Research Article

Secure MedRecord – Your Medical Record, in Your Pocket

Choi Kelvin, Julia Binti Juremi, Ma'en Tayseer Ekrayem Alrashd

School of Computing, Asia Pacific University of Technology & Innovation, Kuala Lumpur, Malaysia.

ABSTRACT

Background: This research outlines the problems faced by users of the availability of medical documents which may vary in terms of having no softcopy, loss of hardcopy due to inefficient storage by the medical practitioners or failure to prepare a copy of their medical documents beforehand. Medical documents may also present an inconvenience to users whereby certain procedures will require a certain amount of time to prepare with a minimal amount of fees taken for medical practitioners to prepare the medical documents for their patients when requested.

Purpose: Hence, this study serves as documentation for a solution to increasing the availability of medical documents through Secure MedRecord. It is a system designed to allow patients to carry a softcopy of their medical documents with them at all times. This is done by allowing patients to access their medical documents via a web application containing the softcopy version of the medical documents.

Results: The web application serves as a platform which allows medical practitioners to manage their patients' medical documents to allow for the patient to obtain a copy of the document for viewing purposes. This improves medical document availability together with providing efficient medical document processing and storage for disaster recovery purposes.

Key Words: Electronic Health Records, Privacy, Security, Healthcare, Medical Records

INTRODUCTION

Secure MedRecord is a web application aim to serve users to conveniently access their medical documents on their devices. Medical documents consist of a patient's medical information which is used to provide a detailed medical history of the patient for medical practitioners to properly diagnose and give proper treatments needed to their patient. A medical record consists of various notes taken over time by the medical professionals consisting of observations, administration of drugs and therapies, test results, reports, x-ray and more. Hence, the maintenance of accurate and complete medical records is a vital requirement for health care[1].

Medical documents have been traditionally compiled and maintained by the healthcare providers of patients with advances in technology leading to online data storage or electronic health records (EHR). This at the same time has led to developments of personal health record (PHR) concept which is supported by the US national health administrations and associations[1]. However, this concept has yet to be fully idealized in other parts of the world.

Medical records are an important document in which the absence of the document will lead to patients unable to receive their continuation of proper care or treatment. However, with recent technological advance, the absence of the document is reduced drastically. The availability of the medical documents may vary in terms of when the patient is travelling overseas and has failed to bring or prepare their medical documents beforehand. Other than that, it can sometimes be troubling to obtain the medical documents when there is a plan to switch clinics/hospital due to certain procedures which will require a certain amount of time and a minimal amount of fees.

On the side note, inefficiency towards the medical practitioner side can also surface from the processing of these documents. This is due to the use of paper as a medium to keep records. This manual method presents itself with a few chal-

lenges such as the lack of security towards the information, inaccessibility to the health record when a file is a misplaced or poor communication between health care providers results to the inaccuracy of medical data[1]. As a result, there is an increase in work burden due to the inefficiency of a manual medical record system. More challenges arise when there is an improper organization of medical records which may lead to no assurance in medical information backup which may lead to not being able to access a patient's medical history[1].

This system targets user groups of the general public and clinical user groups such as the medical practitioners, nurses and clinic staffs. As it is a web application, the clinical user groups would need to register for an account in the web application to be connected with their patients and store their data. An admin which manages Secure MedRecord will the verifies the authenticity of the clinical user groups via their uploaded certifications. Next, the general public will be able to register an account through their web browsers on either their personal computers or mobile devices to then access their medical documents online after being connected with their selected clinic. Users are then enabled to access the information contained within their medical document with the determined user access privileges[1].

As the nature of the challenge is specified, the challenges predicted to be faced by the developer is to develop a user-friendly user interface to allow efficient usage of the electronic health system in the hands of the patients and medical staffs. Each user will have different knowledge in Information Technology hence the challenge will be to keep the interface as simple as possible to be used by all ages of the target users. Next, as the nature of the system is focused primarily on healthcare, it is utmost important to ensure that system security is taken into consideration. Patients' health information is confidential and thus the data which is used in the system needs to be protected based on the security triad model. Implementing security features into the system will be a challenge as there will be a need to understand the types of attack which may happen to the system, the concepts of different methods of implementing the security features and how the system could be misused by the users.

This research aims to develop a web application which enables for a convenient, safe and efficient method to access and manage medical documents such as the medical records and reports.

Objectives
- To identify the basic concepts of medical documents used in the medical industries to facilitate a professional and efficient web application to serve patients effectively.
- To utilize cybersecurity knowledge and system to develop a secure web application.

- To ensure confidentiality by providing authorization of the medical documents with proper authentication such as 2-factor authentication and Recaptcha.
- To incorporate encryption into the web application to provide confidentiality by encrypting sensitive data.
- To ensure the integrity of the passwords by using hash functions to obtain hash values of the passwords used by users of Secure MedRecord.
- To incorporate watermarking or database logs into the web application to improve the integrity of the medical documents.
- To ensure the availability of the medical documents in softcopy format within the web application by deploying the application to the cloud environment.

Literature Review

The current situation and experience of Electronic Health Record (EHR) in Primary Medical Institutions [20]. It is found that a nationwide realization of EHR which is shared with regional health information network would allow for a saving of $78 billion in annual medical expenses which accounts in 4% of a total medical and health expenditure undergone by the United States. The research in EHR has begun in many western developed countries to help solve the inefficiencies and high cost which is brought by the growth of medical and health systems. Presently, many countries are focusing on basic research of EHR. However, it has yet been carried out for large-scale development and adoption of the system[20]. In terms of contents and characteristics of an EHR, the inclusion of personal information which includes basic information like name, sex, history, family history and other basic health history are relevant. Next, the physical examination includes patient lifestyle, personal health examination, prescribed medication for any diseases and health evaluation. It is also important to note that clients who need referral and consultation records should refer to a doctor for record filling as all service records are collected and filed in the responsibility of medical personnel or archivists promptly. They[20] have also mentioned in the research that paper health records would gradually be transferred to an EHR thus, making the contents of an EHR much more diverse.

