reported as SCC Health webserver and workflow is divided into

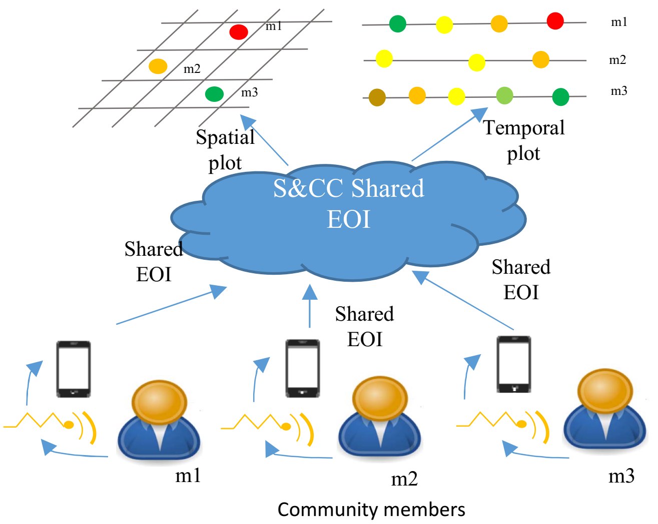

Fig. 1. Workflow of SCC health data from community members to SCC Health server.

three parts i.e. 1) how data are sent from the smartphone to SCC Health database 2) how the data are organized into database and 3) the visualization of data to the end user through spatial and temporal plots.

A. *Data sent to SCC Health server database from smartphone*

Smartphone data are sent to the database into JSON (JavaScript Object Notation) format. These data include participant's hash Id, area code, EoI (Event of Interest), disease type, date time and algorithm type. All participants have unique Id. The surrounding Memphis areas are divided into 19 grids with unique area code name. The mobile app has the mechanism to convert the participant's home address into area code. In the SCC Health server, participants share only their area codes rather than their actual address to ensure their privacy, EoI and severity of their disease. Four chronic diseases i.e. Arrhythmia, Chronic Obstructive Pulmonary Disease, Flu, and Sleep Apnea are visualized through SCC Health Web Server. The date and time of the person is the time of their checking health status. Different types of algorithms are used to calculate the severity of the same disease and user has the facility to choose one of them. So the choice of algorithm for testing the disease is also included for further feedback.

After completing the testing of a disease in smartphone, if a participant wants to share their data to the SCC Health

{"ID":"1","GRID_CODE":"AZ19","DT":"PD","EOI":".7","TIME":"2017-11-03","Algorithm":"BT1"}

Fig. 2. An example of JSON from smartphone to the SCC Health server

Server, he just needs to click a button from app and all the information are bundled into a JSON that is shown in Fig. 2 and transferred to SCC Health database.

B. *Data Organization into Database and Backend*

MySQL is used as database for SCC Health server. Here phpMyAdmin is an administration tool for MySQL. This database has two tables: participants' data table and mock data table. Participants' data table consists of directly collected physiological data from the community members and mock data table consists of some mock data that are randomly created.

In the backend, JSON data are encoded with PHP and inserted into the participants' table of the database. If two participants' send data at the same time, server obeys the rule of FIFO (First-In-First-Out) and inserts the data, which has come first and keeps others in a queue.

C. *The Visualization of the data to the end user (Frontend)*

To visualize the SCC Health data there are three types of login credentials, i.e.

1) Admin: Admin login has the full access of all data and different types of data management. It has spatial plot (google map overlay), temporal plot (time plot with flow and graph), and all data from database of the participants' data table. It has the privilege to create login credential for the participants. Admin can also add .dex file for the algorithm of detecting diseases. To be logged as an admin, one should have certain credentials.

2) User: User login has the privilege to visualize the participants' data with spatial plot and two temporal plots. Login credentials are created by admin for the recruited subjects, and then the subjects can have the access as a user.

