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Development of FHIR based web applications for appointment management in healthcare

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Abstract

The integration of Information Technology systems in healthcare is no new concept, however, the ever growing solutions offered by the IT field are pushing a revamp of older implementations of Hospital Information Systems. Contemporary web-based solutions are now readily available and promise independence from operating systems and desktop bound systems, while incorporating faster and more secure methods. The focus on interoperable systems has been setting new goals towards fully computerized hospital management and the progress of healthcare standards over the years has made interoperability an obligation. The work presented hereby reflects a FHIR web based application to overcome the problem presented by scheduling and appointment management.

Keywords: Hospital Information Systems; Interoperability; FHIR; Schedule Management; Web Development

1. Introduction

The integration of Information Technology (IT) systems in healthcare is no new concept, however, the ever growing solutions offered by the IT field are pushing a revamp of older implementations of Hospital Information Systems (HIS). An HIS can be classified as an abstract global information system for the processing of data, information and knowledge within the health-care institution responsible for the management of its entire operation whether it be financial, administrative or others. [1] In this day and age, the importance of HIS renders them a focal point not only from a hospital's perspective, but to software development companies, especially from a financial perspective. Due to its nature of facilitating previously human lead operations, these systems must aim to achieve optimal results in increased productivity and effectiveness, while being appropriate and efficient to use. The worth of patients' Elec-

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tronic Health Records and its demand for privacy and high availabity demonstrates what is at stake from a security perspective and the safety of its exchange.[2]

A flexible and well founded appointment management system is critical for hospital management because not only does it maintain staff's schedules but also offers better quality of service to patients, through decreased waiting times. This article aims to explore the features and healthcare standards needed to build a reliable appointment management system, suitable for most hospital's needs. [3]

Being on the market for almost a decade now, the AIDA platform has had the ability to come in close contact with hospital staff and taken the first steps into the development of an optimized scheduling application tailored to fit each hospital's own demands.

The ultimate goal of this application is to provide hospital administrators with a tool that is able to provide them with instant solutions for appointment scheduling. The premises highlighted in [4], which state that existing solutions to patient scheduling systems often are based on hand picked rules that aim to satisfy differing objectives, were the base of the approach into the development. The outcome of multiple discussions with hospital staff in different settings emphasized the need for a simple scheduling platform that would suggest optimal days to schedule each appointment, taking into consideration a set of pre-requisite rules.

In order to achieve the simplest and most efficient solution possible, while also exploiting the multiple advantages of HL7 FHIR for resource definition and organization, a higher complexity of schedule definition was agreed upon. This means that in a slot centric scheduling environment, each and every time slot must have clear rules that aide in the scheduling process acting as filters. These rules range from device utilization and practitioner/care team deployment to patients' age or the urgency of appointments preferred. The multiple schedules that hospitals' human resources are bound to group together to form each resource's own schedule and thus, easily providing them with a view of their timetable across any timespan.

2. Background

2.1. Agency for Integration, Diffusion and Archive of Medical Information - AIDA

The Agency for Integration, Diffusion and Archive of Medical Information is a platform based on multi-agent technology which aims to serve standardized applications for storage and management of medical information to healthcare systems in Portugal. Founded by a research group at University of Minho, its goal is to not only assist existing medical applications by controlling the flow of information between systems, as well as to provide capable alternatives that fit each healthcare environment's own needs. [5, 6]

So far, the platform encompasses information systems, implemented as web applications to be served on each hospital's private networks, capable of managing many structural departments such as administration, radiology and business intelligence as well as patients' EHR. This platform model allows for medical information to be exchanged between modules and relies on interoperability to do so effectively while relying on a multi-agent system to control the flow of information and its high availability.

2.2. HL7 FHIR

Founded in 1987, Health Level Seven International (HL7) is a not-for-profit, ANSI-accredited standards developing organization dedicated to providing a comprehensive framework and related standards for the exchange, integration, sharing and retrieval of electronic health information that supports clinical practice and the management, delivery and evaluation of health services. [7] HL7 is a set of international standards describing terminology, ways of transaction and security when dealing with medical information. Its 4th iteration, created in 2011, known as Fast Healthcare Interoperability Resources (FHIR) utilizes either JSON or XML formats to define information in a way that is easier both to implement and understand, taking full advantage of the data types to ensure its premises of secure and reliable data description and exchange.

