A Ubiquitous Intelligent Tutoring System for Aiding Electronic Learning

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Abstract. In the new paradigm of Internet of Things, objects of the daily life will be part of the Web. In order to identify objects or communicate with them, tagging by radio frequency technologies or visual tags are used. The steady growth of mobile devices and increased functionality offered by these, allow them to access information into a tag using a camera or using a simple radio frequency reader. But such tags that identify things have a limited information space, so that the use of fuzzy logic and linguistic variables allow mobile devices to communicate with words compressing the data. This research presents an intelligent tutor that interacts with educational books to customize your self-assessment tasks through tags.

Keywords: Internet of things, NFC, linguistic variables, u-learning.

1 Introduction

The latest research on ubiquitous computing that can be found in the literature, focus on using different technologies to achieve new forms of communication between people and objects [8], as well as between objects only. This is intended to add a new dimension to the definition of ubiquitous computing[10], where information is accessible anytime, anywhere, to any user, but also for any object. This will create a new communications network, which will be dynamic and will consist of objects of everyday life. This new network will be known as the Internet of things.

The large number of mobile devices and wireless technologies are giving the opportunity to develop applications and innovative communications systems. A mobile device can be regarded as an environmental sensor because it has features like GPS location, movement capabilities as an accelerometer, a camera or a radio frequency reader. Although the start of some wireless technologies with mobile devices, its application in the "Internet of Things" will mean an important revolution in computing systems and communication architectures.

Under this concept of the "Internet of Things" is another psychological theory developed in the mid 80's by Edwin Hutchins [4] (1995) and it is known as "distributed cognition". This theory is based on the coordination between individuals and objects, and proposes that human knowledge and cognition are

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not confined to the individual but also on distributed memory spaces, facts, or knowledge of the objects in our environment. The distributed cognition may serve as a learning theory in which knowledge development is the result of a system consisting of the relationship between human agents and objects with which they interact [7].We can find an application example in the systems of distance learning through telematics platforms or other tools of computer-assisted learning. Distributed Cognition illustrates the process of interaction between people and technology, with the aim of determining how to represent, store and provide access to digital resources and other devices.

The distributed cognition makes communication with objects can be understood as the following metaphor [6]: "The data is a physical object". As an example of a metaphor of interaction, one can understand that a mobile device, "ask" or "answer" questions, "help" or "guide" a user, or simply "get information" that interacts with the environment.

Although the technologies for tagging the objects will help to deploy applications in the domain of the "Internet of Things", it is necessary to look for solutions that optimize the use of tags because they have a much reduced space. The theory of fuzzy sets and fuzzy logic can perform computing operations using words. A user can have an intelligent controller in his/her mobile device to communicate with objects inferring linguistic variables with fuzzy rules which are obtained from a tag. For example, a student may be interested in improving their skills in particular learning unit. Through tags in a book and using mobile devices can be improved the performance of a student in a particular subject with customized multimedia resources.

E-learning is one of the most innovative domains that makes use of new technologies in order to improve students' performance and facilitate the cognitive processes that are involved in learning. Through mobile devices and technologies for tagging the objects, it can provide ubiquitous learning solutions (u-Learning), which allow users to interact and communicate with objects. For example, a student who wants to know the name of an object and its meaning in another language, you simply have to take the camera from your mobile device or through a wireless card reader, and then interact with the tags that object. The labels usually save different types of information, such as a URL linking to a resource of an online encyclopedia such as Wikipedia.

In this research it is described a model for the development of ubiquitous applications using radio frequency tags that work with Near Field Communication (NFC) technology. The developed architecture enables mobile devices to communicate with wireless technologies such as NFC tags. In order to develop intelligent applications, taking into account the storage capacity offered by these wireless tags, it is necessary to use fuzzy logic and linguistic variables that allow compress the information. This intelligent tutoring system has a fuzzy inference engine that allow an approximate reasoning to a user from input variables and fuzzy rules that are retrieved from a tag of an object.

This research has the following framework, in section 2 there is a summary about NFC technology under the context of Internet of Things. Section 3

describes the research that is presented in this paper using linguistic variables with fuzzy logic, web services, mobile devices and NFC tags. Section 4 shows an illustrative example where there are code samples. Finally in section 5, the conclusions of this paper are discussed.

2 Internet of Things

Internet is growing and its subsequent evolution is through objects. Its main idea is to keep things interconnected through the Web. In this way objects may have hyperlinks, with which a user can access to multimedia resources that are on the Web. The goal of this research is to interact with objects from mobile devices using the radio frequency technology Near Field Communication (NFC).

2.1 RFID and NFC in Mobile Devices

The radio frequency identification technology (RFID) is implanted in a large number of areas, but probably will have more impact when it would be combined with mobile devices. The use of RFID and NFC technology on mobile devices offers a wide range of applications such as electronic payments, digital distribution strategies or interaction with objects of everyday life.