3) Guest: Guest has the same privilege like user. But only difference is that guest can visualize spatial plot and temporal plots with *mock data*. These *mock data* are arbitrarily entered to test functionality of the web visualization and is not collected from participants. There is no requirement of login credential for guest login. Anyone can visualize the plot through this login.

III. VISUALIZATION

To visualize the health data, SCC web Server has two types of visualization, i.e. 'Temporal plot' with graph and flow, and another is 'Spatial plot' with static and animated view.

A. *Temporal Plot*

Participants can see the EoI in the measurement of severity of persons over time.

1) Time plot Graph: It can be seen from Fig. 3 that the EoI (0-1) has been shown in the Y-axis of the chart and X-axis shows the date and time. This plotting has been done with the help of Google JavaScript API of Chart line. Every single line in the X-Y plane represents a single participant's data. Data

Fig. 3. An example view of the time plot graph of severity data.

collection points are symbolized with circle and two points are connected through edges to keep the continuity of participant's data. To differentiate among different individual's data, multi colored lines have been exploited. If anyone hovers mouse on the line, that line becomes highlighted. When the circles are hovered by mouse, a pop-up message is displayed with date and time of that participant's testing and also with their exact EoI value of that time. The line represents a participant's gradual report of their health status from zero to one. To see the small changes, one can scroll the mouse wheel over the expected area and they can see the changes in small granularity of hour. At first the view of the time plot graph shows the default value. If there is no data in the database, then chart line becomes blank. If there is data, then it takes the oldest date as its first starting date and the last newest date would be the ending date of the chart line. Within these date range and with the default disease type (Flu), the time plot graph as a temporal plot of SCC Health are plotted in Fig. 3.

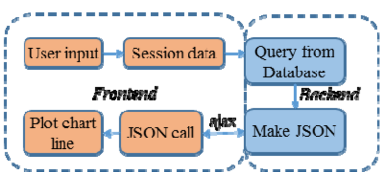

Fig. 4. Mechanism of temporal plot at the SCC Health server.

Start date and end date are selected from the input box of calendar and disease type is selected from the option menu of disease. When user clicks the display button, session variables in the frontend PHP grabs the data and sends the data to the backend file. In the backend, with session variable and query of MySQL, data are retrieved from the database.

Then this data are encoded into a JSON array. In the frontend, this JSON array are called with the help of Ajax. In the frontend JavaScript, JSON array has been parsed and customized the data for 'Line Chart'. Then with the help of the JavaScript google API key, line chart has been implemented in Fig. 3 and the process of generating temporal plot is shown in Fig. 4.

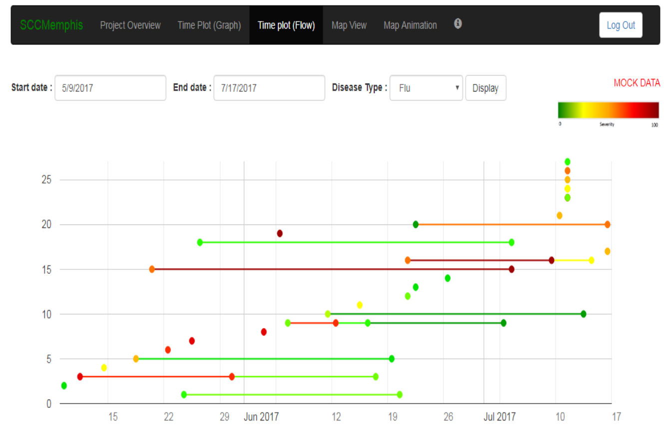

Fig. 5. An example view of the time flow graph of severity data.

2) Time plot Flow: This Flow chart as shown in Fig.5 represents participant's EoI flow over time. X-axis represents time and Y-axis represents number of people. Every horizontal line in the x-y plane represents one person's data. EoI value has been represented by the small colored circle which represents the severity of that participant. EoI values from zero to one are distributed within 0 to 101 color value. Colors are ranged from dark green to dark red where dark green represents the severity is low as 0 and dark red represents to high value of severity to 1. This Flow chart is made with google 'Line chart'. The mechanism of retrieving data from database as similar to the Time plot Graph. The only difference is the customization of data in the line chart.

