

# Imune: A Web-Based Immunization Management System

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**Abstract.** *This paper describes a Web based application, called Imune, which was implemented using Flex, PHP, PostgreSQL, and Apache web server under a GNU/Linux platform. Imune is a management information system tool for the immunization control in any municipality, which was modelled and designed towards the necessities of the Brazilian public health system. The Imune system provides the management of vaccines, patients, mass immunization campaigns, access control to the recorded information, record of immunizations and history of immunizations per individual, and several statistical reports. Imune facilitates the improvement in the strategic planning for the public vaccination system, which results in a better assistance to the population in general and resources savings by governments with the reduction of vaccine lost.*

**Resumo.** *Este artigo descreve uma aplicação voltada para a Web denominada Imune, que foi implementada usando Flex, PHP, PostgreSQL e servidor Web Apache sob plataforma GNU/Linux. Imune é um sistema de gestão para o controle de imunização em municípios de qualquer porte, que foi desenvolvido especificamente para atender as necessidades do sistema de saúde pública do Brasil. O sistema Imune possibilita a gestão de vacinas, pacientes, campanhas de vacinação, controle de acesso às informações registradas, registro de imunizações e histórico de imunizações por indivíduo, além de diversos tipos de relatórios gerenciais. Com o uso do sistema Imune tem-se uma melhoria no planejamento estratégico para o sistema público de vacinação, resultando em uma melhor assistência à população em geral e uma economia de recursos governamentais com a redução da perda de vacinas.*

## 1. Introduction

Nowdays there are many health management information systems commercially available (STC, 2009) (HCS, 2009). However most of these tools provide no modules to manage and control the vaccination process tasks. Moreover most of the available tools are not implemented as Web applications. In the Brazilian Unified Health System (*SUS - Sistema Único de Saúde*) the vaccination process control is based on printed cards, which are manually updated, and only the distribution control of the vaccine is automatized. So to make the SUS more efficient it is very important to implement a vaccination control information system.

This work presents Imune, a Web based application implemented using the PHP (PHP, 2009) (Gutmans, 2005) script language, the PostgreSQL DBMS (Postgres, 2009) and

the Apache web server under GNU/Linux (GNU, 2009). Imune is proposed as a solution to the vaccination control process in the scope of the Brazilian SUS.

As already mentioned the current vaccination control process is based on printed cards that are manually updated. Since many cards are lost and there is no standard format for the information on these cards, it is almost impossible to produce statistical reports about the immunization status of the population as well as to manage and control efficiently the vaccination process.

One of the consequences of this situation is the lack of precise data, which could be used to obtain a precise profile of the individuals and to map the immunization status of the population in order to identify the critical geographical areas and possible expansion of specific diseases due to failures on the vaccination system.

In the section 2, it is presented a comparison of health information systems oriented to the vaccination control process. The section 3 describes the analysis, design and implementation phases of the software engineering process applied in the development of our Imune tool. In the section 4 the social benefits to the population and the improvements in the public health system are discussed. The section 5 presents some future directions for the present work and the section 6 makes some conclusions.

## **2. Related Work**

One of the commercially available vaccination control systems is IMS (STC, 2006), a Web based application developed by Scientific Technologies Co. Currently the IMS is adopted by the government of many states in USA, including Arizona, Washington, and Idaho. IMS has some modules to manage mass immunization, remote vaccination registry, patient records, etc. Since IMS is not an open source application it would be difficult to adapt it to the Brazilian reality. For instance, IMS has no support to internationalization and so it can not provide support to the Brazilian Portuguese language. Moreover, IMS has a very high acquisition cost, which is not acceptable to the Brazilian health system.

In the seventies, the Brazilian public health system already started the use of a national immunization program (*PNI – Programa Nacional de Imunização*) (Datusus, 2009). Only in the nineties, it was developed an Information System for the PNI (*SI-PNI – Sistema de Informação do PNI*). One of the many sub-systems in the SI-PNI is the Evaluation of the PNI (*API – Avaliação do PNI*), which is able to record the quantity of applied vaccines on each group of individuals, distributed according to their age, and to calculate the immunization coverage per basic unit (health care facilities). Thus there is no possibility of control per each individual or some kind of more precise control.

No open source tool was found that could be able to manage and control the tasks in the immunization process. This is one of the motivations to develop a new open source web based application oriented to the immunization process control.