RFID technology covers a wide range of frequencies within the electromagnetic spectrum. In the case of mobile devices the range is 13.5 MHz, which limits the range at a distance of 3cm or almost a touch. The protocol Near Field Communication (NFC) is a radio frequency wireless streaming technology, which gives the possibility to interact with tags and interact with other devices. To connect two devices must be placed just a few inches away or put them in touch. The NFC protocol allows mobile devices to connect to a peer-to-peer (P2P) network automatically. Once the configuration data have been exchanged between the devices using NFC, then devices can use other technologies such as Bluetooth or Wi-Fi. Another of the advantages of NFC is that energy savings because it can maintain communications in an active way (MA) or a passive mode (MP). In MA, both the sender and the receiver generate a radio frequency field on which can transfer data. In MP mode only one device generates the RF field and the other device uses load modulation to transfer signal information. This enables communication between mobile devices by optimizing the use of their batteries. The information transfer rate is 106, 212, or 424 Kbits/s which should be sufficient for applications where a mobile device needs to communicate with objects.

The RFID/NFC can be implemented by Java ME technology that is supported on the most mobile devices. Therefore RFID/NFC can join the real world with the digital via the Web. With the interaction of a mobile device and a NFC tag, a mobile device might get and share information in a simply way.

3 An Intelligent Tutoring System

This section will describe an intelligent tutoring system [1] in the domain of the Internet of Things and it will use mobile devices for ubiquitous learning.

3.1 A Ubiquitous Learning System

This research presents a ubiquitous intelligent tutoring system aimed at allowing a user to carry out self-assessment at the end of a unit using a mobile device, to enhance their skills in a modern language.

For this reason, students can access to multimedia resources from a mobile device with an Internet connection. They can download customized educational files from the Web to enhance their skills.

To communicate with an object, it is necessary that this has a tag. For example, a book could have different NFC tags (see Figure 1) that might be accessible from a mobile device that has a NFC tag reader. The system can obtain a set of rules from this tag. Then if tags are used as repositories of information is necessary to optimize their storage space. Fuzzy logic with linguistic variables allows the system to compress the information by the granularity. In addition, using the approximate reasoning the mobile device resources are optimized.

Therefore, a user can perform a self-assessment of a lesson, by entering in a mobile device a numeric value between 1 and 100 from a discipline of writing, reading and listening, and speaking. Trough the interaction between the mobile device with a NFC reader and a NFC tag placed in the book, the system retrieves a set of fuzzy rules that serve to infer a result with the data previously entered. This result provides access to multimedia resources on a server via the Internet, which will support to improve the skills of the user on that topic in the disciplines most in need. This process is done through the contact between a mobile device and a book.

The system get a set of fuzzy rules and with input variables which are entered by a user, it will infer a result. Then the system will request to a web service with this result a set of multimedia files in a readable format for a mobile device. The web services can improve the mobility of multimedia resources that students need. The format of retrieved documents is text, audio or video.

3.2 Fuzzy Logic and Linguistic Variables

Are variables whose values are represented by linguistic terms [5,12]. The meaning of these linguistic terms is determined by fuzzy sets [2,11]. The linguistic variables are characterized by a quintuple, (v, T, X, g, m) where:

- v is the name of the variable,
- T is the set of linguistic terms of v,
- X is the universe of discourse of the variable v,
- g is a syntactic rule for generating linguistic terms, and
- m is a semantic rule that assigns to each linguistic term t its meaning $m(t)$, which is a fuzzy set in X.

An example of a linguistic variable is shown in figure 2. Its name, is the level of writing a modern language such as English, and it expresses the level achieved by a student in that subject for that discipline. This variable is defined by five basic linguistic terms {***very low, low, medium, high, very high***}. Each of