2.3. Scheduling software in healthcare

2.3.1. SONHO

SONHO is the HIS on which public healthcare is based on in Portugal and has been a backbone of public hospitals since 1995. It has been regarded as such a significant implementation that its use was quickly spread all over the country. In order to keep up with the growing needs of healthcare it was recently redesigned into a new version, allowing for a split of the platform's architecture in different modules, increasing efficiency in each own's operations while also allowing for better support and development. *SONHO* is a very complete healthcare management tool and its features range from storage and access to patients' EHRs as well as its diffusion to scheduling, accounting, billing and administrative management. [9]

Its nature of a HIS of general use in public healthcare offers many advantages from an information storage standpoint and allows the integration of other applications as will is the case of AIDA.

2.3.2. SClínico

SClínico is a complete HIS developed by the Portuguese Health Ministry to supplement public healthcare facilities countrywide. It is used in over 300 facilities countrywide and serves different modules to suit each one's different needs, ranging from system administration to inpatient, outpatient and urgent admission, as well as EHR storage. Its broad usage allows for a unified HIS and cooperation between healthcare facilities, in order to improve the quality and responsiveness of the service in the country.
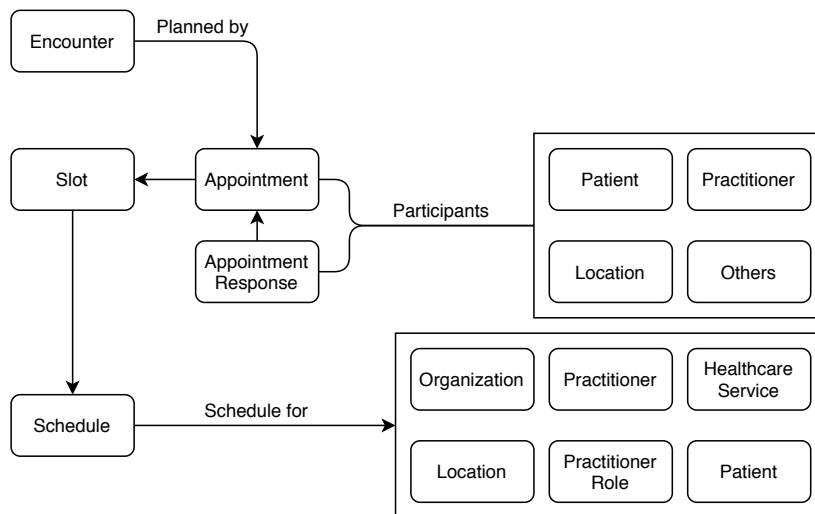
3. Architecture and Methodology

Fig. 1. FHIR Scheduling module, adapted from [3]

The HL7 FHIR Administrative module covers the base data that is then linked into the other modules for clinical content. Before any clinical data can be recorded, the basic information of the patient must be recorded and then the basis of the interaction. An Encounter, defined as an interaction between a patient and healthcare provider for the purpose of providing healthcare service or assessing the health status of a patient, is usually the only precedent of scheduling of an appointment. [7] Figure 1 is a visual representation of the components surrounding HL7's shceduling workflow.

Prior to scheduling, it is necessary to take into consideration the participants of said appointment. Practitioners, devices and locations are subject to their own schedules and these must be overlaid to find suitable gaps. Accomodating patients' needs is also important for they are also subject to their own availability. If possible, when a patient has multiple appointments, these should be booked as close as possible to each other and in the same day.

When availability is finally agreed upon, the appointment should be requested and, according to each healthcare provider's own methodology, either instantly booked or accepted by all participants. According to HL7 FHIR appointment workflow, it should be possible to create waitlisted appointments if the chosen time should not be considered ideal due to the lack of available slots.

3.1. Schedule Administration

Schedule

A schedule is a container of time slots that may be available for the performance of a service and the use of a resource. [7] By definition, a schedule is created according to a location, device, practitioner, among others (see Fig. 1). These fields are all optional and can be combined as necessary. Moreso it should be linked to one or more service types (specific services to be performed during appointments) and specialties which helps to ensure a faster approach at filtering suitable schedules when booking an appointment. It does not provide any information regarding appointments.