Looking back from a point in history, it is seen that developing countries in the West are reducing costs and improving service quality together with efficiency from the perspective of informatization. This is due to the core of information technology is efficiency and sharing. Hence, the interconnection of medical information would result in improvements in patient satisfaction, reduction in both personal burdens and financial burdens of governments. This is proven in Canada where a cumulative income of C$19.2 billion measured from Canadian residents and health care system which is around C$3 billion in 2016. This is where EHR health services in Canada has doubled with 500,000 medical staffs benefitting from digital health such as the reduction in time costs, re-

peated testing avoidance and adverse drug reaction reduction. Medical doctors would also benefit with available visuals on 100% diagnose images, 72% prescriptions and 97% test results to provide strong support for clinical decision making[20]. Based on this research, the developer is positive that the development of Secure MedRecord would be beneficial to allow for the tangible and intangible benefits to be obtainable which was specified in chapter 1 of this report. It is positive that the development of Secure MedRecord's web application will be beneficial towards the medical target users.

Next, EHR is written by medical health professionals and where most patient data are found. These records capture the status of patients across time and are very valuable in diagnosis. Medical codes, such as ICD-9-CM are assigned to a patient's report after a treatment to serve as a justification to prove that the said treatments were carried out[15]. Failure in assigning the codes correct would represent a loss in revenue and risk constitution of fraud. Thus, carried[15] out research to automate the ICD-9-CM medical coding into electronic clinical reports. As a background, Clinical text has no neatly defined structure as it can be the patient's description, personal and family medical history or remarks made by the physician. Hence, lengths of reports would vary in sessions. The researchers also mentioned that EHR software is usually form-based ("suggested causes", "symptoms", "suggested treatment") thus result in thematically well-defined short sentences in each form's field. This causes physicians to ignore certain form structure, use free form data entry fields or worst, misuse any other form entries which would cause a downgrade in information quality. It is also found that physicians alter his/her writing depending on the if the writing is going to be read by other parties[15]. As an example, a typical consultation report would not be written in a clear communication format compared to a report which will be sent to another physician for reference. The non-clear communication report may consist of telegraphic phrases, abbreviations, acronyms or local dialectal shorthand phrases which would confuse. Abbreviation "RA" can stand for 25 different meanings such as "rheumatoid arthritis", "radioactive" or "ragweed antigen"[15].

As a result, the researchers aim to automate assigning of ICD-9-CM code to patient reports to help lower the limitations of EHR and provide artificial neural network-based models for effective labelling. Based on the results, the experiment conduct by the researchers appears to be good. Codes which are associated with patients report would also have sequence number assigned. Thus, are finding a method to factor in sequence number into the models and evaluation methods to help improve their system to work efficiently on the task at hand. Based on the journal, the developers understood the various nature of EHR which needs to be tackled in the development of Secure MedRecord. Designing form

inputs for medical practitioners would need to be done in a way where standards could be applied. It is ideal for free form fields to be designed for the universal usage of recording a patient's information rather than restricting each field for their special purposes. This would follow a traditional approach in the documentation where clinical physicians write their patient's report on a blank piece of paper which is attached in a patient's medical folder.

In terms of medication reminders which would be a feature of Secure MedRecord, a journal has been reviewed by the developer. "Don't Forget Your Pill!" which is a design ineffective medication reminder apps which support user's daily routine [18]. The journal which was conducted by the researchers reports the findings of the functionality review conducted on 229 medication reminder apps and the analysis of 1012 user reviews. It is found that medication regimes are habitual and the daily routine of patients would support in remembering while most existing reminder apps rely on timer-based reminders. Medication non-adherence would reduce the effectiveness of treatment and post-financial burden on health care systems[18]. An estimated cost in non-adherence reaches an estimate of $100 billion each year in the United States which include 10% of hospitals and 23% of nursing home admissions. However, it is also an issue where even motivated people can forget which is one of the main causes where forgetfulness accounts for 30% of unintentional non-adherence. The researchers have made two main contributions where they have reviewed the functionality of smartphone medication reminder apps and highlighted the weakness of the apps. Other than that, a proposed design requirement which takes into account the habitual nature of medication regimes for the development of reminder apps. Remembering medication consumption is a prospective memory task which is divided into two types which are time-based (completed within specific time) and event-based (linked to the event or environment). An online survey was conducted to explore strategies in remembering medicinal consumption whereby 61% answered that it is part of their daily routine. Common causes in non-adherence were 54% having changes in daily routine, 47% being busy or distracted and 46% were simply forgetful[18].

Medication reminder app would allow users to enter multiple medications needed for consuming, show due times, consumption instructions and highlight overdue doses. Based on the survey conducted by the researcher, nearly 97% of the apps identified in smartphone platforms were timer-based reminders. Reminder apps are categorized into 3 types which are Simple Medication Reminders (SMR), Advanced Medication Reminders (AMR) and Medication Management Apps (MMA). SMR offers the basic function to support prospective memory such as scheduling, alerts and sound. AMR offers options in prospective and retrospective memory such as overdosing protection, time zone supports and

user notes whereas MMA support health and medication regimes with multiple user accounts. With that, the developer would utilize SMR as the preferred type of reminder feature to be implemented into Secure MedRecord. This is due to it being a side feature to accommodate user effectiveness in medication adherence following their medical documents. It is also duly noted that most applications available in the smartphone store are time-based reminders thus the developer would adhere to the standards to allow for the easier recollection of usage based on the other applications for the convenience of target users.

Medical documents are subjected to strict security concerns. It has been a renewed interest to find solutions in the privacy of health records due to how the records are easily accessed by healthcare providers[1]. An important aspect to healthcare delivery is the easy access to patient's health information which should be strictly regulated and monitored due to its sensitivity. Hospitals face challenges in missing of files or records, lack of information sharing, insecure records and inaccessibility in patient's health information. This would affect the need for conducting an informed health decision by the medical practitioners. There are also concerns raised such as privacy, data breaches and medical identity theft associated with medical information. The challenges are faced due to the domination of continuous usage of paper in healthcare delivery. There is a need in health information management system for easy storage and access of medical record for informed decisions to be made by medical practitioners[1]. The researcher has suggested Blockchain technology to be used as an approach for accessibility of information while reassuring the security of the private information at all time with authentication for preventing unauthorized viewing thus addressing data security and privacy. This is because although the manual system is still used for decision making and medication management, the paper-based system fails to assure the availability of records for viewing and retrieval.

