MARCIA: Applied Clinical Record Management

Eletronic Health Record Applied with EHRServer

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***Abstract*—The quality of services provided to patients in the health area is directly related to the quality of clinical information. In addition, this information must be consistent, secure and available to health professionals, even though health data is usually distributed across heterogeneous systems. The Electronic Patient Record (EPR) was proposed and applied to minimize integration problems through the construction of health information systems. This work proposes a methodology for the development of interoperable and flexible systems, using the EHRServer framework of the OpenEHR standard. As a case study, this methodology has been applied in Aracati/CE since March / 2017, in the context of the Chikungunya disease. The methodology is supported by a system that implements a set of OpenEHR archetypes representing the clinical treatment of Chikungunya. The system was tested in a Basic Health Unit. The archetypes and the MARCIA Templates were made available to the Clinical Knowledge Manager (CKM), the largest online repository of archetypes on the Web.**

***Index Terms*—Archetypes, HIS, Clinical Management, Basic Health Unit, Chikungunya**

I. Introduction

The Brazilian government and health service private providers have been investing in the construction of Health Information Systems (HIS). One of the solutions is the Electronic Patient Record (EPR), which replaces the paper medical record by electronical medical record and stores the patient's information in a health center [7]. Ideally, these systems should be interoperable, making this information available whenever and wherever needed. However, most of the EPRs used in health centers are proprietary systems built with different architecture, business rules, information technologies and models, in addition to incompatible clinical terminology. These facts hinder the interoperability among the HIS, making it difficult for health professionals to provide adequate care [6]. In addition, we have the diversity of these systems and the complexity of the health area, leading to problems such as: clinical history fragmentation in various HIS, relevant information from patients unavailable in a new health facility, medical error due to the lack of information about the patient, clinical information redundancy across the various EPRs, test results omission (obliging the patient to redo such procedures), waste of time and resources. All these problems negatively impact both the patient care and information management for the decision-making [9] A solution for this problem could be interoperability through interfaces, in which systems exchange information with each other. However, this solution is not reusable and it is inappropriate when the number of communicating systems grows, since each newly added system would require a new interface [12]. The most appropriate solution for achieving interoperability is by means of consensual standards [2]. These standards provide the means for two or more systems to exchange information without adding new functionality to the system, requiring only systems that need to communicate using consensual standards [4]. In Brazil, there is an effort to use interoperability standards for HIS. An initiative was of Ordinance 2.073 / 2011 published by the Ministry of Health in which twelve standards of interoperability between HIS are adopted [11]. Among these standards, we can find the OpenEHR, which proposes a fast construction of flexible and interoperable EHR [3]. This work proposes a methodology for the development of interoperable and flexible systems, using the EHRServer framework of the OpenEHR standard. As a case study, this methodology has been applied in Aracati/CE, since March/2017, in the context of the Chikungunya disease. To this end, we developed a set of OpenEHR archetypes (also called a *Template*) that represent the clinical treatment of Chikungunya disease. Named MARCIA (Applied Clinical Record Management), in portuguese *Manejo de Registro Clinico Aplicado*, the system was developed and implemented in a Basic Health Unit. The archetypes and the MARCIA Template have been contributed to the Clinical Knowledge Manager (CKM), the largest online repository of archetypes available on the Web. This system aim to support primary care professionals along the treatment of the disease, due to the fact

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that this region is being affected by epidemics caused by the mosquito Aedes Aegypti, specifically arbovirosis chikungunya [11].

II. Theoretical Framework

A. OpenEHR

The OpenEHR standard is characterized by being a specifications and free tools set that allow the clinical records development in a modular way [1]. This standard is maintained by the OpenEHR Foundation, which proposes, especially, the Electronic Health Record (EHR) development capable of monitoring dynamism and complexity in the health area, thus generating open, flexible, independent and interoperable systems [2]. The purpose of this standard is to represent the clinical knowledge in a structured way by standardizing and organizing knowledge domain data through Models called archetypes (metadata standards). Archetypes represent clinical information of various natures, for example heart rate [7]:

1) OpenEHR Clinical Model: The archetypes are kept outside the system code, stored in an online repository called *Clinical Knowledge Manager* (CKM), allowing medical experts to manage them independently from system analysts and IT specialists [5]. This allows health professionals themselves to represent complex concepts such as *"blood pressure"* or *"family sickness history"*, especially through the reuse or definition of new archetypes [1]. Thus, as illustrated in "Fig. 1", there is an important and crucial separation for the successful EHR solutions development [5]:

