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PICTAC: A Model for Perceiving Touch Interaction through Tagging Context

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Abstract: A natural interface is one of three key technologies of Ambient Intelligence (AmI); one of its main objectives is to minimize the user's interactive effort, which is the difficulty level that depends on the diversity and quantity of devices that surround people in existing environments. The worldwide penetration of mobile phones at present makes mobile phones excellent devices for delivering new services to users without requiring learning effort. An NFC-enabled mobile phone will allow a user to demand and obtain services by touching its different elements in a given smart environment. In this paper, we present a proposal in which we analyze the scope of touch interaction and develop a perceived touch interaction through tagging context (PICTAC) model.

Keywords: Ubiquitous Computing, Context Aware, Touch Interaction, Tagging Context
Categories: F.1.1, H.1, H.1.1, H.1.2, H.5, H.5.2

1 Introduction

Proponents of Ambient Intelligence (AmI) [Aarts et al., 1999], which has evolved out of ubiquitous computing [Weiser, 1991], propose a new way of thinking about computers according to which computers disappear in their environments, meaning that a computer that perceives and responds automatically to the presence of people creates a *smart environment*.

The AmI paradigm visualizes environmental management through applications that continuously perceive the characteristics of the entities that comprise it and the natural interaction between them. These applications must provide services either proactively or with the smallest possible interactive effort. Another characteristic of this type of environment is that even with a strong technology, it is “invisible” to people insofar as it is embedded in daily objects in the environment.

The final objective of a smart environment is to satisfy user needs by providing services that require minimum interactive effort from them (i.e., the ideal service is one that the user receives without explicitly demanding it).

To reach this goal, a smart environment must be able to perceive all interaction techniques that people can presumably develop. Of these methods, the interaction of contact (or touch interaction) represents an opportunity area, justifying the design of a system that perceives. This interaction technique is simple, requires minimal effort and is part of the natural reactions of people when they want to use an element of the environment, assuming it is within reach. That is, if the device we want to use is near, we say we “touched” it.

Touch interaction can replace complex techniques and even intricate learning processes, such as sending a photo to a new device or printing a document on a printer that has never been used. Touch interaction can also allow an older person to be able to request a meal merely by touching a picture of it. This feature and its ease of use by older people should be excellent in addressing certain current issues, such as dependency or ambient assisted living.

Besides being a simple technique with respect to interaction between persons or between a person and an environmental element, it may allow a large flow of information, which would represent a significant enhancement in a smart environment.

A system that perceives and administers an environment’s touch interaction will be able to offer services to users beyond their wildest imaginations and, moreover, will be fundamental to the construction of the ideal smart environment.

Our work thus proposes touch interaction, which can be used to demand services when interacting with environmental elements or entities. According to our proposal, after perceiving this interaction, the application that manages this environment will be able to obtain information on the entities involved that, when properly combined with the information in the application’s databases, will enable services to be delivered.

In the next section, we present a summary of related work. In section 3, we describe some aspects related to the environment and the elements that compose it. We present the elements of a *perceive touch interaction through tagging context* (PICTAC) model, the relationship between the model and real-life technology, the visualization of model and the relations among its elements. Finally, conclusions in section 8 concludes the paper .

2 Related Work

We have developed projects with different sensorial technologies separately [Bravo et al., 2005] [Bravo et al., 2006] and in combination [Chavira et al., 2007]. Currently, we are focusing our efforts on NFC technology.

A variety of projects have designed and implemented services through NFC-enabled mobile phones. A common feature of most of these studies is that the tag’s content is only one service or one action, a concept known as “one tag, one service”. This means that tag memory, which could be used to store the context and several services, is wasted.

Physical browsing is an "interaction paradigm of touching the tag with the device to activate the hyperlink which emulates the traditional hyperlink invocation mechanism of clicking" [Kindberg, 2002]. The key aspect of physical browsing is physical selection, which refers to the way in which the user selects the entity from the environment with which it will interact. This physical selection (or interaction technique) can be carried out on TouchMe, PointMe, ScanMe and NotifyMe [Välkkynen, 2007]. The technologies used to carry out physical selection include Infrared, RFID, NFC, WPAN and visual codes.

The MULTITAG project proposes a "touch & interact" interaction technique in which a combination of a conventional touch screen, a NFC-enabled mobile phone and a conventional display that is controlled remotely with a mobile phone provide alternative solutions that can be used to overcome mobile technology's limited visual output capabilities [Hardy et al., 2008].

In the MoreLab Research Group's Touch2 project, three services were developed for NFC-enabled mobile phones, namely, Touch2Open (i.e., electronic door key), Touch2Launch (i.e., virtual post-it) and Touch2Print (i.e., for printing documents) [López-de-Ipiña et al., 2007]. The services are independent of one another, and each one requires different programs to be installed in the mobile, and so each tag can only contain one of the services. These three services were based on the current NFC application domain taxonomy published by the NFC Forum and summarized as a) service initiation and configuration, b) P2P data sharing and communication and c) payment and ticketing.