With the challenges faced by manual systems which were confirmed in the interview where respondents are not satisfied with current situations, electronic records would ideally be used to solve certain challenges and minimize the problems undergone by manual and traditional methods. It is found that reduction in memory strain of medical practitioners, improved effectiveness and efficiency in healthcare and increased accountability in health support[1]. This also allows for the reduction in medical errors, redundant service, better clinical decisions and coordination on service delivery due to easily accessible and retrieval of information for healthcare providers. Due to the regards of security and privacy, the developer of Secure MedRecord would integrate certain security features such as hashing,[2] factor- authentication, cloud deployment and server logging to allow for a secure web application to be built. However, due to the limitation in technical skills and time in development, Blockchain im-

plementation will not be accomplished in this iteration of the application. A future version of the application may adopt Blockchain technology.

The study conducted by Ibrahim, Z. et al.[9] attributes the lack in quantitative follow up in reluctance of clinicians treating their patients which active schedules incline physicians to use insufficient descriptions of cases which results in lower quality of care. As patient records are confidential, the studies are burdened with delays in obtaining consent and approvals from patients. Strict rules prohibit other parties which are not directly involved in the treatment to view the records and patients which tend to visit several healthcare providers during their treatment would distribute their medical documents to the different organization each with their own rules, regulations and protocols and policies. Hence,[9] aims to provide a multi-agent platform for convenient control of feedback provision of patients to allow effective consent to be given for information access. Objectives of the multi-agent platform provide an online tool for patients to provide treatment regardless of the location of treatment of one or healthcare institutions[9]. Another objective is to reduce cost with the automation of obtaining patient consents in real-time. It is found that the healthcare system mostly requires the collection and management of heterogeneous data which ranges from clinical notes to medical information found on the web and medical ontologies/concepts.

To address the diversity of terminologies and languages utilized in the management of electronic patient records, the researchers have created an ontology-driven model to serve common languages understood by all agents created in the system which will be illustrated in Figure 1.
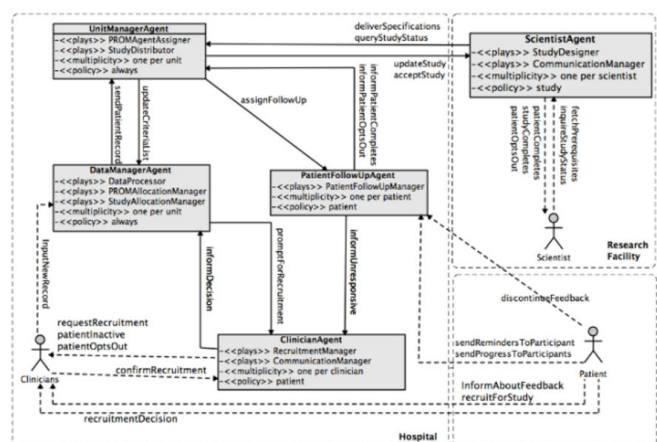

Figure 1: Agent Class Diagram[9].

Initial analysis conducted by the researchers uncover issues comprising of security which are the confidential nature of patient records where manipulation and transportation of records are proven challenging to realize. Patients have the right to provide consent to other medical practitioners out-

side of the hospital to see the treatment information. This article was studied by the developer due to its nature in patient consent to allow for a clearer idea in the development of Secure MedRecord. As the aim of the development is to provide a user-friendly web application for users to utilize to keep a copy of their medical record, the developer would allow for a concept less design to be implemented to allow common language to be understood by all parties of the web application. Due to the variety of rules and regulations available in a different healthcare institution, the developer would adhere to the standards which are applied in Malaysia from the Ministry of Health for the overall flexibility in Secure MedRecord.

Another ontology-based or concept-based system due to the cost in the development of an EHR is greatly increasing from the difficulty in handling of clinical concepts, temporal data, documents and financial transactions[5]. At the same time, this increases the risk in the failure rate of implementation which threatens the investments in the sector. Ontology-based system help in allowing code reuse, extensions and customizations which would reduce the development cost. At present, EHR offers web-based support with the sharing of records across establishments[5]. However, constant efforts are made to introduce this technology in Egypt for practical usage. Ontologies or concepts have been used widely in health care modelling, automation and research to achieve desirable outcomes. The requirement in an effective EHR is standardization, data quality, reference domain knowledge and user interface[5]. Data quality helps improve decision making, boost user confidence of data which encourage further usage and allow for data consistency for better statistics and results. The user interface, on the other hand, is important due to the management and time take to view results and process the results. To allow for standardization, the employment of ontological modelling was done.
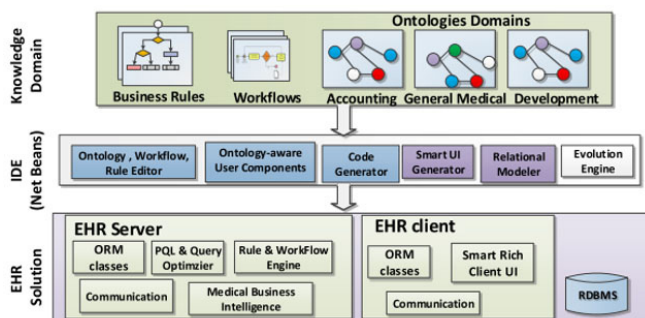

Figure 2: Proposed EHR solution[5].

The approach done by the researcher to develop the proposed EHR is with the usage of software factories to associate with shorter development times, cost reduction and maintainable code. This is illustrated in Figure 2. The persis-

tent layer underwent is based on a relational database model which support MySQL, PostgreSQL and Oracle database engines which allow for persistence or perseverance. With the constant effort undergo to introduce EHR in Egypt, the developer is certain that Secure MedRecord will be an effective web application which can be used by target users in Malaysia. The developer will incorporate the 4 requirements of effective EHR into the design of Secure MedRecord for effective development together with the usage of relational database model of PostgreSQL which is clearly defined in the materials and methods of chapter 3.

MATERIALS AND METHODS

Programming Language Chosen

Secure MedRecord is a web application designed to be run with the user device's web browser. Hence suitable web programming languages will need to be chosen. In terms of design and structure of the website, a combination of both HTML (Hypertext Markup Language) and CSS (Cascading Style Sheet) will be utilized as they are core technologies in building web pages. HTML will assist in providing the structure of the page whereas CSS would assist in the visual layout and presentation for the variety of devices.

Next, functionalities and user experience of the web application would need to be implemented with the help of programming language for the manipulation of data. A comparison of programming language for this would be created by the developer in the following section, Table 1.

