Designing an Online Medical History Visualization Framework for Doctors

Forhad Hossain[1], Mohamed Mehfoud Bouh[1], Mostafa Taufiq Ahmed[3], Rafiqul Islam[4], and Ashir Ahmed[5]

[1,2,5]Faculty of Information Science and Electrical Engineering, Kyushu University, Japan
[3]Department of Neurosurgery, M A G Osmani Medical College, Bangladesh
[4]Medical Information Center, Kyushu University Hospital, Japan

***Abstract*—** This study explains development architecture of a web-based medical history visualization framework for doctors to make accurate clinical decisions. Health events are digitally recorded more frequently than ever. Study assumes that the health records will be made available in a standard format for doctors. However, not all health events are required for a doctor to check. The collected health records need to be arranged, filtered, and demonstrated in a doctor-friendly system. This paper proposes a "Smart Health Gantt Chart", a one-window, doctor adaptive and interactive visualization. The system architecture of the Smart Health Gantt chart is designed, and the major components are described. This is a work-in-progress document and does not have any results yet. Components of the proposed visualization tool, functionality and expected results explained in this study.

***Keywords*—** Digital Health, Electronic Health Records (EHR), Health Data Visualization, Past Medical History, Portable Health Clinic.

I. INTRODUCTION

Past medical history is needed for effective clinical decision-making. Usually, a doctor or a medical assistant on behalf of the doctor takes the past medical history by listening to the patient directly or collects a past medical history checked form on paper or in a digital mood. Nowadays, hospitals/clinics keep a record of previous diagnosis and treatment history, but it is not shareable with other service providers even not with the patient. Patients' access to their own medical records is an important element of patient-centered healthcare [22]. In early 2020, the European Commission (EC) announced a common European Health Data Space (EHDS)—a legal, governance, data quality, and operability framework—to facilitate access to and reuse of health data to improve health care delivery, research, and policymaking [24]. But still, medical history maintenance in digital mood and data sharing with the patient, doctors, or researchers are not common practices in most countries, especially in developing countries. Digitization of health records and online visualization can help in this regard. Digital health systems like Portable Health Clinic [2, 3, 12] are contributing to digitizing health records in a standard manner in developing countries. EHR (Electronic Health Records) [6] practices are increasing and contributing to improving health performance. Our question is, how EHR can improve the performance of a doctor? or to analyze past medical history? To understand the medical history of an individual quickly and accurately, there is a need for the appropriate visualization. Standard EHR data and visualization can help the doctor with effective decision-making. There are many existing visualization tools on the market, but we did not find any tool which is fully dedicated to the doctors to save time and increase the productivity of a busy doctor. We proposed a unique personal health data visualization tool, where a patient's entire medical history will be visualized in a Smart Health Gantt Chart in one window to make a quick understanding and effective decision-making for a doctor [11]. In this paper, we are explaining the framework of the proposed visualization tool. Section 2 states related research, section 3 states the concept of a doctor-friendly medical history visualization framework, section 4 states implementation of the framework, and section 5 states the expected outcome.

II. RELATED RESEARCH

Data visualization is everywhere in today's world. In healthcare services, the use of data visualization systems is increasing. There are many existing tools offering health data visualization services and creating a good impact on the development of healthcare efficiency. Every tool has different objectives and contributes or aims to contribute to a specific area. The "Lifelines2" [23] is a timeline-based visualization system to show personal medical history. Users can analyze individual data or multiple patients' data at a time. This system allows comparison, filtering, alignment, or sorting to find out the correlation between different health events. It shows too much information in one window, and it is time-consuming for a doctor to find important medical history in a short period of time. The "hGraph (Health Graph)" [17] system visualizes an individual's primary