## **3. Imune System**

Imune is an information system tool for the vaccination process control, which was modelled and designed towards the necessities of the Brazilian public health system. The current version of Imune includes the management of vaccines, patients, mass immunization campaigns, access control to the recorded information, record of immunizations and history of immunizations per individual, and many statistical

reports. The Imune development was completely based on methods and techniques from object oriented software engineering (Pressmann, 1995), including analysis, design, implementation, tests and deployment phases and the use of UML (Unified Modelling Language) (Scott, 2003) and design patterns oriented to web applications (for instance, the Model/View/Controller design pattern) (Gamma, 2000).

Since the main objective of Imune was to give support to as many individuals as possible and to be available to all primary healthcare facilities, it was adopted only open source and free technologies and tools.

The Imune was developed under GNU/Linux using the PHP script language on Apache web server and PostgreSQL DBMS. Thus, Imune can be adopted according to the originally proposed goals as well as to other future necessities. It can be easily adapted to other realities, since its source code is freely available and well documented. For instance, Imune can export data in a format compatible with the systems of the Brazilian SI-PNI. This allow the integration of the systems and the sharing of information between them.

In the analysis process it was used UML in order to produce a standard documentation for the future Imune developers. The analysis process started with a study of the activities related to the Brazilian public immunization system and the identification of the system requisites. Several interviews with health specialists were conducted in order to collect data, identify existing problems and determine how a management information system could help to solve the problems.

Based on the obtained information, use case diagrams were modelled using the Poseidon for UML Community Edition (Gentleware, 2009), where are represented the expected functionalities and the interaction of the users with the system, among another aspects. Based on the use case diagrams and all collected information, class diagrams were modelled using UML to capture the concepts and structure of the information system. The figure 1a) shows part of the main class diagram.

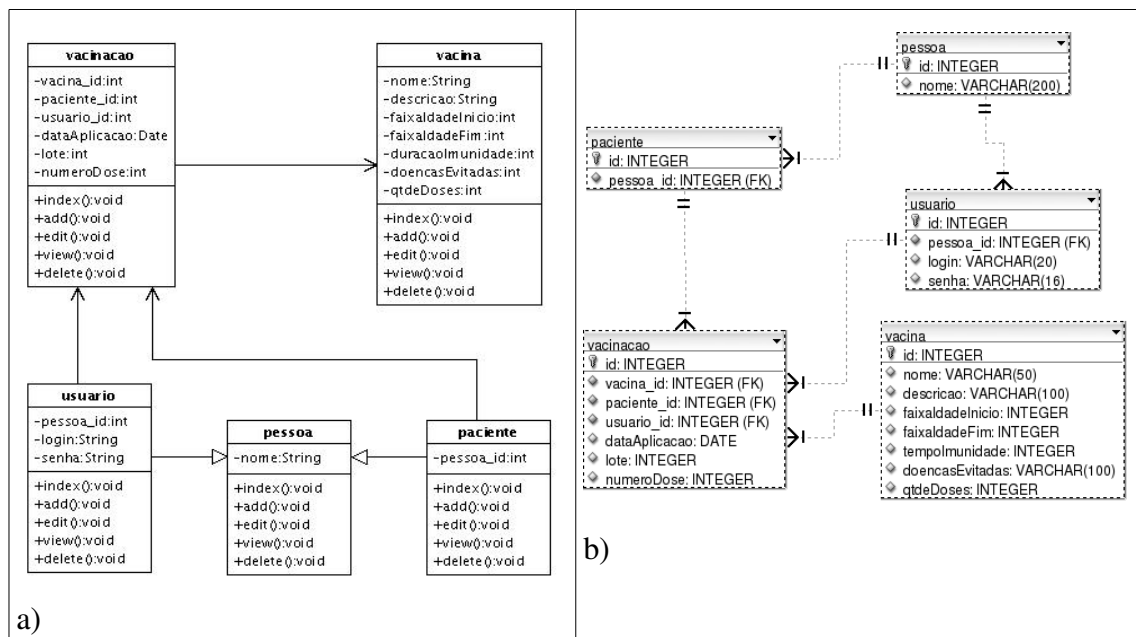


Figure 1. a) Class Diagram; b) ER Diagram

As shown in the figure 1a), there are two kinds of person (*pessoa* class): “user” (*usuario* class), responsible for the vaccination (*vacina* class), and “patient” (*paciente* class). Then, at this point, sequence diagrams were modelled to represent the main behaviours of the information system.

An OO-ER mapping (Object Oriented to Entity-Relationship mapping) was performed, the DBDesigner tool (Fabforce, 2009) was used to edit the obtained ER model and to generate the SQL scripts for the database and tables creation. In the figure 1b) it is shown the ER diagram edited in the DBDesigner. As illustrated by the figure 1, for most of the class diagrams, the OO mapping was one-to-one.