Table 1: Comparison between JavaScript and C#

Language	JavaScript	C#
Type	Object-oriented	Type-safe object-oriented
Static Typing	Dynamic	Static
Platform	Cross-platform compatible	Cross-platform compatible
Generic Support	No generic support	Has generic support
Framework	Supports various framework	Supports .Net framework
Versatility	Very versatile	Very versatile
Complexity	Less complex in understanding	More complex
Querying	Separate libraries for native querying	Has LINQ, powerful .NET component for native querying
Scope	Limited scope	Robust language

Based on the comparison Table 3.1.1, it is seen that C# is much more of a suitable choice for development. This is

due to the language syntax of C# is much consistent when compared to plain JavaScript with the usability of between beginners and expert developers. Hence, the developer has chosen to use C# as the main language chosen for the development of Secure MedRecord.

Next, C# is also utilized in various applications. Being very versatile in its versatility, C# is often used in the creation of dynamic websites due to its object-oriented, efficient, easily scalable and maintainable. It is utilized by big companies such as Microsoft and Stack Overflow. Thus, being cross-platform compatible for development of full-grown web application for the benefit of the developer in developing Secure MedRecord.

Programming Framework

ASP.NET Core
With the chosen programming language of C#, Microsoft's ASP .NET Core framework is chosen to be utilized for the development of Secure MedRecord. It is a cross-platform, open-source framework for high-performance development of modern, interconnected web applications with cloud-based utilities[17].

Based on the development of Secure MedRecord, the benefits of utilizing ASP .NET Core are:

1. Architected for testability.
2. Coding page-focused scenarios for productivity through Razor Pages.
3. Develop to be run on Windows, macOS and Linux.
4. Community-focused and open-source.
5. Integration of modern development workflow and client-side frameworks.
6. Cloud-ready, environment-based configuration system.
7. High performance, lightweight and modular HTTP request pipeline.
8. Tooling to simplify modern web development.

Based on the utilization of ASP .NET Core, MVC (Models, Views Controllers) features will be used. This is to obtain the benefits which were listed by undertaking ASP .NET Core framework in the development of the web application. Libraries which are supported in the framework targets .NET Framework libraries. Advantages of these are cross-platform, improved performance, side-by-side versioning, open-source and new APIs. However, the disadvantage of this framework is the vendor lock-in through a Microsoft ecosystem. Technologies needed would need Microsoft Visual Studio and other Microsoft services to operate the web application efficiently.

Nevertheless, with the abundance of benefits and resources able to be provided through the utilization of C# programming language and ASP .NET Core framework, the devel-

oper will be able to utilize the key benefits from a Microsoft ecosystem to develop, run and build the Secure MedRecord web application for the usage of its objectives. Integration of the web application with cloud services is also easy and possible with Microsoft Azure cloud platform through the implementation of ASP .NET Core and the Microsoft ecosystem. Thus, obtaining availability, scalability and resiliency from the cloud, and security from the SLA of the cloud provider. Further security implementations are mentioned in the following sections of this documentation.

IDE (Interactive Development Environment)
An IDE is a software suite utilized to consolidate the basic tools necessary to write and test a system or software. The chosen IDE which will be used to develop Secure MedRecord is Microsoft Visual Studio Community 2019. Microsoft Visual Studio is an IDE developed by Microsoft to allow for the development of applications for Android, Mac, iOS, Windows, web and cloud[10]. Main advantages and features of Visual Studio are easy debugging and diagnosis, frequent testing and release, customizable, and efficient collaboration enabled.
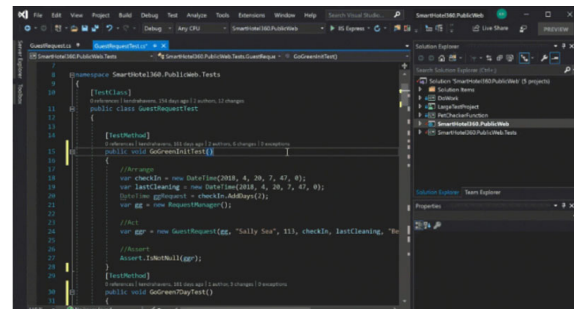
Figure 3: Microsoft Visual Studio user interface[10].

Figure 3 above illustrates the user interface of Microsoft Visual Studio where the solution explorer which contains all related files to the project can be seen on the right tab of the page. Figure 4, on the other hand, illustrates the various packages and extensions available to be downloaded using the NuGet package manager.
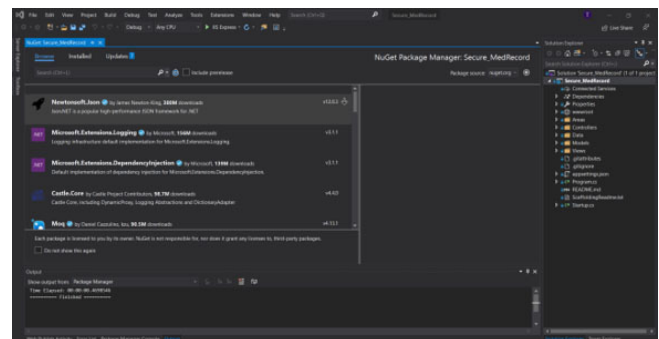
Figure 4: Nuget Package Manager.

Microsoft Visual Studio was also chosen with its benefit of

enabling cloud connection to be integrated easily. As Visual Studio is part of Microsoft, seamless integration and features to connect with Microsoft Azure are enabled in the IDE through the cloud-connected development environment. Thus, developers are given the advantage to stay up to date, code efficiently with built-in features and collaborate easily[10].

Libraries/Tools chosen

Rotativa

Rotativa is an open-source package which enables the generation or printing of PDF documents from web applications of the database. It is a library which contains the framework and web kit engine to help render HTML[19]. Through the usage of Rotativa, it enables for Secure MedRecord to return certain specified URL as PDF. Thus, enabling users to download a copy of their medical record or their medical card which will contain the medical information needed by the users. It is also worth to note that the PDF downloaded will contain watermark which represents its authenticity.

Benefits of Rotativa includes easy and efficient where installations are not needed. Thus, access rights or hosting restrictions are prevented. Libraries are available to be used immediately for the creation of PDF with one line of code or a simple HTTP JSON call[16]. Performance and reliability are also guaranteed with rotative implementing cloud computation power. Lastly, rotative allows for control where PDF activity is monitored by the user itself.