health records. There are multiple functions in a unified graph that can be apparently viewed but it shows only a limited healthcare data set. It is not to visualize the entire medical history. The "TimeLine"[5] is a problem-centric visualization system to show the medical records in a specific domain but does not include all the general cases. The "Health Timeline"[18] organizes and displays clinical data in an interactive timeline to understand health and treatment status. It was an experiment with some selective health records. It was not to visualize a patient's entire health history and classification of health events; health data collection mechanism was not defined specifically. Faisal et al. [2013] identified five application themes for medical information visualization: planning, examination of patient's medical records, representation of pedigrees and family history, communication and shared decision making, and life management and health monitoring [7]. Meyer et al. [2016] focused on three basic prerequisites to develop a health data visualization tool. First, the visualization should be for a mobile phone. Second, visualization of complex and heterogeneous health data covering multiple facets of healthy living. Third, the visualization should be neutral in the sense that its primary goal should not be to induce a health behavior change or reach a certain goal [20]. Patient-Centered visualization can include hundreds of encounters and thousands of medical events (such as diagnoses, procedures, medications, and lab tests) and unstructured clinical notes [8]. Kopanitsa et al. [2014] implemented several open-source visualization solutions for ISO 13606 archetype-based medical data to present diabetes related information to the patients [16]. We are proposing a doctor-friendly online medical history visualization tool to visualize the entire health history of a patient in a quick and accurate manner. So that, a busy doctor can save their time understanding patient medical history briefly and it should be shareable with any doctor in anywhere the world.

III. CONCEPT OF A MEDICAL HISTORY VISUALIZATION FRAMEWORK FOR DOCTORS

In our previous studies, we have proposed a unique personal health data visualization tool, where a patient's entire health history can be visualized in a Smart Health Gantt Chart in one window [9]. Patient health history can be collected, stored, and managed in EMR (Electronic Medical Records), EHR (Electronic Health Record), and PHR (Personal Health Record) forms. Health data can be collected from multiple locations. It will be integrated into the system by following standardization like FHIR (Fast Healthcare Interoperability Resources) [4] and OpenEHR [15]. All health data will be classified into a few categories and key health information will be visualized in the Gantt chart as health events. Other necessary health information and relevant documents (like prescription, diagnostic report, etc.) will be available in the same window. Patient demographic information and static health information will be available in the dashboard. Doctor preference-based visualization and health prediction are also planned to include in the system. The concept developed such a way where a doctor can see patient medical history quickly and accurately.

A. Major Modules and System Components

1) Health Data Collection and Standardization. Health data will be collected from multiple sources. It can be collected from an individual, from clinic/hospital/medical assistants on behalf of the patient, or from medical devices. Medical history can be in paper-based documents, digital records, or inpatient memory. We are assuming that data will be integrated into the visualization framework by following standard formatting which is mentioned in Fig. 1[10]

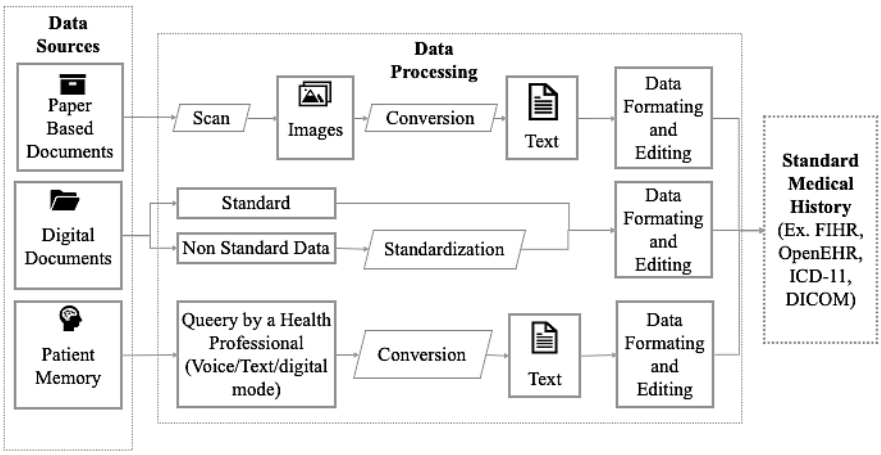

Figure 1: *Collection of medical history in standard manner*

2) Classifications of Medical History. The patient's entire medical history will be visualized in nine categories. We did not find any standard definition to categorize the medical history. In our study, we analyze 30 past medical history collection form which is used by hospitals/clinics. We have collected these forms by random search on google. Based on these forms we categorize medical history into nine broad categories which are widely used. These classification categories can be changed with the recommendation of doctors or based on further study.

3) Medical History Visualization. Patients' entire health records will be visualized in a doctor adaptive smart health Gantt chart as mentioned in Fig. 2. The key health summary of a particular patient will be visualized in the health Gantt chart based on doctor preferences. Other associated data like copies of medical reports, medication histories, and some other detailed health information will be available in the dashboard.