> **Domain modellers:** Health professionals define models that describe consensual concepts and create template models that will be used in health facilities. The template is a set of archetypes that represent a clinical record. The manipulation of these archetypes is done through specific software tools such as *Archetype Editor*, which maps them into formal languages, ADL *(Archetype Definition Language)* or XML (eXtensible Markup Language).
>
> **Software developers:** Information Technology Professionals develop software that understands these models and adjusts to their definitions, ensuring version control of information and data management capability. From the formal representation, the archetypes can be implemented in the software, using some frameworks or libraries available through the *OpenEHR Foundation* [13].

B. EHR Server

The *EHRServer* is a Electronic Health Record (EHR) server standardized with the *OpenEHR* standard used as a clinical information repository. Through this server, it is possible to register and query EHR data in a Service Oriented Architecture. This architecture allows distinct systems to connect, send, and request data to the *EHRServer*. The *EHRServer* uses the *MySQL* database manager and the *groovy* programming language to generate software artifacts that will write files to a database, in addition, the server is abstracted in 3 layers:

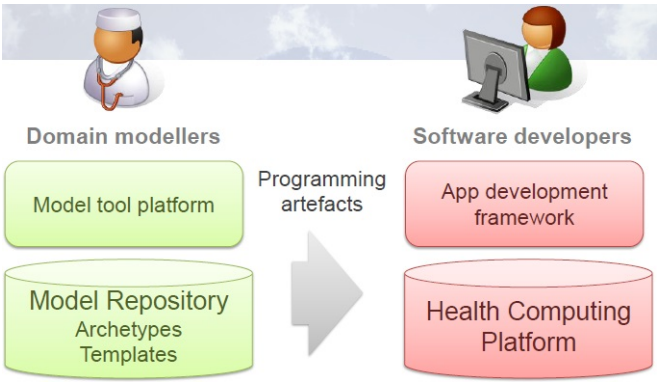

Fig. 1. Dual model of OpenEHR standard. Source OpenEHR(2017).

Data layer, **Logical layer**, and **Persistence layer** (Where data is stored). The EHRServer (API) application program interface allows the integration of an Electronic Medical Record (EMR) application to use two basic services, **Commit**, which sends EHR data patient to The EHR Server, and the Query EHR data from a patient by EHR Server [15].

C. Related Works

There is a community effort on the road to standardizing systems through the use of archetypes. [12] defines an archetype model to map the formal clinical knowledge base for the construction of computational artifacts focused on telehealth. In turn, [14] implements an interoperable RES based on the openEHR standard for basic care of the Bahia State Harmony Foundation (FLH/BA, in Portuguese). Although using traditional system development methodology (Analysis, Design, Implementation, Testing and Deployment), it was the first proof of concept of the openEHR standard in Brazil.

[16] proposed a shareable RES architecture and the creation of twenty archetypes for the primary care of the Minas Gerais Health Secretariat (SES/MG, in Portuguese) using ISO 13606.

III. Proposed Methodology

Developing interoperable HIS is never an easy task. However, the OpenEHR standard provides a set of interoperable software building features that may be modified later without changing source code, unlike traditional methodology. An important framework of this standard that facilitates this process is the EHR Server, which will be used in this work. Based on this new paradigm, we propose the following methodology. "Fig. 2" for the generation of the proposed solution:

1) Requirements: Initial phase, where the system requirements are defined. A formal specification describing the functions of the future system;
2) Archetypes: In this phase, the archetypes are searched in the CKM. These archetypes (metadata) represent the requirements of the health information system;
3) Composition: Then, the archetypes are clustered in a single base archetype (composition), giving rise to the template;

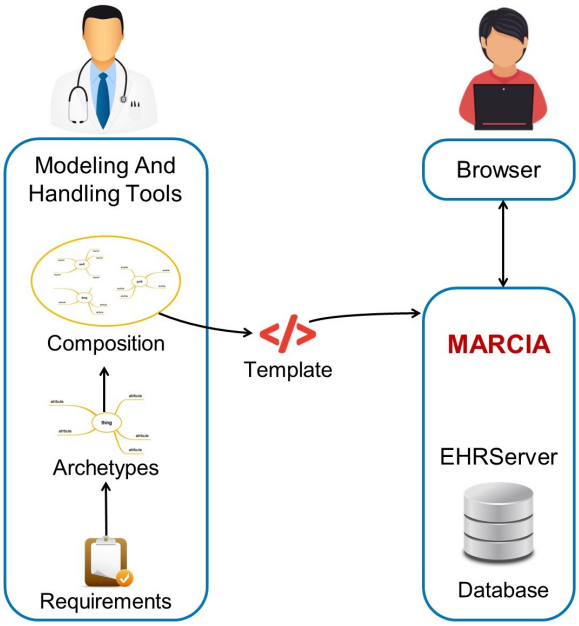

Fig. 2. Proposed Methodology.