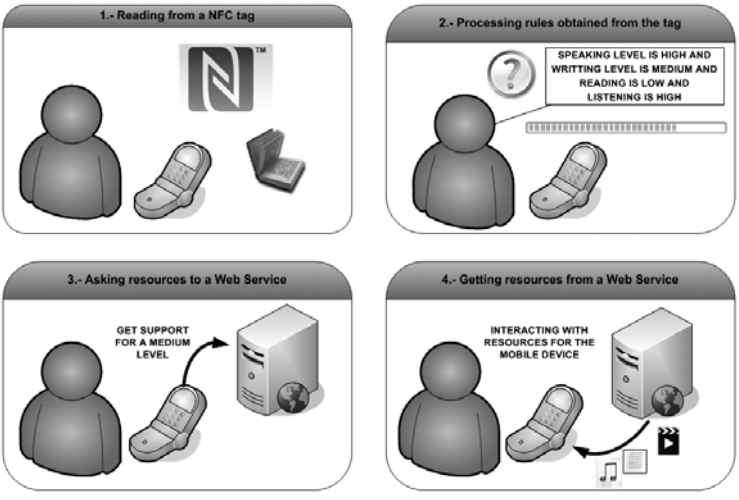

Fig. 1. Process of the ubiquitous intelligent system

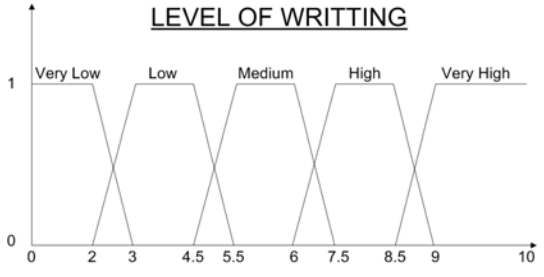

Fig. 2. Example of a linguistic variable in fuzzy logic

these basic linguistic terms are defined in an underlaying domain of knowledge from 0 to 10 that a student can improve in that discipline of a modern language.

Linguistic variables use the granulation to compress information, by including many values in a linguistic label. This is done to optimize the limited space with the labels that have NFC tags.

3.3 A Fuzzy Controller for Mobile Devices

The expert system for mobile devices is an open-source fuzzy inference engine for java, which was developed by Edward Sazonov [9]. It was adapted to Java ME. The inference engine enables the evaluation of fuzzy rules with linguistic variables that are introduced by users. The fuzzy rule base is retrieved from a NFC tag. The fuzzy engine the trapezoidal membership function to represent the most common forms of representation of fuzzy sets: the rectangular function, trapezoidal function and triangular function.

Quantifiers of a fuzzy rule can express different degrees of membership in a fuzzy set. The fuzzy controller defines three quantifiers:

- **"not"**-$X_{not} = 1 - X$
- **"very"**-$X_{very} = X^2$
- **"somewhat"**-$X_{somewhat} = \sqrt{X}$

The linguistic variables, membership functions, quantifiers and fuzzy operators are referenced by their symbolic names, represented by text strings in the following format:

```
<label> if LV1 is <hedge ...> MF1 <and/or LV2 is <hedge ...>
MF2 and/or ...> then LVN is <hedge ...> MFN ...
< and rule label weight is <hedge ...> weightMF>

<label> set LV1 is <hedge ...> MF1 <and LV2 is <hedge ...>
MF2 ...><and rule label weight is <hedge ...> weightMF>
```

- **"label"** defines a text label of a rule. The same label can be assigned to more than one rule.
- **"if"** indicates the start of the evaluation of a fuzzy rule.
- **"LV"** defines a linguistic variable and they are identified by their names. Each linguistic variable has one or more associated membership functions.
- **"is"** is a keyword that separates linguistic variables, linguistic quantifiers and membership functions.
- **"hedge"** this inference engine has three predefined quantifiers, "not", "very" and "somewhat". The user can use with the rules arbitrarily. Example: *if written is not very high ...*
- **"MF"** is a membership function. The membership functions are identified by their names. Each membership function is defined as a trapezoidal function.
- **"and/or"** these keywords indicate the logical operations that will be made in fuzzy expressions.
- **"then"** is a reserved word that separates antecedents from consequents of a fuzzy rule. Example: *... then support is very low.*
- **"rule"** is a reserved word that indicates the weight of a rule, and it can be modified in the expression. Example: *... then start rule: speaking is low ...*
- **"weight"** is a reserved word whose purpose is to change the weight of the rule.
- **"set"** is a reserved word for unconditional assignments.

3.4 An Architecture for Interacting with Objects

The architecture defined for NFC tags (see Figure 3) is divided into the following components:

- A **tag reader** that establish communications with radio frequency tags. From these tags are obtained a set of fuzzy rules. The fuzzy rules are stored as a xml file.

– A **fuzzy controller** to infer a result using the linguistic variables that are introduced by a user and the fuzzy rules retrieved from an NFC tag.
– A friendly **graphical user interface** for interacting between a user and a mobile device.

Fig. 3. Architecture for interacting with objects

This simple architecture allows the development of ubiquitous applications that are accessed from a mobile device with an NFC tag reader.

4 An Illustrative Example

Having seen the technologies that are used in this intelligent system, this section shows an example of how to implement this research.

Students will use the NFC tags in textbooks to improve their skills. A book could have NFC tags with relevant information about speaking, writing, reading and listening skills using fuzzy rules. The NFC tag will contain a set of fuzzy rules as shown in Table 1, and an identifier for each unit of a book to link with several multimedia resources.

A NFC card can use a markup language as XML for data format. This file will be processed in a simple way. To process the XML file is used the *k*XML parser for Java ME technology.