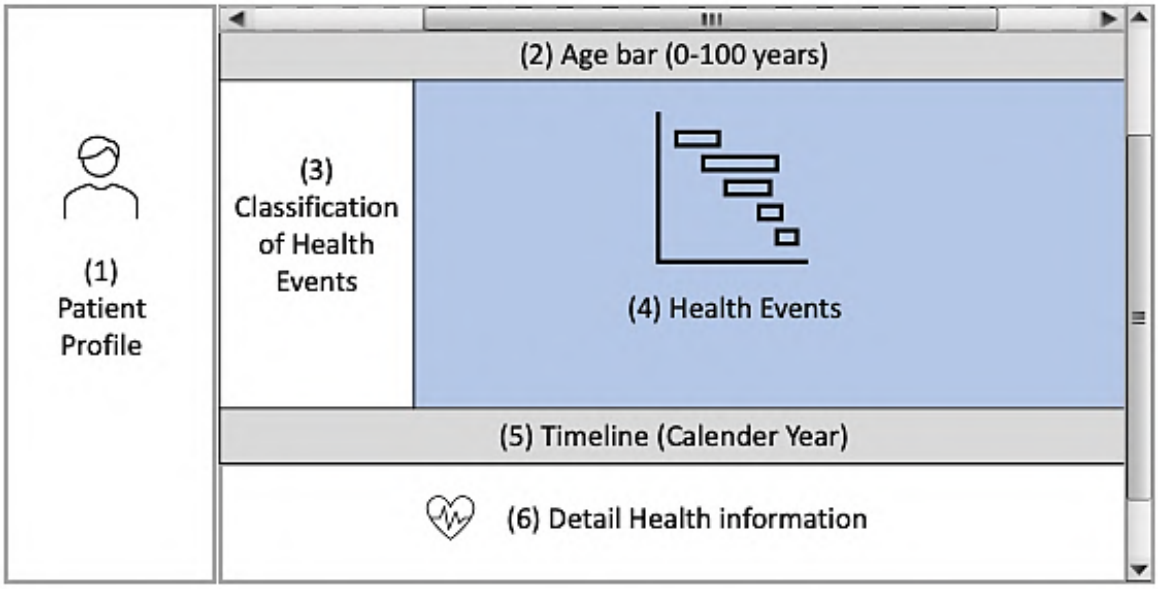

Figure 2: *Smart Health Gantt Chart's dashboard view*

B. Components of Smart Health Gantt Chart

In the Smart Health Gantt Chart there will be six components:

1) Demographic and Static Health Information. Patient name, ID, blood group, gender, marital status, etc. this demographic information will be included in the system to identify the patients. Other static health information like Smoking, Alcohol, Food Allergy, Dietary information, Insomnia, Exercise, etc. will also be included which usually a doctor wants to know at the beginning of a doctor consultation.

2) Age bar. On the upper side of the Gantt chart, there will be an age bar to show the patient's age. The medical history will be visualized by the following age so that doctor can understand at which age the patient faced that medical condition.

3) Classification of Health Events. There is no standard yet to classify the health events. Every organization follows its own customized format to collect past medical history in different categories. We have studied 30 past medical history forms and we divided all items into the following categories:

- Immunization
- Health Checkup-Vital Sign
- Surgery
- Communicable Disease
- Non-communicable Disease
- Inherited Disease
- Medication
- Obstetric History (only for Women)
- Mental Health

4) Health Events. A "health event" means an event relating to the health of the mind or body of a person or an unborn [14] baby. Event means "specific occurrence, such as an episode of illness; often used in the terminology of clinical trials" [13]. Health events are also known as event summaries. An event summary captures key health information about significant healthcare events that are relevant to the ongoing care of an individual. An event summary indicates a clinical intervention, improvement in a condition, or that a treatment has been started or completed. An event

summary contains allergies and adverse reactions, medicines, diagnoses, interventions, immunizations, and diagnostic investigations [1]. In the proposed tool health events are defined as "health events are the summary of specific occurrences related to health complexities, preventive and treatment actions". It has the following characteristics:

- Name of preventive measures
- Preventive measures for what complexities
- Types of preventive measures
- Name of diseases in two broad categories (CD, NCD)
- Name of treatment actions
- Interventions of preventive measures and treatment actions
- Methods of treatment actions
- Measurement items, results, interventions of primary health checkup
- Connections of inherited diseases (diseases name and to whom with)
- Day/Month and year of the occurrence following Coordinated Universal Time (UTC)
- Status of problem and treatment in four categories risk level

5) Timeline. In the below line of the Gantt chart, there will be a scrolling bar for timeline/years. Years means from birth year to highest life expectancy (approximately 130 years). This will be connected with age bar and health events. It might be helpful for the doctors to understand which year, at what age the patient faces what type of health condition.

