Modelling Software Agents: Web-Based Decision Support System for Malaria Diagnosis and Therapy

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**Background and Purpose:** The aims of our research as presented in this paper consist of formalizing the design of software agents and demonstrating its practicability in web-based medical decision support system specifically for malaria diagnosis and therapy to assist Healthcare professionals at medical consultation in order to optimize the quality of care of the patients with malaria disease.

**Methods:** The Software Agent System proposed is a functional model based on a contractual specification as the awareness of an agent in pursuing their goals and executing tasks. The agents are designed according to the requirement for an effective diagnosis and delivering the therapy strategies for malaria as per the supplied sign-symptoms and Laboratory test.

**Results:** The contribution of our work is mainly the contractual specification, a λ – Contract. As we demonstrate in the scenarios presented as results, the contract ensures the behaviour of the agent in achieving their goals and executing tasks.

**Conclusions:** The Software Agent System is adopted to cope with a complex and dynamic domain such as medicine and specifically the web-based medical decision support system for malaria diagnosis and therapy of the Optimization of Malaria Treatment (OMaT) system. Our proposed functional model facilitated the implementation of the SA. Specifically, we point out the fact that a λ – Contract can ensure the consistency and the credibility of the reasoning of the Software Agent.

**Keywords:** Software agents, Functional Model, Contractual Specification, Medical decision support

1. Introduction

The healthcare problems facing developing countries are great. A long time, malaria is one of the most challenging infectious diseases caused by the parasite called Plasmodium and localized in areas of Central and South America, Asia and Africa. Malaria should be considered a potential medical emergency and should be treated in time. Delay in diagnosis and treatment is a leading cause of death. Thus, the technical capability to perform a correct and a timely diagnosis, with an appropriate treatment of malaria infection in an ill patient is of critical importance in endemics regions, specifically in rural or isolated areas.

Medical decision support systems [1], [2], [3], [4] based on eHealth and mHealth can be used to serve the unserved. [5]

eHealth revolution in Africa is the main and most suitable vehicle for optimizing the quality of care and reducing the large death being caused by infectious diseases such as malaria where Specialists are not available.

“Developing the advanced care services raises new challenges in terms of modelling, infrastructures, supports tools, and the very understanding of telecaring networks and its operating rules.” [6]

As stated in [7], “software agents are a computer software technology that provides a powerful new method for solving complex problems and implementing complex systems”. Also in [8], “the motivations for the use of agents in the medical domain consist of the multitude of aspects that the agents can analyze during the diagnostics elaborations and the realization of different medical tasks. Agent-based approaches may integrate and extend different problem solving technologies.”

Our study, as presented in this paper, consists of formalizing the design of software agents and demonstrating its practicability in web-based medical decision support system specifically for malaria diagnosis and therapy to assist Healthcare professionals at medical consultation in order to optimize the quality of care of the patients with malaria disease.

The contribution of our work is mainly the contractual specification, a λ – Contract, as the awareness of an agent in pursuing their goals and executing tasks.

1. Materials and methods

The piece of core, in our research, remains a software. A software is a term employed for the various kinds of programs for the operations of computers and related devices.It is covered by a software engineering that is a computer science discipline concerned by the studies of the methodologies to design and to build software. The process of software development is to translate requirement into code.

So far, a software which performs a given task using information learned from its environment to act in a suitable manner so as to complete the task successfully, is a called a software agent. The environment includes humans, computers, devices, operating systems, computer applications, databases, networks, and virtual domains.

“Several researchers are working towards the standardization of agent technologies and in the realization of development environments to build agent systems. Such development environments provide some predefined agent models and tools to make easy the development of systems.”[9]

In point of view of medical software development, we pay attention to the software requirement specification IEEE standard 830-1998 [10] and medical software design standard IEC 62304 [11].