Google reCAPTCHA

Google reCAPTCHA is a free service from Google to prevent application against spam and some other types of automated abuse such as brute-forcing to crack passwords with automated script or bots[8]. The library and tool are utilized in Secure MedRecord to further strengthen the security of the web application. This would help in minimizing abusive traffic by returning scores based on user interaction on the website. There is three versions of reCAPTCHA with the developer using reCAPTCHA v3 in Secure MedRecord's login and register pages. This is chosen due to its main advantage of not having user interactions to complete challenges to be necessary. The 3 main advantage of reCAPTCHA is the advance security which protects against spam and abuse, ease of usage to minimize friction and effortless interactions for users, and creation of value which applies human bandwidth to benefit everyone[8].

Microsoft Azure Storage

Having the benefits such as high availability and durability, secure, scalable, managed and accessible, Azure Storage is Microsoft's cloud solution modern data storage scenarios[11]. These benefits are obtained through the usage of Blob and Table storage for Secure MedRecord web application. Table Storage is chosen to be utilized in Secure MedRecord for the storage of user medical symptoms. This is due to the common uses of Table storage of storing structured data for web-scale application and quick querying of data from the storage. It is ideal for structured, non-relational data[12]. Medical symptoms are defaulted to be abundant in its use case. Thus, to conduct efficient filtering and querying of the data, Table storage is suitable to be implemented. This is due to the information contained within the symptoms are to be categorized based on their specific categories. These categories are set to be the partition key of each table row which will be efficient for filtering through Partition Scan which uses the PartitionKey and another non-key property for querying. Thus, facilitating better adaptability to utilize filtering of data based on partition keys.

Blob storage is utilized in Secure MedRecord for the storing of doctor files which contain their medical practitioner license. It is implemented in Secure MedRecord as it is an object storage solution. It is developed to provide storage for a huge amount of unstructured data such as binary or text data. Blob storage is ideal for serving and storing of files, images and documents for distributed access directly to the browser.[11] Other than that, Blob storage enables the files to be accessed anywhere from HTTP or HTTPS. Thus, Blob storage is utilized in Secure MedRecord for efficient file storage to store doctor medical license files.

Database Management System Chosen

A database management system (DBMS) is a software designed to assist in defining, manipulating, managing and retrieving data in a database. General manipulation of data such as data format, field names, file structure and record structure will be done by a DBMS together with the definition of rules to manipulate and validate data. Examples of DBMS available are MySQL, PostgreSQL and Microsoft SQL Server Database.

Comparison of DBMS:

MySQL is a popular open-source relational database which has proven its performance, reliability and user-friendliness. It is used by high profile companies such as Facebook, Twitter and YouTube. PostgreSQL, on the other hand, is an open-source object-relational database which comes with features like data indexing, user configuration settings, version control and NoSQL ("not only SQL") databases which gives it a special advantage. Companies such as Apple, Skype and Cisco utilize PostgreSQL. Lastly, Microsoft SQL Server Database is a relational database management system developed by Microsoft with features of data analysis, data encryption, end-to-end business intelligence and more. It is currently being utilized by well-established companies such as J.P Morgan, Accenture, MIT and Dell.
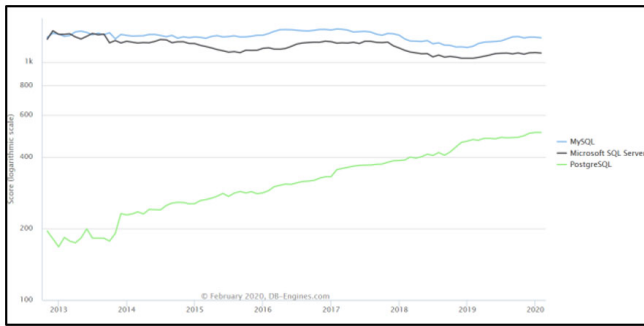
Figure 5: DBMS Engine Ranking score[3.]

Based on the Engine Ranking score in Figure 5 which is the ranking of DBMS based on popularity and user adoption, PostgreSQL is gaining popularity with PostgreSQL being adopted consistently over the past year with both MySQL and Microsoft SQL Server maintaining in their popularity, Table 2.

Table 2: Comparison between MySQL, PostgreSQL and Microsoft SQL

DBMS	MySQL	PostgreSQL	Microsoft SQL
Engine Ranking Score	1346.11, over-all rank is 2	369.44, over-all rank is 4	1093.75, overall rank is 3
XML & Data Scheme support	Yes	Yes	Yes
Native C library	No support	Support	Support
Work Performance	Not too well in heavy load strain	Works best in systems and execute complex queries	Robust with compression and partitioning features
CHECK constraint	No	Yes	Yes
Partial Indexes	No	Yes	Yes
Materialized Views	No	Yes	Yes
Array Data Type	No	Yes	Yes
Cloud storage	Yes	Yes	Yes

Based on the comparison of Table 3.4.1 above, the developer has decided to choose Microsoft SQL Server Database as the preferred DBMS in the development of Secure MedRecord due to its advantages in certain feature availability and data protection. According to Microsoft [4], Microsoft SQL provides data integrity with its advanced security as mentioned by the National Institute of Standards and Technology (NIST). MySQL and PostgreSQL, on the other hand, require the server to be set to strict SQL mode else the value which is inserted and updated will not be adjusted properly. Other than that, Microsoft Azure SQL Database which is Microsoft

SQL Server cloud engine offers cloud hosting and file storage for better data availability and security which is needed in the requirements of Secure MedRecord. Azure SQL has availability of 99.995% with advanced data security of always encrypted, compliance assured with built-in auditing, insights with Azure Security Center and Multi-layered security[2]. Hence, Microsoft SQL Server is much preferred by the developer with its extra cloud storage utilities and security features offered.

Operating System Chosen
The chosen operating system which will be utilized by the developer in the creation of Secure MedRecord record is Windows. This is due to Secure MedRecord is targeted to be developed into a web application which will be supported on the web browsers of target users. The Windows version of choice is Windows 10 with a 64-Bit architecture. This is mainly because it is the most updated Windows operating system currently in the market. In terms of security, Windows 10 inherits a multitude of security including built-in antivirus called Windows Defender. It contains Secure Boot, Device Guard, Microsoft Passport and Windows Hello which are security features for both access control and system utilization[13]. Windows 10 also has an addition of ransomware protection together with exploit/threat protection.