6) Health Event Details. Into the Gantt chart view, doctors will be able to see key summary information of health. It will be a mouse-over pop-up information and clickable for a detailed view. Below the Gantt chart in the same window, detailed information will be visualized for a better understanding. Detail information could be prescription, diagnostic report, imaging report, important notes in text, etc.

C. Functional Requirements

There are three major requirements in the proposed visualization tool, which can help to make a doctor friendly medical history visualization:

1) Quick and accurate view. In the health Gantt chart view, X- axis represents the timeline from birth year to standard life expectancy age. Y-axis represents the health events. Each health event can be titled as pre-defined classification, in the health summary diseases names will appear on the screen but it will be programmed following ICD (International Classification of Diseases) 11 [21] or the latest version of this code. This will help to make this Gantt chart a universal standard. Any doctor from anywhere in the world would be able to understand the disease name or health complexities. The four-color status will help to understand the urgency of these complications. Here, green indicates 'cure', yellow indicates 'not cured but not so risky', orange indicates 'risky', and red indicates 'emergency'. These will be helpful for a quick understanding of the level of complications of each health problem. This smart health Gantt chart can visualize the medical history of any person, it could be a child or an old person. Scrolling zooming options can help to check the large volume of health data.

2) Collection of medical history in a standard manner. The medical history of an individual may not be on a single platform and may not be of the same standard. For the data collection and data integration following task can be required. For the paper-based documents will be required to scan the documents to convert them into images. Optical Character Recognition (OCR) could be used for that. Medical history can be collected as digital data from EHR, EMR, PHR, or IoT (Internet of Things) devices. There are two kinds of digital data; standard (FHIR/OpenEHR enabled) and non-standard. Standard data can be transferred directly for pre-processing, but non-standard data should pass a gateway to convert into a standard format. Medical histories from patient memory can be asked in written text or voice form. Text and voice should be converted into standard medical data format.

3) Adaptive behavior of the tool. The visualization tool should be doctor friendly. Intelligent features can be added to make it smart and effective for doctors. An individual may have too many health complexities and may visit different kinds of doctors but when he visits a urologist, the urologist might be interested to see only a urology-related health summary. If all other health data appear in the same window at the same time, it may create confusion for the doctors and it will be time-consuming for the doctor to sort out only urology-related data.

A tool will be required to sort the relevant health events and highlight them. This smart health Gantt chart could show the prediction of future health status based on available previous medical history.

This prediction might be helpful for the doctors in decision making as well as it can be helpful for the patient to maintain a healthy lifestyle. It is not necessary to predict all health events.

D. Technical Challenges

There are a few technical challenges like how we can be it faster, doctor adaptive, and accurate prediction. To design an effective and fast, the code must be well written and structured.

The queries sent to the database should be optimized by writing thoughtful SQL queries to improve database performance. To make doctors adaptive, a deep learning-based recommender system [19] can be adopted. Appropriate technology can be used to predict future health status.

IV. IMPLEMENTATION OF THE VISUALIZATION FRAMEWORK

This section explains the way the visualization framework will be developed, its workflow, and the technologies to be used to do so.

A. System Architecture

To implement the "Online medical history visualization" framework, we came up with three major components in the system architecture (as in Fig. 3). The components are explained below:

1) Front-end application. This is where the doctor will be able to interact with the tool. In other words, this is where the patient's past medical history will be visualized in the Smart Health Gantt Chart. The doctor's device might be a smartphone (mobile application), a laptop, or a desktop computer. In the case of a laptop or a desktop computer, the front-end is a web application. Additionally, the web app will be deployed on a PaaS (Platform as a Service).