4) Exportation: After the *template creation*, it will be exported (usually in an Operational Template (OPT) [1] or *XML Schema Definition* (XSD);
5) Template Upload: Then the template is uploaded to the *EHR server*. In this work we will use the clinical server *EHRServer*, which allows the reading of archetypes and *templates* for processing and manipulation of these;
6) Template Implementation: once the EHRServer template is read, it is time to implement it, using some kind of framework and other necessary tools;
7) Generating System Form: After the application is deployed, it will be created the *HTML* form for interaction with the end user, made available through a *browser*.

A. Applied Methodology

1) The system requirements are based on the chikungunya clinical management protocol (edition 2017)[2] , made available by SUS, the *Brazillian Health System*. The objective is to implement the registry of clinical procedures adopted in cases suspected of the disease, which are summarized in four actions: *Anamnese* (record the patient's clinical history); *Physical Examination* (record information on physical examination findings in patients); *Blood Examination* (Register the results of laboratory tests done to confirm the suspected case) and *Conduct* (record clinical conduct as prescription of medications and contraindications).
2) Once the software requirements are defined, it is time to search the Clinical Knowledge Manager (CKM) for the archetypes that represent the clinical knowledge of each action. In case it doesn't exist yet in CKM, the archetype will be created using an appropriate tool, such as *Archetype Editor*. Next we present the *Chikungunya* archetypes:
   - **openEHR-EHR-COMPOSITION.encouter.v1:** Base archetype for others. It represents a composition through which the other archetypes will be integrated.
   - **OpenEHR-EHR.OBSERVATION.IdParent.v1:** Archetype of identification of the person registered in the system, possessing identification code, personal data and demographic data.
   - **openEHR-EHR-OBSERVATION.history.v1:** Archetype that represents the patient's medical history (anamnesis).
   - **OpenEHR-EHR-CLUSTER.exam.v1:** Archetype that represents the physical examination findings performed on the patient.
   - **OpenEHR-EHR-OBSERVATION.Serology.v1:** Archetype that represents the patient's blood test result. The confirmation of arbovirose comes by blood test. This archetype was created to represent the amount of information on: hemoglobin, hematocrit, leukocyte and platelet. The values of this information are essential to prove or rule out a suspected case. The "Fig. 3" shows the mental map of this archetype, which also serves to represent the serology of the arboviruses Dengue and Zika Virus. Then this archetype was submitted to the CKM.
   - **openEHR-EHR-SECTION.clinicalDecision.v0:** Archetype that represents information involving medical conduct as indications and contraindications.
3) After defining the set of archetypes, it will be clustered into a single *composition* archetype type, and then the system *template* is generated. It consists of the relevant clinical information set to be printed through a form, resulting in the system interface. The figure 4 shows the mind map of this template.
4) After the *template creation*, it will be exported (usually in an Operational Template (OPT)) or *XML Schema Definition* (XSD);
5) Then the template is uploaded to the *Server*. In this work we will use the clinical server *EHRServer*, which allows the reading of archetypes and *templates* for processing and manipulation of these.
6) The template was implemented using the Grails framework, generating the system source code. After that, the *HTML* form of the applications were created for interaction with the end user.

This methodology can be applied to any other interoperable

[1]Operational Template, standard format used by frameworks in the implementation.

[2]Available at http: //portalquivos.saude.gov.br/images/pdf/2016/December/25/chikungunya-new-protocol.pdf.

Fig. 3. Mind map of Serology Archetype.

system development process based on the openEHR standard. The "Fig. 4" Shows the mind map that represents the clinical management of Chikungunya. This template was submitted to CKM as a proof of validation.