Web Server Chosen
A web server serves files which would form web pages to users which are also known as a client which request for the file based on the HTTP (Hypertext Transfer Protocol). This is known as the client/server model. If a web server was to face interruption, users would not be able to access the web pages hence resulting in a denial of service. In this case, this would be inconvenient due to the nature of medical documents being important. Hence, the developer has chosen to adopt the cloud environment with the utilization of cloud supported web servers.

Secure MedRecord will be hosted by Microsoft Azure under its cloud web hosting plans which uses the Internet Information Services (IIS). IIS is created by Microsoft for the usage of a Windows Server. It enables for the service of standard and dynamic HTML webpages such as ASP .NET applications or PHP pages. With the SLA of Microsoft cloud provider, Microsoft Azure enables for greater availability through GEO availability and the multiple availabilities and performance testing together with scalability through its scale up and scale out services available. Microsoft Azure has a wide range of hosting plans which comes in different pricing lists.

Figure 6 illustrates the pricing comparison of the web hosting plans provided by Microsoft Azure. Secure MedRecord is planned to be deployed with the standard production plan which can be upgraded to different tiers upon workload requests.

Figure 6: Azure Web Hosting Prices[2]

Web Browser Chosen

A web browser is a software program which allows for users to locate, access and load web pages into their devices. Secure MedRecord is a web application which would utilize web browsers and technology to perform its task over the internet. A web application performs its task with the combination of server-side scripts to handle storage and retrieving of information together with client-side scripts to then present the information to the users of the web application[7]. Thus, presenting of the information will utilize the availability of a web browser in the user's devices.

In the development of Secure MedRecord, the developer has chosen to focus on two widely used web browser which are Firefox from Mozilla and Google Chrome. The develop has chosen to utilize Google Chrome as the primary web browser. The following information is the comparison between Firefox and Google Chrome.

Design:

Figure 7: Comparison of Firefox (top) and Google Chrome (bottom) design.

In terms of design, Figure 7 illustrates the web browsers having a similar style of headers. However, Firefox is deemed much more user friendly due to the bigger back and forward buttons, customizable menu bars and simpler setting options available for users to configure. Google Chrome, however, does not have a customize toolbar option available for users which can be seen in Figure 8 below.
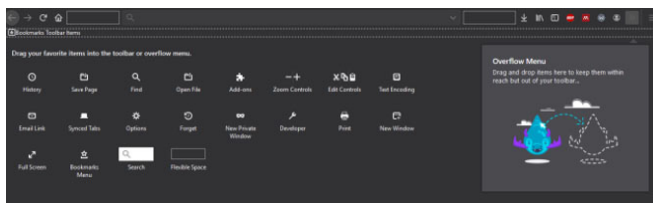

Figure 8: Customize option in Firefox.

Benchmarking:

Evaluation of the performance and capabilities of the web browser can be done through the performance testing which is done by using synthetic benchmarking software[6]. The benchmarks would test the time taken in loading, performance rendering and standard support in the chosen web browsers. Figure 9 below illustrates the benchmark test conducted with 5 different synthetic benchmarks.
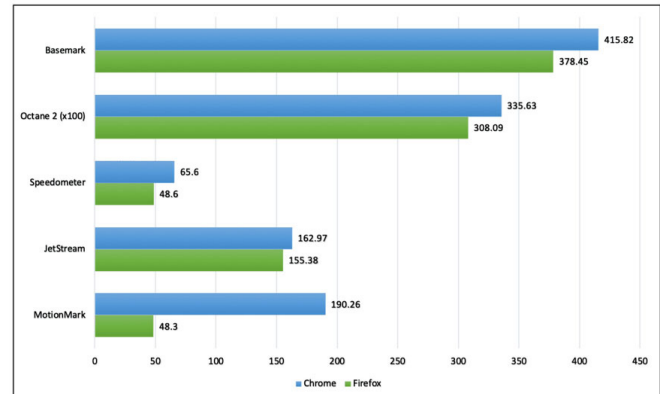

Figure 9: Benchmark performance of Firefox and Google Chrome[6.].

Based on the scale shown in Figure 10 it is shown that Google Chrome is performing better than Firefox.

Modern Standards Support

Web standards are technologies which are set out by World Wide Web Consortium (W3C) which would define coding and interpretation of the web. These standards assist the interoperability and cross-compatibility between web browsers and server[6]. A test which is conducted towards Firefox and Google Chrome with the utilization of HTML5Test.com which would help measure the 555 standards shows that Firefox supports 473 web standards whereas Google Chrome support 481 standards out of the total of 555 standards available. Hence, Google chrome is much beneficial in supporting modern standards support. However, this does not translate much different when compared with Firefox in terms of practical use. The test is illustrated in Figure 10 below.

In terms of memory or RAM, which is essential for quick access of application, more RAM or memory usage would slow the computer down. In the test, Figure 11 illustrates Firefox consuming more RAM than Google Chrome hence slowing users computer down.

With the comparisons made of both Firefox and Google Chrome, it is shown that Google Chrome has a better advantage overall. Thus, the developer has chosen to utilize and focus on the deployment of Secure MedRecord on Google Chrome with its advantages. However, Secure MedRecord

would also support the running of the system with another web browser such as Firefox and Microsoft Edge with the primary target web browser of choice being Google Chrome.
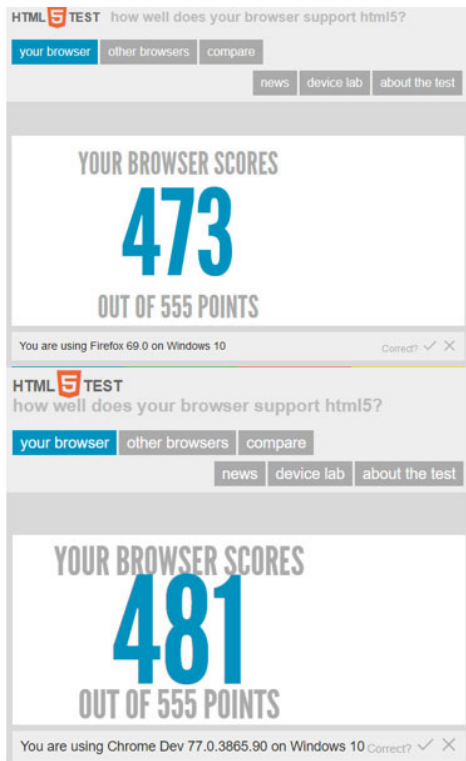

Figure 10: HTML5Test.com on Firefox and Google Chrome.
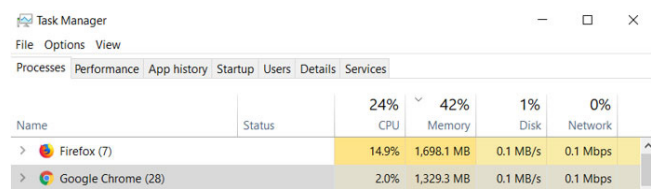
Memory:

Figure 11: Memory test of Firefox and Google Chrome.