Slot

Slot resources are used to provide time-slots that can be booked using an appointment. They do not provide any information about appointments that are available, just the time, and optionally what the time can be used for. Slots can also be marked as busy without having appointments associated. [7] When creating timed slots, waiting list or overbooked appointments should be considered, and may be allowed by specifyng different appointmentType variables. These are useful for specifying other rules associated with these slots.

3.2. Graphical UI Development with Vue JS

Vue JS is a Javascript framework for building user interfaces. It features an incrementally adaptable architecture based on hierarchic component composition. Front-end development is a complex and multidisciplinary task, crucial in the development of web applications where the user experience (UX/UI) is key to the application's utilization. [8]

3.3. Back-End Server Development with Node JS

Node JS is an open-source Javascript runtime created in 2009. It allows the development of server-side scripting tools manage HTTP requests and responding accordingly and securely, when user credentials are verified. Its implementation is useful as a REST API for applications to manage access to the databases it links directly to. This is especially influential in the AIDA's platform scope, as administration applications have a direct impact on scheduling and business intelligence ones will be making use of the data to further influence hospitals' decisions on the subject.

4. Discussion

While being able to take credit for their innovation and reliability across the last decades, former Hospital Information Systems tend to become obsolete as the years go by. As mentioned previously, systems like *SONHO* have had a huge impact on public healthcare but have not been able to keep up with newer applications. State of the art applications now have access to more optimized features for security purposes, workflow management and record keeping. It is also worth noting that academic literature has come a long way in the field ever since Norman Bailey [10] published their investigation in 1952. From the optimization of static scheduling algorithms to the introduction of dynamic ones, it is now possible to design optimal tools based on each hospital's own approach.

Built around the solid definition on HL7 FHIR, AIDA OGT, the most recent application within the AIDA platform's scope, presents itself as a modern way to solve the scheduling problem in healthcare facilities.

First and foremost, the application's architecture and data definition allows for the conversion and storage of structural identification from different nomenclature systems of clinical definition such as SNOMED CT and OpenEHR.
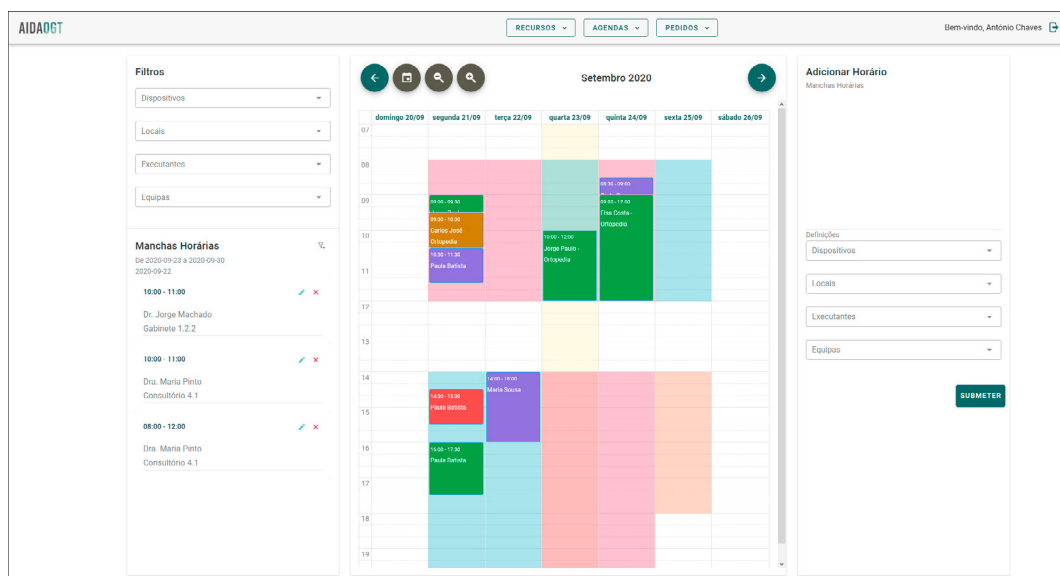
Fig. 2. AIDA OGT's Scheduling Management module

This was the first step towards making the implementation in different environments as simple as possible, followed by the conversion of existent information to an application defined standard. This conversion encompasses a complete restructuration of data into newly created database tables and the creation of services to maintain and update new entries in real time to ensure every implementation's safety of deployment and execution and to facilitate future updates.