B. Architecture Based on Marcia System Components

MARCIA system uses the framework EHRServer OpenEHR standard. The architecture of MARCIA has 5 layers, as specified in this standard. "Fig. 5" shows the UML component diagram of this architecture which is divided initially into 2 large groups: server block (back end) and the application block (front end). The server block is structured in three (3) layers numbered from one to three layers (1 to 3). The application block is divided into two (2) layers numbered from four to five (4 to 5).

- **Database Server** - In this first layer we can find the database server, where the clinical data of each patient is stored for later retrieval and manipulation. This layer represents the persistence of that data on the server. The framework EHRServer is already installed in the MySQL DBMS;
- **Service Layer** - Here we find the services provided by the server, as specified in the OpenEHR standard. These services are: Electronic Health Record - EHR (services on patient's electronic records, such as consultations or insertion of new clinical data); Demographic (Services related to demographic information of the patient, such as: queries and changes of personal data and geographic location); Identification (this component has the unique identification service for each patient record, such as the PMI [3] used by the OpenEHR); Security (this component will provide the data access security service, such as user authentication); Knowledge (this component relates the template, previously defined, in the use of the other services during the processing of the application. This component also has clinical terminologies such as ICD-10 and SNOMED CT [10].
- **Virtual EHR API** - This layer comprises the APIs needed to communicate the services described above. For each service, the server has two main functions to perform this communication and to provide these services. These functions are: **commit** - essential function for sending data from the application to the server (insertion of data to be stored), **query** - this function retrieves data stored on the server to meet an application request (as a query to a history of the patient);
- **Application Layer** - These two last layers (4 and 5) are part of the front end of the MARCIA system. The components of this layer are: Integration (component that allows integration of the application with other modules of the system); Queries (component that allows the consultation and / or recovery of the data stored in the database); Logic of the Application (rules of the application, including procedures and business logic in use); Clinical Application (rules of clinical procedures to be adopted properly, as the correct completion of some fields of a clinical file). In this module it is found the implementation of the template defined previously, respecting all these rules;
- **Presentation Layer** - The topmost layer of the architecture corresponds to the presentation layer, where the application forms GUI [4] are presented. This layer will serve as interaction with the end user, receiving requests from this and presenting the results compiled by the system. "Fig. 5" shows the five components of this layer: FormCadastroPaciente(Patient Registration Form, that involves their personal and demographic data); FormRegistroHitria (Patient History Registration Form, also called Anamnesis); Physical Exam Form (Physical Exam Registration Form of registration of physical examination by the doctor on the patient); FormSorologia (Clinical Record form the outcome of blood tests); FormRegistroConduta (Medical Conduct registration form, as prescription of medicines, contraindication and recommendations).

IV. RESULTS

A. Benefits of the MARCIA system in the Basic Health Unit of Aracati/CE

The MARCIA system, using the structure of the EHRServer, allows the electronic registration of the clinical management

[3]PMI: Patient Master Index.

[4]GUI: Graphical User Interface.