Deliverables

The electronic health system – Secure MedRecord allows users to carry a softcopy of their medical documents with them daily provided they have a device with them. With the use of this system, users can conveniently visit other clinics or hospitals with ease as the doctors of the newly visited health service has access to their medical documents base on the patient's consent. Other than that, medical staff would be able to export their patients' medical data to enable softcopy storage to be available. Next, the system enables the medical staff to process the patients' data efficiently as the less manual filing of medical information will need to be done. Below are the lists of core functions to be performable by the

electronic health system:

- Allows end-users to login and logout of the system.
- Allows medical staff to create the patients' medical documents within the system.
- Allows medical staff to update their patients' medical documents in the system.
- Allows patients to view their medical documents.
- Allows patients to download their medical documents.
- Allows the patients' new medical staff to view their medical document with consent.

Also, the extra features of the system are:

- Allow patients to submit a request for an additional medical report to be created by their health providers.
- Allow patients to schedule for an appointment with their clinical health providers.
- Allow patients to store their emergency medical information such as blood type, medication, allergies and emergency number via a medical card.
- Allow patients to store their medical symptoms as a note before a consultation.

RESULTS AND DISCUSSION

User Acceptance Testing Result Analysis

Interface Design

Figure 12 above illustrates the results for the interface design category of the UAT. Based on the results obtained from 3 users, 2 of the users gave a 5-point rating whereas 1 user gave a 4-point rating. The results specify that users are satisfied with the interface which minor room for improvement in future updates.
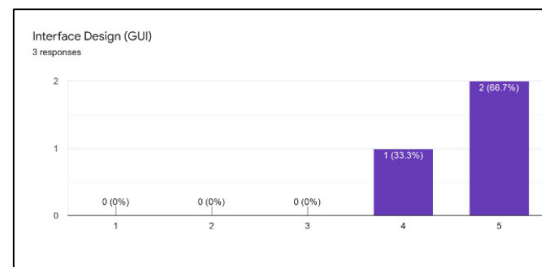

Figure 12: Interface Design UAT results.
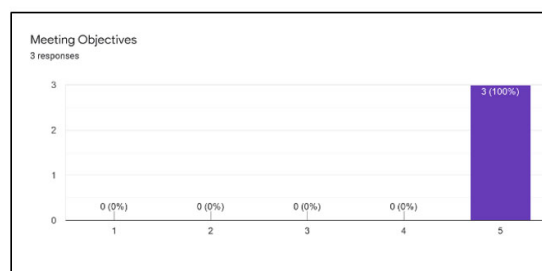
Meeting Objectives

Figure 13: Meeting Objective UAT results.

Figure 13 illustrates the meeting of objectives of the project UAT results. The objectives of the project are specified in Chapter 1 under section 1.6 Scope and Objectives. Based on the stated objectives, all 3 users agree that the developer has fulfilled the objectives by responding with a 5-point rating of very good.
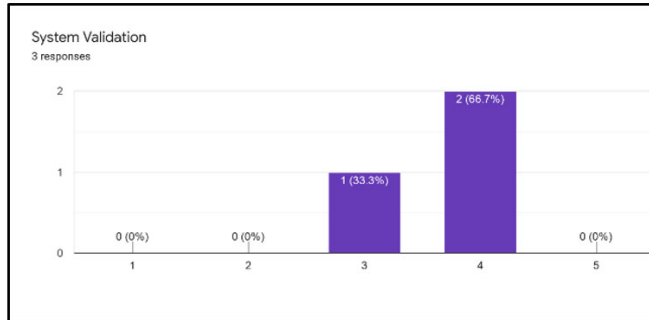
System Validation

Figure 14: System Validation UAT results.

Figure 14 illustrates the system validation UAT results of Secure MedRecord. Based on the results, 2 users gave the score of 4 which is good, and 1 user gave the score of 3 which is average. This shows that there is room for improvement in the web application's system validation section which is the admin and user side functionality.
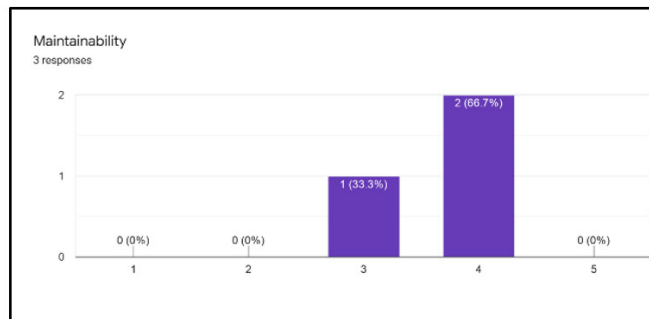
Maintainability

Figure 15: Maintainability UAT results.

Figure 15 illustrates the maintainability UAT results of Secure MedRecord. Based on the result, 2 users gave the score of 4 which is good, and 1 user gave the score of 3 which is average. This shows that there is room for improvement in the web application's system maintainability function. Improvements of the web application can be available in future iterations of the product.

Figure 16 illustrates free from bugs UAT results of Secure MedRecord. Based on the result, all 3 users gave the score of 4 which is good. This is due to minor bug issues during the generation of PDF file and login validation which surfaces from time to time due to the library and reCAPTCHA verifications. With that, there is minor room for improvement in the web application's system where

the minor bugs can be a patch in future updates of the web application.
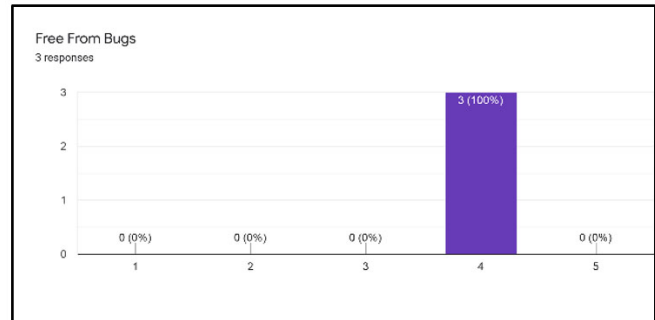
Free from Bugs

Figure 16: Free from Bugs UAT results.