B. Spatial Plot (Google Map overlay)

1) Static Map View: The surroundings of our community in google map are divided into 16 grids as shown in Fig. 6. The most populated area is again divided into four quads. The grids are assigned with arbitrarily generated area code and each grid has their own rectangle defined by latitude and longitude. The area code is assigned to each participant based upon their home address. All home inside the same grid has the unique area code. Participants share their EoI values with SCC Health server and EoI of the participant is averaged with other participants' EoI value who live in the same area code as

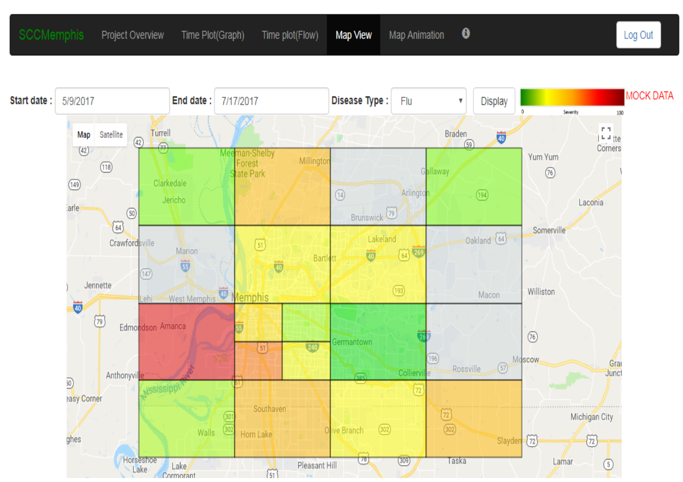

Fig. 6. An example of static spatial plot (Google map overlay) of data.