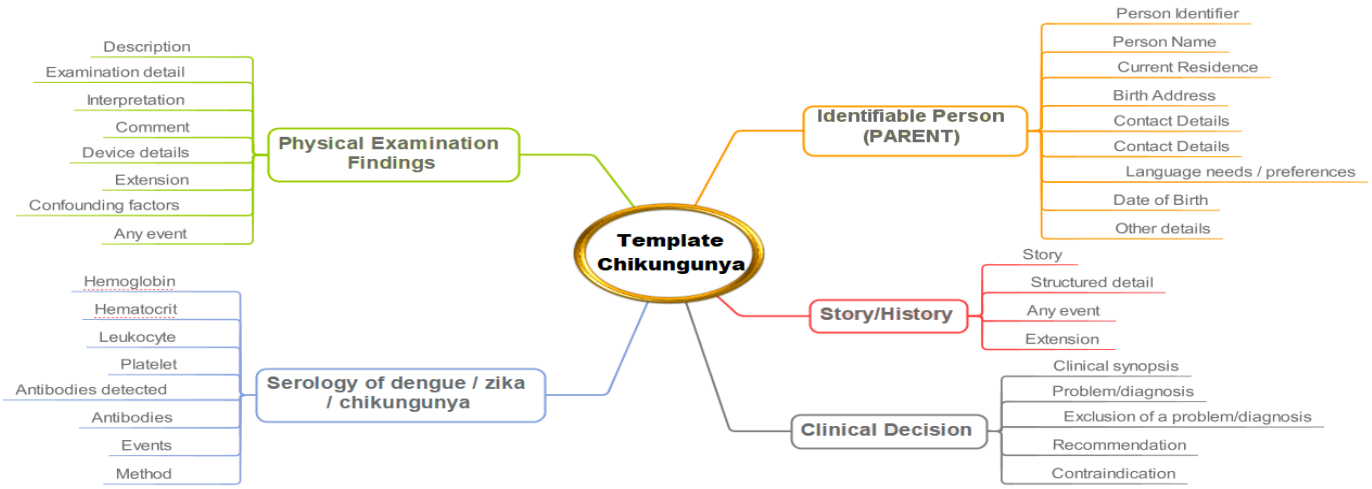

Fig. 4. Mind Map of Chikungunya Template.

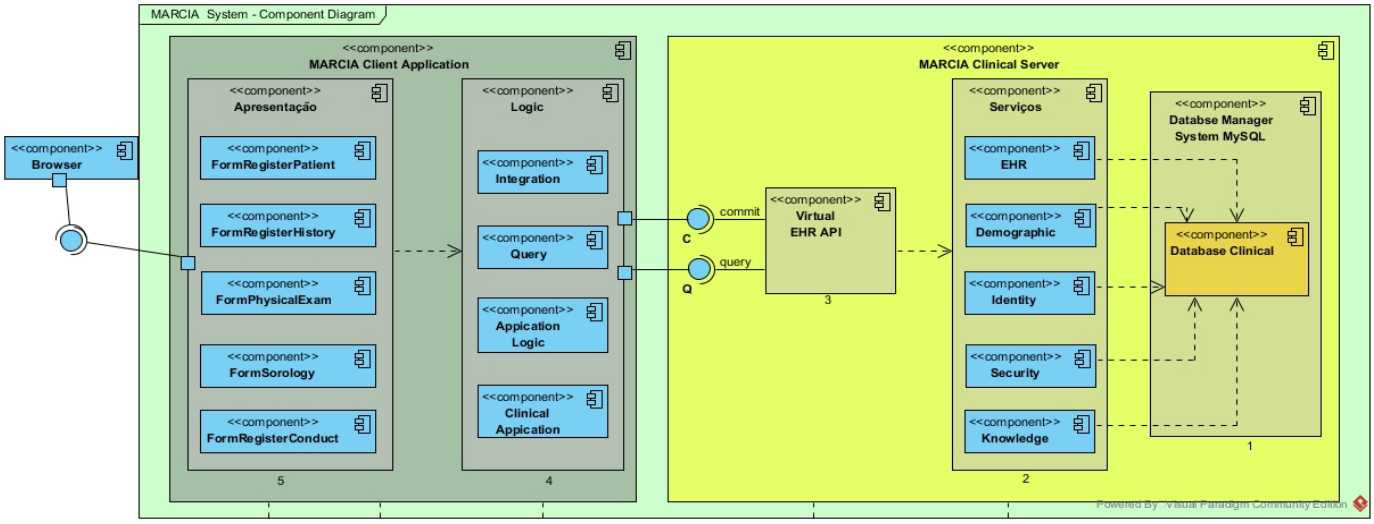

Fig. 5. MARCIA component diagram.

of Chikungunya, which will be used in a Basic Health Unit (BHU). This will provide the epidemiological and demographic information of each patient in the micro-region served by this unit. This tool makes it possible to maintain the electronic epidemiological record of Chikungunya for each patient, managed by the professionals of the health unit. ”Fig. 6” shows the BHU scenario with the MARCIA system. The four activities of clinical management of Chikungunya (Anamnesis, Physical Examination, Laboratory Examination and Clinical Conduct) described previously are shown in this figure. Thus, for each new service of this unit, it is possible to retrieve the epidemiological clinical history of the user for a better understanding, analysis and care. The MARCIA system is flexible to changes, allowing the healthcare professional to adjust updates to the template when needed, without having to change the source code, as specified in the OpenEHR standard. In addition, because it is an interoperable system, it is possible that this information is shared with other SISs that have agreed standards of interoperability. The MARCIA methodology can be reusable for building different Health Information Systems (HIS), even using other types of frameworks. As a validation of this methodology, it was applied in a UBS of the Municipality of Aracati-CE.