2) Back-end application. This is where the server will handle the requests coming from the doctor(front-end) and start speaking with the health events database.

The structure of the database and the format of the medical records will follow international standards such as FHIR, openEHR, etc. As well as to the Front-end, the back end will be deployed on a PaaS too.

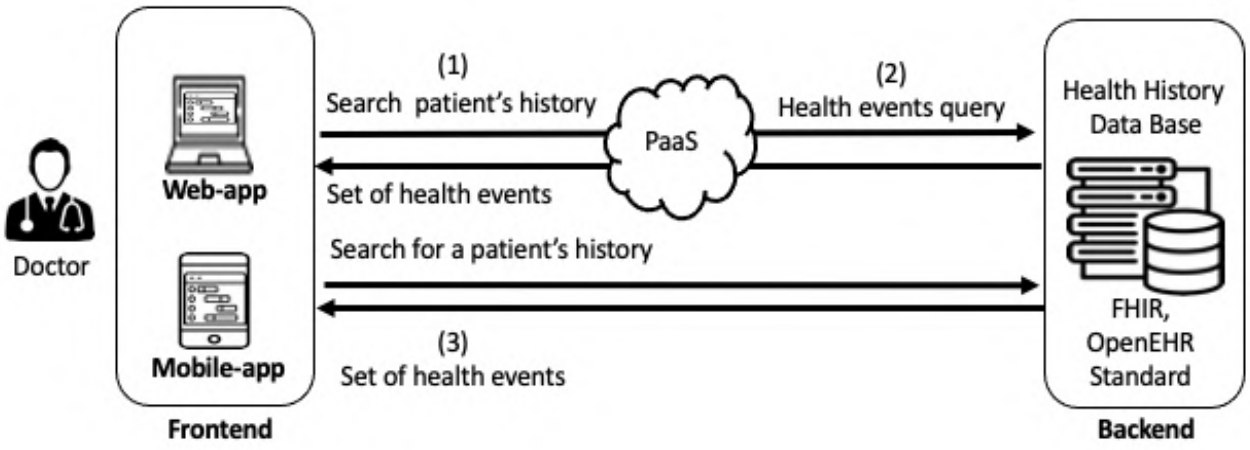

Figure 3: *System architecture of the proposed visualization framework*

3) Data Collection. Standard medical data will be integrated into the system. Medical history can be collected from multiple EMRs through standard data formatting steps. We are assuming that data standardization will be done by others and our job is to integrate that into the system.

B. Smart Health Gantt Chart Generation

The Smart Health Gantt Chart will generate followed following steps:

- The doctor will make a request by using the front-end application. The request will consist of a patient's ID.
- The front-end will form an HTTP request and send it to the back end.
- The back-end server will receive the request, do its logic, and form a query to the health events database. After getting the result from the database, the back end will send back a set of the patient's health events to the front end to be visualized in the doctor's interface.

C. Development Architecture

We are considering creating an experimental environment by using the following technologies. They are selected based on their availability and performance. The development architecture of the Smart Health Gantt chart is shown in Fig. 4.