The application follows the web development standards in workflow management and security. Thorough unit testing and debugging are featured to ensure no stone is left unturned and the final product's behaviour will not fail unless its external dependencies do.

Ultimately, the application's design features a modular system of competences, meaning the final product may vary in different environemnts, to suit each own's needs. This is especially important when designing new modules which can then be easily added to an existing implementation. Figure 2 encapsulates the schedule management module, already implemented in AIDA OGT, which stands in its first trial version.

Through the course of the last months, some challenges have arisen. The information conversion and maintenance on each different healthcare environment is no easy task but a detrimental one, and its hoped to instigate a normalization of medical information all around the hospitals which, for the last decade, have chosen AIDA as a service to assist in their entire operation's management. It is also worth noting that not every hospital has the same principles in workflow and while the adaptation to multiple settings is one of the key factors of the application, it may generate new hurdles towards development. Overcoming these difficulties, as well as having personal inputs from medical staff from different settings has made entire development process more widely comprehensive and the implementation superior all around.

5. Conclusion

Over the course of the last year, AIDA's personnel has been working closely with portuguese public hospitals in order to create a set of tools specifically tailored to boost productivity, through reducing the dependance on human resources to perform necessary tasks. The latest project aims at the development of an application to manage general scheduling and appointments in a way that benefits patients and workers.

With the development of this application in mind, this article's intent is to explain some of the more technical points on which the application stands, from an architecture perspective to the use of industry standards that back

the data models' design and information exchange. It also regards some consideration and critical evaluation of some applications whose use has been the most widespread in our country's public healthcare system.

This approach, backed by the industry's professionals opinions, has been a key factor in the genesis and instantiation of AIDA OGT, which stands in its first trial version as of now.

Acknowledgements

References

[1] Miranda, Miguel, Gabriel Pontes, Pedro Gonçalves, Hugo Peixoto, Manuel Santos, António Abelha, and José Machado, "Modelling Intelligent Behaviours in Multi-agentBased HL7 Services" *Computer and Information Science 2010* (1): 95-106

[2] Salleh, Dr. Abdollah, "Hospital Information System" *https://drdollah.files.wordpress.com/2014/07/information-systems-in-health-care.pdf* (1): 3

[3] Csenar, Christopher (2019) "Design and development of a FHIR based mobile application for appointment scheduling in clinical context", *St. Pölten University of Applied Sciences* (2): 29

[4] Heasley, McKay N. (2011) "Dynamic Appointment Scheduling in Healthcare" *Department of Mathematics, Brigham Young University*

[5] Cardoso, Luciana, Fernando Marins, Filipe Portela, Manuel Santos, José Manuel Machado and António Abelha "The next generation of interoperability agents in healthcare" *International Journal of Environmental Research and Public Health* (4): 11

[6] Peixoto, Hugo, Manuel Santos,António Abelha and José Machado "Intelligence in interoperability with AIDA" *International Symposium on Methodologies for Intelligent Systems*

[7] HL7 FHIR Documentation, *http://www.hl7.org/fhir/*

[8] Brambilla, Marco, A. Mauri and Eric Umuhoza (2011) "Extending the Interaction Flow Modeling Language (IFML) for Model Driven Development of Mobile Applications Front End" *Department of Electronics, Politecnico de Milano*

[9] Marto, Vítor M. (2017) "A Gestão da Mudança em Sistemas de Informação: a migração do sistema de gestão de doentes para a aplicação SONHO V2 no Centro Hospitalar de Leiria, EPE" *Escola Superior de Tecnologia e Gestão, Universidade de Leiria*

[10] Bailey, Norman T. J. (1952) "A Study of Queues and Appointment Systems in Hospital Out-Patient Departments, with Special Reference to Waiting-Times" *Department of Mathematics, Brigham Young University*