B. Result of the MARCIA system proposal

The MARCIA, provides the epidemiological information for health management, electronically, as shown in ”Fig. 7”, and also the SINAN system [5]. The communication among the systems is done through RESTFullAPI, implemented in each system. The MARCIA is a proof of concept of interoperability, contributing to health managers in decision making. These are some examples of improvement in the notification process:

- Electronic registry of epidemiological information;
- Greater security in data access, manipulation and storage;

[5]SINAN: ”Sistema de Informação de Agravos de Notificação”, in portuguese

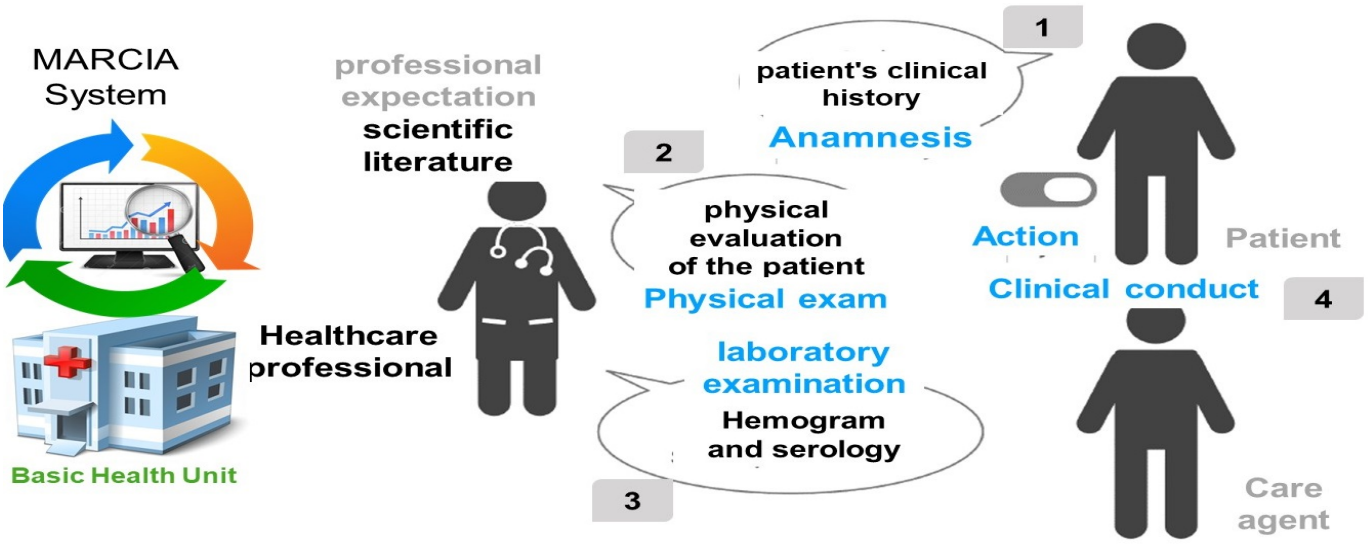

Fig. 6. Scenario with the MARCIA system in the Basic Health Unit (Adapted from BACELAR and CORREIA, 2015).

- Permissibility of restoration of the clinical history of each patient for each new care;
- Sharing information with other systems, providing interoperability;
- Greater control and monitoring of suspected cases in each micro-region served;
- Transmission of real-time information for analysis and decision making by the managers;
- Optimization of the disease notification process.

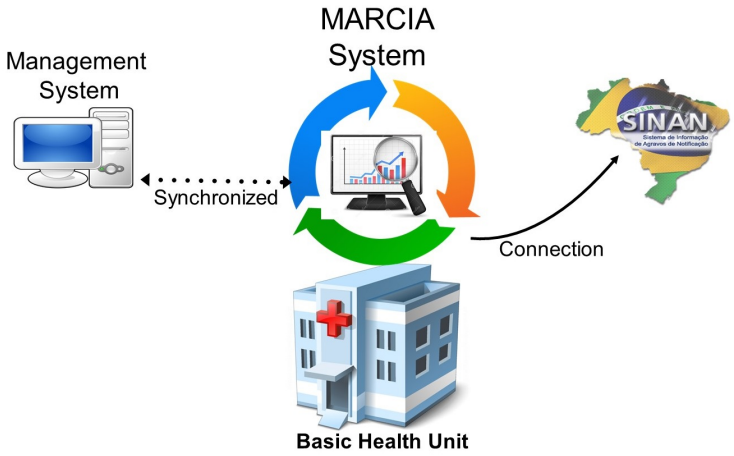

Fig. 7. Connecting MARCIA with other systems.

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