Feedback from Testers

Based on the feedbacks obtained from the 3 participants of the UAT from the 3 forms, 2 users gave feedbacks on the routing of the webpage to create a much more efficient usage process. Next, additional search features could be implemented to facilitate better maintainability of the information found in each function of Secure MedRecord. Lastly, additional features were recommended by the 3rd participant where extra fields can be added into the form during the creation of medical record to facilitate doctor friendly and accurate creation of the medical record for their patients. These features are taken into consideration for future iterations of the web application by the developer.

To summarized, results obtained from the 3-testing method conducted by the developer upon completion of the implementation stage which is unit, integration and user acceptance testing are discussed. Unit testing of Secure MedRecord was executed based on the test plans created with the results showing that the proposed system is validated from logical errors. Each sub-processes of each function were tested throughout to ensure that the functions are free from bugs. Next, in the integration testing stage, interface links between the functions are tested. The actual outcomes are compared with the expected outcomes of the test plan to evaluate the results status of the integration testing. Each interface link is tested precisely with the different roles available in the web application which are the admin, user and doctor respectively. Based on the result statuses obtained, each result has returned a pass value thus, assuring that the integration testing is completed successfully. Lastly, user acceptance testing was conducted to test the ease of using the system on a group of representative users. Based on the results obtained, the participants are satisfied with the system used with additional feedbacks provided to the developer.

DISCUSSION

Critical Evaluation

Secure MedRecord is a web application system design as a solution to increase the availability of medical documents and information. It is a system designed to allow patients to carry a softcopy of their medical documents such as their medical card and record with them at all times. Other than that, it features the usability of allowing users to save their medical symptoms, schedule appointments with their doctors for medical consultation and send a report request to notify their doctors of their needs. The project has outlined the problems faced by users of the availability of medical documents which may vary in terms of having no softcopy, loss of hardcopy due to inefficient storage by the medical practitioners or failure to prepare a copy of their medical documents beforehand. Other than that, for the creation of medical reports, inconveniences can be presented to users whereby certain procedures will require a certain amount of time to prepare with a minimal amount of fees taken for medical practitioners to prepare the medical reports for their patients when requested.

Thus, with the completion of the project through the implementation, testing and deployment of Secure MedRecord, the aims and objectives presented by the developer has been fulfilled. Taking note to the security implementations featured in the design of this web application, several security features have been successfully implemented to further secure the web application. Data which concerns the health of an individual falls under the special category of personal data which also refers to sensitive data. Under the General Data Protection Regulation (GDPR) and Personal Data Protection Act (PDPA), heavy consequences are issued if a breach in data security were to occur. Professional secrecy, referring in medical terms as medical confidentiality or the Hippocratic Oath prohibits the disclosure of information of patients. Thus, data confidentiality is strictly reinforced in this web application through the implementation of encryption where only authorised parties can access the data. Other than that, authentication to ensure proper authorization is implemented with proper authentication with additional Two-Factor Authentication, password hashing and Google reCAPTCHA implementation. This is in hopes to incorporate trust between patient and doctor while adding a trusting environment of Secure MedRecord for users to feel comfortable in utilizing the web application for their medical assistant needs.

To continue, understanding from the feedbacks obtain during the data gathering and analysis stage and testing stage of user acceptance testing, the developer understands that Secure MedRecord as a web application has room for further improvement and growth. With competitors having similar concepts which were researched during the literature review in this project, the developer understands that Secure Me-

dRecord will need to evolve to provide better efficiency and usability for the general public and doctors to obtain the trust and likelihood to adopt the usage of Secure MedRecord. As the current system is the first release of the web application, the developer wishes to further enhance the system to develop further improvements in not only the security implementation of the system but also the usability of the system to match with current systems in the world currently known today.

Lastly, with the modernization of medical practices undergone in today's world, the developer has positive hopes for the adoption of Secure MedRecord in the day to day life of users to obtain the benefits and convenience in managing their own medical health where their medical information are in the reach of their pockets. Thus, minimizing availability issues users might phase in their day to day life in the event of medical consultations, references, emergencies or recalling their medication intake, allergies or symptoms. With that, it is concluded that Secure MedRecord, as the developer hopes, would allow facilitating convenience in users the day to day life with the technology of the cloud, security and availability as technology has always been to help users overcome problems by providing solutions.

CONCLUSION

Much research and development have been done and completed by the developer for the completion of the project. In the first chapter, the aim and objectives of Secure MedRecord are clearly defined together with the problem statement for the reasons for developing the web application. Next, domain research is executed together with research in similar systems currently available in the market. This is to understand the subject matter together with the existing advantages and limitations of the systems available for the development of the web application to ensure that it is unique and fulfil certain requirements for user adoption. Technical research was done in chapter 3 which allows for adequate information to be obtained for the development of Secure MedRecord. Next, system development methodology was compared and chosen for the suitable and effective development of Secure MedRecord which will be followed by the developer during the development in the second half of the project. The gathering of information through the survey with the distribution of questionnaires and analysis of information gathered has allowed the developer to gain the understanding of users and their requirements for the effective development of the project.

To continue in the second half of the research has allowed for the system architecture design to be illustrated such as the abstract architecture and interface design. Based on the designs, implementations can be made in through the specified designs. Chapter 8, on the other hand, explains the features

available in Secure MedRecord and the release plans which the developer shall follow for proper time management during the development of Secure MedRecord. Next, the testing phase of the project development.

With the specified research conducted, the developer can do enough research to investigate the subject matter and obtain a vision in specifying what is to be achieved in the second half of the project later in the development. This would allow for the fulfilment of the objectives specified by the developer to complete the aim of Secure MedRecord. In terms of gaps within the research and design of the project, the developer wishes to continue doing his best in the security implementation of the web application to allow for proper usage and security to be obtained for the benefit of users in a safe environment. This would require further development of technical skills of the developer together with the knowledge in information system security to be utilized in further iterations of Secure MedRecord in the future.

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