And we refer to the potential and application of agents in healthcare environment that have been discussed in [12], [13], [14], [15], [16] and [17]. Mainly, we take in account the survey of agent-based intelligent decision support systems to support clinical management and research, presented by Foster at al. [18]

Our Software Agent System is adopted to cope with a complex and dynamic domain such as medical industry. Specifically, our Software Agents, developed under the project “Optimization of Malaria Treatment” (OMaT) [19], are focussed on a web-based medical decision support system for malaria diagnosis and therapy. They are designed according to the requirement as described in the consensus guidelines [20] and protocols for the management of malaria [21] for effective diagnosis and delivering the therapy strategies for malaria as per the supplied sign-symptoms and Laboratory test.

* 1. Functional Model of Software Agents (SAs)

In the following lines, the functional model of the Software Agent is presented to provide an overview of the system.

*Definition 1: Software Agents (SAs)*

The Software Agents are a set of computational entities that exists in the form of set of programs or components that runs on the dedicated server and can interact with extern components. They act with minimal intervention from humans. They can require special and punctual collaboration with other embedded agents in pursuing their goals and executing tasks.

SAs are divided into two parts: code component ζ and data component К. Code component can be activities, services and applications that may act both as callers and as called. Data component is a content provider. It is passive and only received calls. Code component is a set of actions that can perform the Data component.

The Software Agents pursue goals or carry out tasks in order to meet their design objectives. The main objectives related to the SA which acts in the system OMaT are to provide interaction mechanism with Healthcare Practitioner (HCP) and to generate diagnosis and to suggest treatments. This is the general context of use of our SAs and their specialization.

In doing so, this is considered as a multiple objective constrained optimization problem. The purpose, in one hand, of the optimization problem is to evaluate solution alternative according to multiple criteria. In the other hand, the constraint in the objective optimization problem, means that if *O* is reachable the f(c) is supported by some proof system. Thus, we define a λ – Contract as our proof system.

 SA is defined as the following:

 SA:  (1.1)

where ζ is set of code component, *К* is a set of data component.

 The specification of the SA is the following:

 SA:: = c0 | c1 → c2 | c1 ↔ c2 | c1© c2 (1.2)

where

(i) c0 a stand alone application.

(ii) c1→ c2, denotes that the application c1 calls the application c2, in other words it means the application of c1 followed by the application of c2.

(iii) c1 ↔ c2 means that the application of c1 can be runs in parallel with that of c2.

(iv) c\* is the complement of the application c.

(v) c1© c2 means that the application of c2 is embedded to that of c1.

(vi) | denotes the alternative state of the system.

*Definition 2: Code Component*

A component ζ is defined as:

  (2.1)

where ζ is a code component that performs φ actions with set of input value *v* concerning a particular patient ina component data *K*. ζ returns information regarding disease *d* and therapy strategy *t* on basis of following relations:

 , (many-to-one relation), (2.2)

 D = {d1, d2, …, dn}, 

where D is a set containing treatable diseases and/or types of malaria, *d* is the diagnosed symptom and/or

species of Plasmodium; and,

  (One-to-one relation), (2.3)

 T = {t1, t2, …, tn}, 

where T is a set containing different therapy strategies, t is a suggested therapy.

*Definition 3:Action*

Action is defined as a composition of a set of atomic tasks. Consider the following action structure:

 A ::= ε | a0 | a1a2 | a1→ a2 | a\* (3.1)

where

(i) ε is the empty action or a standard alone action.

(ii) a0 denotes a finite or countable infinite number of basic actions that needs further construction.

(iii) a1a2, the concatenation of actions a1 and a2 means the action of a1 followed by the action of a2.

(iv) a1 → a2 means that the action of a1 can be replaced by that of a2.

(v) a\* is the complement of the action a.

(vi) | expresses alternative state of the system.

*Definition 4: Optimization*

The purpose of the optimization problem is to evaluate alternative solution according to multiple criteria.

 *max{f1(c)=o1}*

 *max{f2(c)=o2}*

 *…*

 *max{fk(c)=ok}* (4.1)

where *f(c)* is the objective function, *o* is the highest objective function value.

*Definition 5: λ – Contract*

The achievement of the goal pursued by the agent with awareness is sustained by a proof system call λ – Contract.

The idea of contract is borrowed to those related to human activities where there are commonly two parties; a provider, which performs some task for other a client.