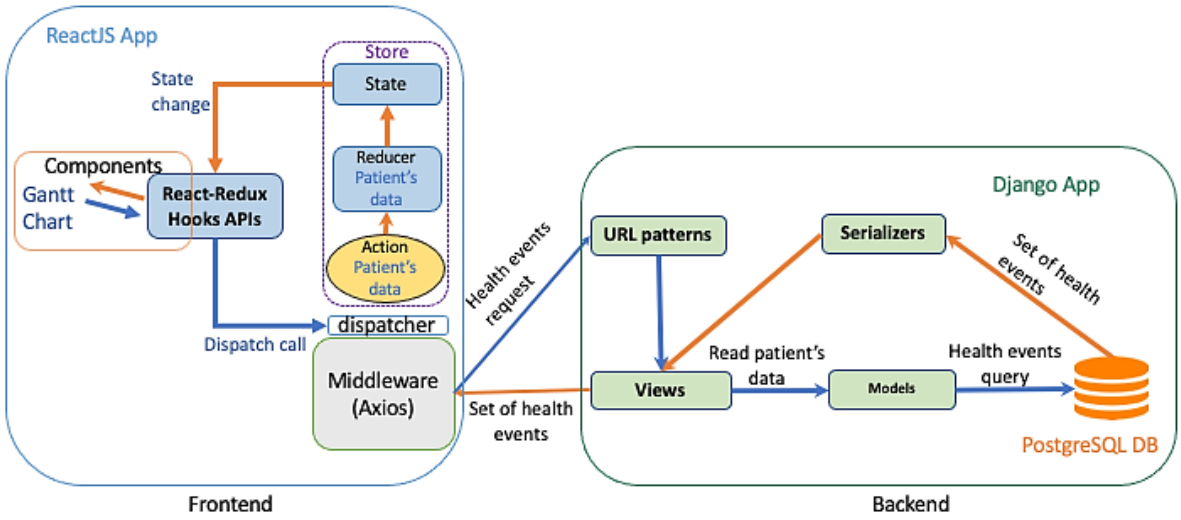

Figure 4: *Development architecture of the proposed visualization framework*

1) Technology for the front-end application. For the front-end, we are going to use a JavaScript library called ReactJS because of its flexibility, performance, and its large community.

2) Technology for the back-end application. For the back end, we are going to use a Python framework called Django because of its scalability, reliability, flexibility, and simplicity. Django will connect its models to the database, while Django Rest Framework will serialize those models into a JSON (JavaScript Object Nation) format. For the database, we are going to use PostgreSQL which is a Database Management System and goes well with FHIR data.

V. EXPECTED OUTCOME

The proposed visualization tool could bring the following solutions to increase the efficiency of a doctor and to increase the performance of overall health services:

- It can save doctor's time and increase the productivity of the doctors to serve more patients ensuring quality service
- Life-long medical history record in a digital, structured, and standard manner
- Medical history can be shareable with the patient and any doctor with the permission access of the patient
- Medical history summarizing in a quick and accurate understanding manner for the doctors
- Medical history can be visualized in anywhere through the internet and appropriate devices
- It can reduce medical errors and unnecessary medical cost

VI. CONCLUSION

The scarcity of doctors exists almost everywhere in the world; it is the worst in developing countries. Doctors need to provide quality medical services within a short time. During the doctor consultancy "history taking" takes a longer time. Also, if medical history is not documented in a standard manner, it may create medical errors. On the other hand, paper-based medical records if difficult to collect in long run, and difficult to explain to doctors in a short period of time. Digitized medical records are not shareable with the patient or other doctors from the different clinics and every clinic just stores medical history under their service not the entire medical history of a patient. This proposed tool may solve these issues. A doctor-friendly medical history visualization tool can improve the performance of a doctor and the entire health service. Which is part of connected health to maximize the use of healthcare resources, increased technology-enabled health service facilities, and create flexible opportunities for the consumers. In this study, the concept, requirements, and architecture of the proposed tool are explained and in the next phase, the prototype will be developed for the experiment.

ACKNOWLEDGMENT

This research was supported by JST SCORE University Promotion Type, Grant Number JPMJST2072, Japan.

REFERENCES

[1] Australian Digital Health Agency. Event summaries, My Health Record, 2019, Retrieved May 27, 2022 from https://www.myhealthrecord.gov.au/for-healthcare-professionals/howtos/event- summaries

[2] A. Ahmed, M. Hasan, M. B. Sampa, K. M. Hossein, Y. Nohara, and N. Nakashima, "Portable Health Clinic: Concept, design, Implementation and Challenges,"Mobile Technologies for Delivering Healthcare in Remote, Rural or Developing Regions, pp. 105, 2020

[3] A. Ahmed, A. R. Hargrave, Y. Nohara, E. Kai, Z. H. Ripon, and N. Nakashima, "Targeting Morbidity in Unreached Communities Using Portable Health Clinic System," IEICE Transactions on Communications E97.B,3, pp. 540–545, 2014, https://doi.org/10.1587/transcom. e97.b.540

[4] D. Bender and K. Sartipi, "HL7 FHIR: An Agile and RESTful approach to healthcare information exchange," In Proceedings of the 26th IEEE International Symposium on Computer-Based Medical Systems. IEEE, pp. 326–331, 2013, https://doi.org/10.1109/CBMS.2013.6627810

[5] A. A. T. Bui, D. R. Aberle, and H. Kangarloo, "TimeLine:Visualizing Integrated Patient Records," IEEE Transactions on Information Technology in Biomedicine 11, 4, pp. 462–473, 2007, https://doi.org/10.1109/TITB.2006.884365

[6] R. S. Evans, "Electronic health records: then, now, and in the future," Yearbook of medical informatics 25, S 01, S48–S61, 2016.