In the design phase, the modules of the system were defined. The first one, patient module, allows to record personal information of each individual, including address, phone, email, etc. This module also provides the history of vaccinations of the patient, which can be viewed and updated via Web.

Another module, vaccine module, provides the registry for the different kinds of existing vaccines. For each kind of vaccine specific information is recorded by the vaccine module, which also provides the vaccination history of each patient in the system. In the vaccination history is included all vaccines taken by a given patient, as illustrated in the figure 2.



**Figure 2. Vaccination history**

As illustrated in the figure 2, the vaccination history of a patient includes the already applied vaccines and the vaccines yet to be applied, according to the patient’s birthday. The red buttons indicate vaccines that are already due according to my age, the green buttons represents vaccines that may be applied, and the blue buttons indicate the already applied vaccines. By clicking on a green button the vaccination form is presented, in order to register the application of the corresponding vaccine. Thus, the vaccination history is the start point to the application of the vaccines on a patient.

In the design phase, user and permission modules were also defined. These modules allow managing the accesses to the system functionalities by the users. A user can only access the functions enabled for the group of the user. For instance, it is possible to define specific permissions for users that only are enabled to apply vaccines, for others which can manage the personal information of patients, etc.

Another designed module is the campaign module, which allows the definition of mass immunization activities. This module can send messages to inform the patients about the next applicable vaccination. For the Imune implementation, the database was created by the SQL script, which was automatically generated by the E-R modelling tool DBDesigner. The dynamic web pages were codified using the PHP scripting language conforming to the Model/View/Controller design pattern. The model was implemented using Propel (Propel, 2008), an Object Relational Mapping framework in PHP. The view part of the system was implemented using the Flex platform (Adobe Flex, 2008), and the reports were implemented using iReport (iReport, 2009).

In the collaborative development work was adopted the control version system SVN (Subversion, 2009) as source code repository and the Eclipse platform (Eclipse, 2009) as IDE tool, including plugins for PHP, Flex (Adobe Flex, 2008), and for the access to the SVN repository.

#### **4. Benefits Provided by the Imune System**

One of the most important social benefits provided by Imune is a better assistance to the population in general. This improvement is due to the fact that the information system allows a more personalized and faster assistance, since there is no need to manually search for printed cards. The wasted time in the current situation is one of the main problems of the Brazilian public health system.

Another important social benefit provided by an information system based on the Web is the improvement in the strategic planning for the public vaccination system. Currently, the SI-PNI has no individual control for patients. The control is based only on groups of individuals, according to some criteria as age or sex. Personal data of patients are recorded manually on printed cards at each primary health care facility.

Using Imune, which is a web based application accessing a unique database, the public vaccination system obtain an unified, secure, consistent and precise source of information about the immunization status of the population in general. Applying some filters and data mining techniques, it is possible to obtain precious information and patterns that can be very useful for the public health system planning. By means of simple queries to the Imune database, it is possible to identify, for example, the geographical regions with lesser or greater engagement to mass immunization campaigns, or to identify the necessity of implementation of regional or specific mass immunization campaigns. This example is just one illustration of how the use of data mining techniques on the Imune database can help significantly in the strategic planning of the public health system.

With precise information and control, not merely based on estimates, the rendering of accounts on the public resources by the governments can be more efficient and transparent. All information in the Imune can be made available on the Web in the form of reports about cities, regions, states, or nationwide.

Another benefit provided by Imune is the reduction of the vaccine lost, which results in the public resource savings. Currently it is not possible to determine with a good precision how many vaccines will be necessary for a certain period of time at each primary health care facility due to the manual control of the patient information. With Imune this estimates can be easily performed based on simple queries on the Imune database. It is also possible to perform comparisons between vaccinations that were

applied on geographically near health care facilities and to send the excess of vaccines to the places where the demand yet exists.

## 5. Conclusions and Future Work

In the present paper it was presented some problems of the current reality of the Brazilian public vaccination system and described the Imune, a Web based application which copes with some of these problems. Imune is an open source tool based exclusively on free technologies with a very low cost of ownership and easily adaptable to other realities on other countries, since the Imune source code is freely available and well documented. In order to adopt worldwide accepted standard, Imune will incorporate the Health Level Seven (HL7, 2006) (Health Level standard in future versions). Another future work is the exploration of data mining techniques to produce reports that will help in the strategic planning for the public health system.

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