Table 1. Example of the rule base for improving in a modern language

IF				THEN
SPEAKING	WRITTEN	READING	LISTENING	SUPPORT
Low	Low	Low	Low	High
Low	High	High	Low	Medium
Medium	High	High	Medium	Low
Medium	Low	Low	Medium	High
High	High	High	High	Low
High	Low	Low	High	High

```
<?xml version="1.0" encoding="UTF-8"?>
<NFC>
<id>1039</id>
<rules>
<rule id="1">If Speaking is Low and Written is Low and Reading is Low and
 Listening is Low then Support is High</rule>
<rule id="2">If Speaking is Low and Written is High and Reading is High and
 Listening is Low then Support is Medium</rule>
<rule id="3">If Speaking is Medium and Written is Low and Reading is Low and
 Listening is Medium then Support is High</rule>
<rule id="4">If Speaking is Medium and Written is Low and Reading is Low and
 Listening is Medium then Support is High</rule>
<rule id="5">If Speaking is High and Written is Low and Reading is Low and
 Listening is Low then Support is High</rule>
<rule id="6">If Speaking is High and Written is High and Reading is High and
 Listening is High then Support is Low</rule>
...
</rules>
</NFC>
```

To implement the fuzzy controller is necessary to define the linguistic variables with the underlying numerical domain. Having defined the linguistic labels in the system, fuzzy rules are introduced in the application which have been obtained from the NFC tag. The following code shows an example:

```
// Create Lingustic variables and define membership functions
LinguisticVariable spoken = new LinguisticVariable("speaking");
spoken.add("high",7.5,8,8.5,10);
spoken.add("medium",4.5,5,6,8);
spoken.add("low",0,0,4,5);
LinguisticVariable written = new LinguisticVariable("written");
written.add("high",7.5,8,8.5,10);
written.add("medium",4.5,5,6,8);
written.add("low",0,0,4,5);
LinguisticVariable reading = new LinguisticVariable("reading");
reading.add("high",7.5,8,8.5,10);
reading.add("medium",4.5,5,6,8);
reading.add("low",0,0,4,5);
LinguisticVariable reading = new LinguisticVariable("listening");
reading.add("high",7.5,8,8.5,10);
reading.add("medium",4.5,5,6,8);
reading.add("low",0,0,4,5);
LinguisticVariable support = new LinguisticVariable("support");
support.add("high",7.5,8,8.5,10);
support.add("medium",4.5,5,6,8);
support.add("low",0,0,4,5);
// Create a fuzzy engine
fuzzyEngine = new FuzzyEngine();
// Register all Linguistic Variables
fuzzyEngine.register(speaking);
fuzzyEngine.register(written);
fuzzyEngine.register(reading);
fuzzyEngine.register(listening);
fuzzyEngine.register(support);
// Create a block of rules
String rule="if speaking is medium and written is high and reading is low";
rule+="and listening is medium then support is medium";
fuzzyBlockOfRules = new FuzzyBlockOfRules(rule);
// Register the block
fuzzyEngine.register(fuzzyBlockOfRules);
// Parse the rules
fuzzyBlockOfRules.parseBlock();
// Perform the evaluation
fuzzyBlockOfRules.evaluateBlock(); // faster execution
// Obtain the result
double result = support.defuzzify();
```

Then a user can introduce ratings about his/her skills in a modern language through a mobile device. The interaction with the device will be easy for the user. Once a result is inferred, a request to a web service via the Internet to get personalized multimedia resources. The REST [3] architectural style is ideal for deploying the Web service, because it is based on the principle of "hyperlink" to digital resources via URIs. To process the XML document the system uses the library *k*XML and it is used the library MMAPI for managing multimedia files in Java ME with mobile devices. Figure 4 shows a screenshot of the system.

Fig. 4. Example of the interaction between the user and the system

5 Conclusions

This research made possible to carry out a ubiquitous application for interacting with objects of the environment in an intelligent way. The ubiquitous intelligent system has been implemented under the electronic learning domain, which is one of the most innovative domains technologically. The following are the conclusions of this research:

- The NFC tags are suitable for use as repositories of information despite their limited space. For this reason, fuzzy logic and linguistic variables are an important tool to optimize the storage space of the tags. With NFC tags a student can interact with objects such as a textbook. Nfc labels as a complement to the Internet, support for developing intelligent mobile applications.
- In addition,fuzzy logic allows the development of cognitive systems through approximate reasoning, which allows working with devices that have limited features such as mobile devices.
- A Mobile device applied to e-learning is becoming more used because it can bring an expert system that simulates an intelligent tutor and it helps students to assess the difficulty of contents. A mobile device can recommend multimedia resources that are on the web to improve students skills.

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