[7] S. Faisal, A. Blandford, and H. W. Potts, "Making sense of personal health information: challenges for information visualization," Health informatics journal 19, 3, pp. 198–217, 2013.

[8] D. Gotz and D. Borland, "Data-driven healthcare: challenges and op- portunities for interactive visualization," IEEE computer graphics and applications 36, 3, pp. 90–96, 2016. https://ieeexplore.ieee.org/document/6627810

[9] F. Hossain and A. Ahmed, "Visualization of Healthcare Data for Busy Doctors in Developing Countries to make Efficient Clinical Decisions," 10th Social Business Academia Conference, November 2021, https://bit.ly/3L5GP3L

[10] F. Hossain, R. Islam, M. T. Ahmed, and A. Ahmed, "Technical Requirements to Design a Personal Medical History Visualization Tool for Doctors," 8th International Conference on Human Interaction and Emerging Technologies, August 2022.

[11] F. Hossain, R. I. Maruf, T. Osugi, N. Nakashima, and A. Ahmed, "A Study on Personal Medical History Visualization Tools for Doctors," 2022 IEEE 4th Global Conference on Life Sciences and Technologies (LifeTech), pp. 545, March 2022.

[12] N. Hossain, F. Yokota, N. Sultana, and A. Ahmed, "Factors Influencing Rural End-Users' Acceptance of e-Health in Developing Countries: A Study on Portable Health Clinic in Bangladesh," Telemedicine and e-Health 25, 3, pp. 221–229, March 2019, https://doi.org/10.1089/tmj.2018.0039

[13] Law Insider, Farlex Partner Medical Dictionary, 2016, Retrieved May 26, 2022 from https://medical-dictionary.thefreedictionary.com/event

[14] Law Insider, "Health Event Definition",2016, Retrieved May 27, 2022 from https: //www.lawinsider.com/dictionary/health- event

[15] D. Kalra, T. Beale, and S. Heard, The openEHR foundation, Studies in health technology and informatics 115, pp. 153–173, 2005.

[16] G. Kopanitsa and M. Taranik, "Applying open source data visualization tools to standard based medical data," Studies in Health Technology and Informatics 200, 1, pp.155–157, 2014.

[17] A. Ledesma, M. Al-Musawi, and H. Nieminen, "Health figures: an open-source JavaScript library for health data visualization," BMC Medical Informatics and Decision Making 16, 1, March 2016.

[18] A. Ledesma, N. Bidargaddi, J. Strobel, G. Schrader, H. Nieminen, I. Korhonen, and M. Ermes, "Health timeline: an insight based study of a timeline visualization of clinical data," BMC Medical Informatics and Decision Making 19, 1, August 2019.

[19] J. Lu, D. Wu, M. Mao, W. Wang, and G. Zhang, "Recommender system application developments: A survey. Decis. Support Syst. 74 pp. 12–32, 2015.

[20] J. Meyer, A. Kazakova, M. Büsing, and S. Boll, "Visualization of complex health data on mobile devices," In Proceedings of the ACM Workshop on Multimedia for Personal Health and Health Care., ACM: NewYork, NY, United States, pp. 31–34, 2016.

[21] World Health Organization, "International Classification of Diseases 11th Revision," 2019, Retrieved May 28, 2022 from https://icd.who.int/en

[22] A. Pagliari, T. Shand, and B. Fisher, "Embedding online patient record access in UK primary care: a survey of stakeholder experiences," JRSM short reports 3, 5, pp. 1–7, 2012.

[23] F. Roque, L. Slaughter, and A. Tkatšenko, "A Comparison of Several Key Information Visualization Systems for Secondary Use of Electronic Health Record Content," In Proceedings of the NAACL HLT 2010 Second Louhi Workshop on Text and Data Mining of Health Documents. Association for Computational Linguistics, Los Angeles, California, USA, pp. 76–83, 2010, https://aclanthology.org/W10-1112

[24] M. Shabani, "Will the European Health Data Space change data sharing rules?," Science 375, 6587, pp. 1357–1359, 2022