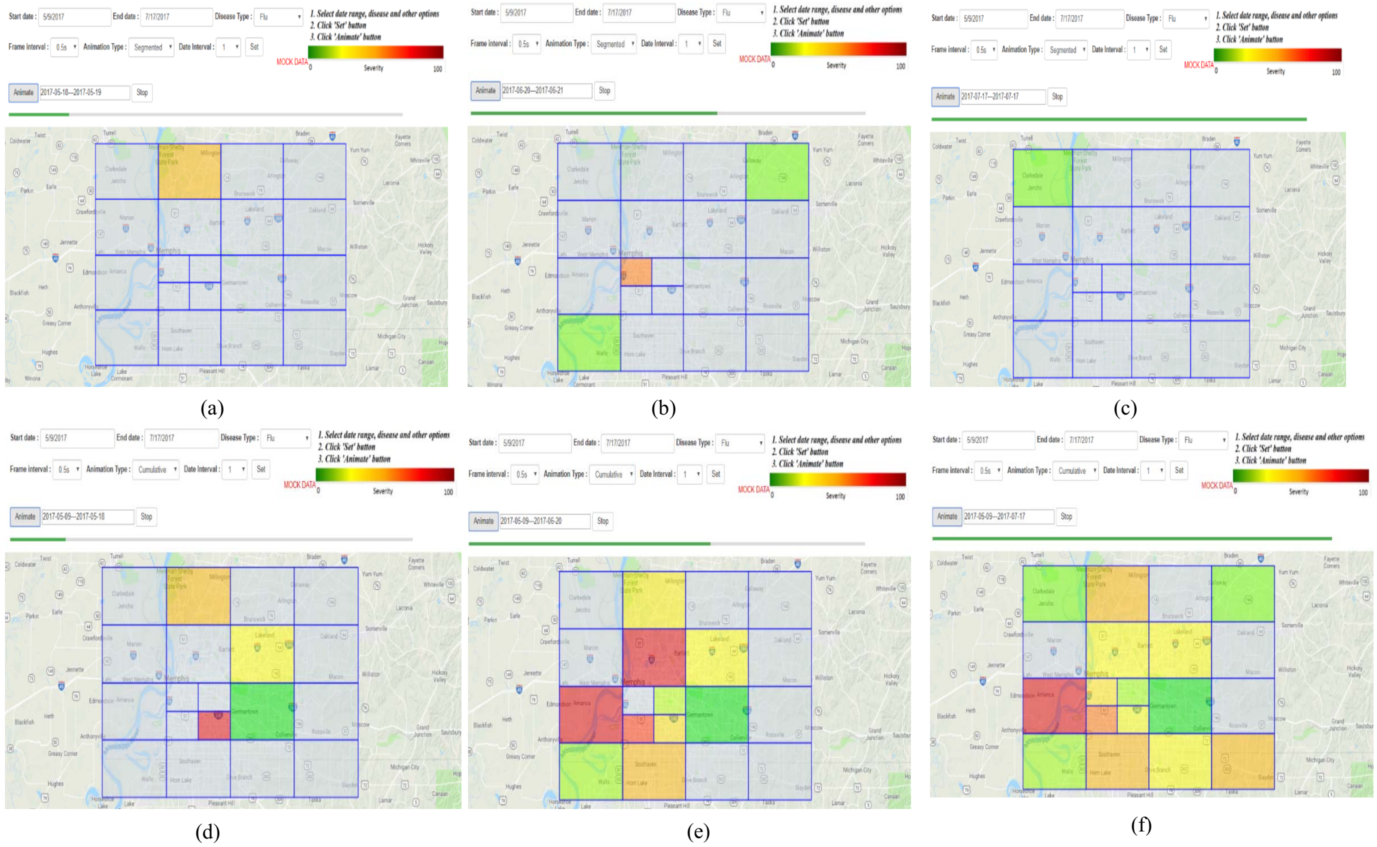

Fig. 7. Animation of spatial plot. (a), (b) and (c) are the chronological order of segmented spatial animation and (d), (e) and (f) are the chronological order of cumulative spatial animation

defined in (1). This adds a layer of privacy, as it is not possible from the visualization, or from the server data to detect any participant's exact home address.

$$EoI_{av}^{i} = \left(\sum_{u=1}^{N}\left(\sum_{u=1}^{M} EoI^{j}\right)/M\right)/N \quad (1)$$

In (1), i is the grid number, u is the participant's number, N is the maximum number of participants in that i'th grid who submit EoI for that particular disease and that particular time, and j is a participant who submits multiple measurements within that timeframe with last submission as M.

Participant can select date interval (i.e. start date and end date) and give a choice of disease type. After clicking the display button, backend file grabs the data of date interval and disease type. A MySQL query are written to retrieve the EoI value, area code, and participant's ID for the selected date interval and disease type. EoI value is first averaged with the same persons and then this average value is again averaged with the number of participants who live in the same area code. This average value is then multiplied with 100 and then keeps only integer value that is the index of color code. The color code is ranged from 0 to 100. Hence, every EoI becomes the index of color code and this color code indicates the color of that area code.

The GeoJSON has a featured based property. This property has been changed by color and area code. The backend file makes a GeoJSON link with the changed color code. In the front end this GeoJSON link has been used to change the color of each area code and thus google map overlay represents color of grid code.

2) Animation of Spatial Plot: To view the result of spatial plot day by day, animation on the google map are taken into consideration. There are two types of animation, such as cumulative and segmented day based animation. The cumulative animation represents the animation from the starting day and then add day depends upon the choice of user. Each frame of animation adds next day EoI value and averages them and displays the animation till the end day. In this animation, every single day or the bin of segmented day EoI values are averaged and represented in the animation. This individual day or the segmented day is not added with the previous date. Fig. 7 represents these two types of animations.