The model of contract used is developed in [22]. Thus applying to software agent, a contract leads to the interaction between applications or functions into an application. Ideally, a contract should cover all essential functional and non-functional aspect of an application.

The specification of a contract can contain in general the following pieces of information:

a. Operation semantics describe each operation using: - Informal text, - pre/post condition - invariant

b. Interface protocol provides the constraints on the order in which operations may be called.

c. Service level covers guarantees regarding the qualities or non-functional requirements such as: timing constraints, network availability, data safety for persistent state, capacity, security and performance.

This information can be introduced in one of the following basic element of the contract:

***Request-Response Protocol***

*Data-Field*

*Execution-information*

*Message*

 *Message-client*

 *Message-provider*

***Context***

***Results***

The Request-Response Protocol is transactions divided into two parts, contracted and contractor, one for requests and the other for responses. Transaction data-fields are used for performing two kinds of data-fields: the execution information that controls the execution of the transaction, and the message addressed to the contracted or the contractor. Furthermore, the Request-Response Protocol, in the SA, facilitates easier integration of nun-functional requirement with functional requirement. The Context determines actions performed by the agent. The Result is the achievement of the goal pursued by the agent.

1. Results

We have had the objectives to formalize the design of software agents and to demonstrate their applicability to web-based medical decision support system. This was possible by the prototype that we designed and implemented under the name “OMaT” [23].

The prototype are developed using PHP, XML, HTML, JavaScript and CSS as front end and raw files, MySQL and NoSql Data base as the backend.

The proposed solution, in form of web applications includes a Generic Medical Decision Support System and is expected to assist Healthcare Professionals at medical consultation and decision of the patients with malaria disease. It contains five basic components that constitute the main menu: newCase Agent, openCase Agent, iLaboratory Agent, GIS Agent and Knowledge Repository (KR) Agent.

We describe only the component newCase to point out the use of our model specifically the contract. The component newCase is a succession of sub components namely: newCase1, newCase2, newCase3, and newCase4. The newcase1 allows the HCP to supply first information on the clinical examination. The newcase2 generates a Report of Clinical Diagnosis and allows the HCP to supply secondly information on the laboratory test. The newCase3 generates the Report of Diagnosis, the Report of Symptomatic Report and the Report of Therapy Strategies. Also it allows the HCP to write his own medical prescription based on the reported information. The newCase 4 allows the HCP to download a file in form of Electronic Medical Record (csv format), to print the Medical Decision Report and to receive it in an email.

In the following, we emphasis the use of contract by pseudo code based PHP to illustrate the implementation of different agents acting for the medical decision support.

* 1. Usage Scenario of λ - Contract by the Software Agents

Specification of OMAT System:

OMAT ::= Login → Menu

Menu ::= newCase | openCase | iLab | GIS | KR

newCase ::= newCase1 → newCase2 → newCase3 → newCase4

newCase1 ::= newCase1 | GIS | KR

newCase2 ::= newCase2 | iLab | KR

newCase3 ::= newCase3 | KR

newCase4 ::= storage | print | sendEmail

Where GIS is a Geographic Information System, KR is a Knowledge Repository and iLab is a Remote