IV. RESULTS

The web visualization tool has been developed over the last year and deployed (http://sccmobilehealth.com). All functionalities have been implemented and tested. The response time of the first page of the SCC Health server is 0.267 sec. and the total code size is 455 KB.

The sensor data are properly visible through temporal and spatial plot. The guest login allows anyone to see the functionalities and uses mock data for every disease type. In guest login, these data sets can be fully visualized through temporal and spatial plot. The data collected from deployment will be stored in a separate database. These data sets will be collected from recruited subjects and sensor data collected from the various sensors (e.g. core body temperature). The recruited subjects and admins will have user name and passwords to observe these data. Also to verify functionalities for admin and user login, we have temporarily used test data sets.

In order to verify the effectiveness of the visualization tools, an informal survey is conducted among randomly chosen individuals from Memphis community. The survey consists of two sessions, i.e. pre-session and post-session containing same set of questions. The overall tone of the participants of the survey is positive. Although, in the pre-session survey some participants were not willing to share the physiological sensor-data (30%), but after seeing the visualization tools in the post-session survey they were willing to share their data as they got an understanding that their identity will not be revealed (90%). The participants stated several different ways that this is an effective visualization tool, e.g. "*the database will help prevent spreading of a disease by taking proper precaution method*". For temporal plot, a participant described that *"Having access to the tool will help community to stay alarmed and know about what disease is growing"*. Another participant commented on spatial plot: *"The color code helps and gives us good vision toward the health of the community."* Fig. 8 shows the outcome (in percentage) of participants regarding how effective the web based visualization is for the community health status.

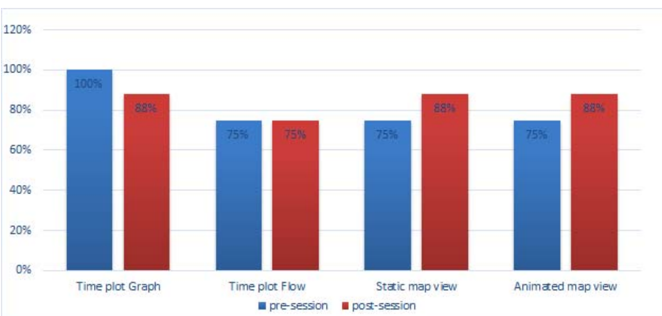

Fig. 8. Participants' responses of likely using the visualization summarized from the survey questionnaire.

V. DISCUSSION

Monitoring health status can be beneficial to the social networking point of view if the health related social networking is developed while properly maintaining the privacy and security. Through this health social network, one can visualize the condition of region. This can help also the researchers to find the same patterned patients and can easily co-relate with their treatment pattern that help them to find better treatment. With the smart technology, community members can monitor their own diseases through sensors data that can collect required physiological signals. To evaluate community health status, we propose SSC to become connected to a SCC-Health network where they can anonymously monitor population health status in real-time. To make the health web effective, more people need to have interest to share their own EoI data [11].

In this visualization, SCC members can measure and visualize their severity of arrhythmia, COPD, sleep apnea, and flu in terms of EoI (representing disease severity from 0 to 1 encoded with colors). They can also monitor the continuous disease severity in terms of time interval from the temporal flow plot with the colored circles. It can be easily viewed from the plot of flow. Spatial plot represents the averaged severity of a particular area in a time interval. From this visualization, one can learn about disease spread and trends. The change of EoI values can easily be visualized from the animation of spatial plot. From these visualizations, community members can be benefited to lead a healthier life.

This research is being conducted in collaboration with an epidemiology researcher from the School of Public Health at the University of Memphis, and a medical doctor from Memphis area. Incorporation of this health professionals also augments the validity and impact of this research to build a healthy, smart, and connected community.

VI. CONCLUSION

This paper proposes the strategy for spatiotemporal graphical visualization of the community-based Smart and Connected Community (SCC) Health data through multiple plots and animation. We have developed the SCC-Health webserver framework for visualization from scratch and demonstrated full functionally with mock data. The benefit of this framework are:

a) SCC members contribute and gather knowledge about the community health status from the temporal and spatial plots.

b) As personal or identifiable information is not shared, SCC members will likely to be more confident about their privacy and inclined to share anonymized EoI to the server.

c) Stakeholders can also take advantage of the platform by monitoring the most affected diseases, spreads, and trends of the community and efficiently deploy resources.

In our future work, we will add measurements to display how a particular disease is spreading throughout the region and will also explore forecast capability about the imminent danger of a disease outbreak via on our planned pilot study.

REFERENCES

[1] K. Gobakis, A. Mavrigiannaki, K. Kalaitzakis, and D. D. Kolokotsa, "Design and development of a Web based GIS platform for zero energy settlements monitoring," *Energy Procedia*, vol. 134, pp. 48–60, 2017.

[2] M. N. K. Boulos, "Web GIS in practice III: Creating a simple interactive map of England's Strategic Health Authorities using Google Maps API, Google Earth KML, and MSN Virtual Earth Map Control," *Int. J. Health Geogr.*, vol. 4, pp. 1–8, 2005.

[3] R. Chen *et al.*, "ExplICU: A web-based visualization and predictive modeling toolkit for mortality in intensive care patients," *Proc. Annu. Int. Conf. IEEE Eng. Med. Biol. Soc. EMBS*, vol. 2015–Novem, pp. 6830–6833, 2015.

[4] M. Frink, J. V. Gyllinsky, and K. Mankodiya, "Visualization of multidimensional clinical data from wearables on the web and on apps," *2017 IEEE MIT Undergrad. Res. Technol. Conf.*, pp. 1–4, 2017.

[5] M. H. Loorak, C. Perin, N. Kamal, M. Hill, and S. Carpendale, "TimeSpan: Using Visualization to Explore Temporal Multi-dimensional Data of Stroke Patients," *IEEE Trans. Vis. Comput.*

Graph., vol. 22, no. 1, pp. 409–418, 2016.

[6] R. Wang, M. Nacenta, X. Zhu, and Q. Dai, "Visualization of health behavior data for children and young adults," *2017 Comput. Conf.*, no. July, pp. 1207–1216, 2017.

[7] M. Mirto, S. Fiore, L. Conte, L. V. Bruno, and G. Aloisio, "A spatial data analysis infrastructure for environmental health research," *2016 Int. Conf. High Perform. Comput. Simul.*, pp. 435–442, 2016.

[8] M. M. Jankowska, D. Lopez-Carr, C. Funk, G. J. Husak, and Z. A. Chafe, "Climate change and human health: Spatial modeling of water availability, malnutrition, and livelihoods in Mali, Africa," *Appl. Geogr.*, vol. 33, no. 1, pp. 4–15, 2012.

[9] A. Houghton, N. Prudent, J. E. Scott, R. Wade, and G. Luber, "Climate change-related vulnerabilities and local environmental public health tracking through GEMSS: A web-based visualization tool," *Appl. Geogr.*, vol. 33, no. 1, pp. 36–44, 2012.

[10] S. Purushe, G. Grinstein, M. B. Smrtic, and H. Lyons, "Interactive Animated Visualizations of Breast, Ovarian Cancer and Other Health Indicator Data Using Weave, an Interactive Web-based Analysis and Visualization Environment," *2011 15th Int. Conf. Inf. Vis.*, pp. 247–252, 2011.

[11] B. Morshed, B. Harmon, M. Zaman, M. Rahman, S. Afroz, and M. Rahman, "Inkjet Printed Fully-Passive Body-Worn Wireless Sensors for Smart and Connected Community (SCC)," *J. Low Power Electron. Appl.*, vol. 7, no. 4, p. 26, 2017.

[12] J. S. Luciano, G. P. Cumming, M. D. Wilkinson, and E. Kahana, "The emergent discipline of health web science," *J. Med. Internet Res.*, vol. 15, no. 8, pp. 1–12, 2013.