***2° Contract to guarantee action of calling another Agent and to express optimization problem***

***newCase2 Agent side:***

* *1. <?*
* *2.* ***# OMAT SYSTEM***
* ***3. # newCase2 AGENT***
* ***4. ## Request-response protocol***
* *5. session\_start(); //Set a self control of the system*
* *6. while(($userNameSystem=$userNameInput) and*
* *7. ($passWordSystem=$passWordInput))*
* *8. { count++; // Try again*
* *9. if ( count>5)*
* *10. { echo "Login Failed!";*
* *11. echo "<script>window.close();</script>";*
* *12. exit;}*
* *13.} endwhile*
* *14. // verify required information posted by newCase1*
* *15. if(empty($\_POST['listOfInputValue']))*
* *16. { // Missing some information*
* *18. $errors = “These values are required:".$listOfValuePost;*
* *19. setcookie('$errors ', $Errors);*
* *20. // Return to newCase1*
* *21. echo "<script>window.location='../newCase1.php'</script>";*
* *22. exit;*
* *23. }*
* *24. …*
* *25. $patientStatus; $signSymptoms;*
* *26.* ***## Context***
* *27. function checkTestSymptom($hypothese) {*
* *28. switch($signSymptoms)*
* *29. {*
* *30. case 1: $hypothese="Uncomplicated Malararia"*
* *31. case 2: $hypothese="Complicated Malararia"*
* *32. case 3: $hypothese="Others diseases"*
* *33. }*
* *34. }*
* *35. function checkTreatSymptom() {*
* *36. switch($patientStatus)*
* *37. { //Following symptoms/signs*
* *39. case 1: $treatSymptom= typeofTreatSymptom1;*
* *38. ...*
* *39. case m: $treatSymptom= typeofTreatSymptomm;*
* *40. }*
* *41. }*
* *42. ...*
* *43. // Input Values in newCase2 form*
* *44. ...*
* *45. // Laboratory test*
* *46. // Possiblity to call iLab*
* *47.* ***## Results***
* *48. // Generates a Clinical Diagnosis Report*
* *49. // Submit data value to newCase3*
* *50. Submit();*
* *51. ...*
* *52. ?>*

***1° Contract to guarantee action of calling another Agent***

***newCase1 Agent side:***

* 1. <?
* 2. # **OMAT SYSTEM**
* **3. # newCase1 AGENT**
* **4. ## Request-response protocol**

5. *session\_start(); //Set a self control of the system*

* *6. while(($userNameSystem=$userNameInput) and*
* *7. ($passWordSystem=$passWordInput))*
* *8. {*
* *9. count++; // Try again*
* *10. if ( count>5)*
* *11. {*
* *12. echo "Login Failed!";*
* *13. echo "<script>window.close();</script>";*
* *14. exit;*
* *15. }*
* *16. } endwhile*
* **17. ## Context**

18. Input Values in newCase1 form

* 19. // Enter Patient Profile Data: Sex, Age, Weight,
* Country, …,
* 20. // Enter Signs/ Symptoms Data
* 21. *…*
* **22. ## Results**
* *23. // Submit data value to newCase2*
* *24. Submit();*
* 25. ...
* 26 ?>
1. Discussion

The Software Agent System is adopted to cope with a complex and dynamic domain such as medicine and particularly the web-based medical decision support system for malaria diagnosis and therapy of the (OMaT) system.

Our clinical decision support system for treatment of malaria is based on consensus guidelines and protocols for the management of malaria. Thus, our system only deals with information theory and medical practice identified in advance, limited and structured so for its efficiency and completeness. This constitutes the knowledge base of the Software Agent.

The proposed functional model facilitated the implementation of the SA. Specifically, the λ – Contract ensures the consistency and the credibility of the reasoning of the Software Agent.

Experiments on a set of test cases were performed. The results observed in our experiments were satisfactory. The system can generate diagnosis based on signs/symptoms and can advice treatment automatically in a real-time.

To demonstrate and to illustrate the application of our functional model, we present two agents: newcase1 agent and newcase2 agent. The newcase1agent allows the HCP to supply first information on the clinical examination. Based on information supply by the newcase1 agent, the newcase2 can analyse it and can generate a Report of Clinical Diagnosis. This will allow the HCP to supply other information for the purpose of the laboratory test.

 The “Contract 1° expresses in line 24 the definition 1 where the newCase1 agent calls the newCase2 agent. The “Contract 2° expresses in lines 6 to 23 the definition 1 where the called newCase2 agent reacts to the call of the newCase1 agent. Also, the “Contract 2° expresses in lines 27 to 40 the definition 2 where the newCase2 agent acts and generates a clinical diagnosis.

Our system uses a request/response protocol in which it can receive information from the user or other agents and can respond or react.

The quality of the system depends on the reliability of the information entered, protection against handling errors and lack of dangerous results. Therefore, the human machine interface that we have proposed is quite responsive and easy to use to facilitate the work. A click allows the user to enter data.

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