3 Environmental Considerations

The model we propose would endow an environment with the capability of perceiving touch interaction, which we define as the intentional approach of two entities to obtain a service. This implies that when an entity approaches another one, a touch interaction arises. The objective of this model is limited to touch interaction, which involves only two elements, of which one is a person. This is the reason why touch interaction, as it concerns us, is defined as *a person's deliberate touching of an environmental entity, where the latter can be another person, for the purpose of obtaining services*.

Context is any information that can be used to characterize the situation of an entity, which may be a person, user, object, place or application [Dey, 2000]. Owing to the fact that we are interested only in a specific interaction technique between a person and an environmental element or another person, we define the context limited to touch interaction as *any information on the involved entities that is required to deliver the services offered through touch interaction*.

3.1 Entities

The objective of PICTAC is to develop a system that manages the touch interactions in an environment that includes at least one person. This is the reason why a so-called "entity application" will not be considered by us.

Because the capacity to participate in a touch interaction that is perceived by the environment is not related a person's natural ability and because a system must take into account a person, their data must be previously captured. If we attribute these capabilities to the person entity, we create the *User* entity as used in our model.

An object entity is too general for the purpose of the model. From the standpoint of the provided service, we can distinguish two categories of objects, namely, *devices*, where service can be demanded through a touch interaction (i.e., electronic or computer equipment) and *objects*, where service is not suitable or cannot be demanded through touch interaction (e.g., a desk, furniture). However, in the case of the latter, through their location and continued use, we can take advantage of objects in the model we are proposing and use them to offer services. This is the reason why we have broken down the object category into two types of entity, namely, object and device. It must be remembered that an object does not even have the capacity to process and communicate, which is the reason why any capacities that it may have depend both on the available computer device to allow it to participate in a touch interaction and on the user's capacities.

Place is an entity that allows us to represent a part of a smart environment or even the entire environment because it has the capacity for self-inclusion such that the place may contain entities (or even another place). Nevertheless, while a user has the capacity to reject the service offered by a place, places must be considered because upon touching the place, a user may be provided with a service regardless. In fact, entering (and thus touching) the smart environment may even occur through the opening of the door. A summary and comparison of PICTAC and Dey entities is shown in Table 1.

Entities	**Adaptation**	**PICTAC Model**	
		Entities	**Description**
Person User	Only the person or equipment is considered	**User**	Person with the capacity to participate in a touch interaction
Object	There are two types of objects, depending on the form of the services	**Object**	Those that offer a service that is not "suitable" or cannot be requested through touch
		Device	The service can be demanded through a touch interaction
Place	The same	**Place**	Represents a part of a smart environment or even the entire environment
Application	Not relevant for our purposes.	Not used	

Table 1: Comparison of PICTAC and Entities Presented in Dey [Dey, 2000]

Whenever a user touches any of the four entities described above, it will generate one of the four classes of touch interaction managed by PICTAC, namely, user-place, user-device, user-object and user-user, as shown in Figure 1.

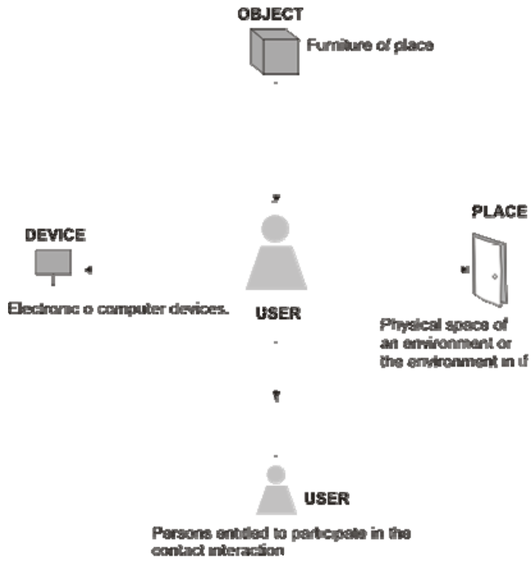

Figure 1: The Four Classes of Touch Interaction in the PICTAC Model

4 The PICTAC Model

The objective of the model that we propose is to develop a system that endows the environment with the capacity to perceive touch interaction using the *tagging context*, which we define in section 4.2.

The model consists of three parts, namely, the properties required of the environment, tagging context and the services that can be offered.

4.1 Environmental Requirements

The PICTAC Model is designed such that the system developed can easily integrate with other applications in a smart environment, or the system can be the only one of its type operating in the environment. To develop a system that can manage touch interaction and maximize the use of the information flow generated for the delivery of services, the environment must have two infrastructures.

1. Processing and storage. These are considered together so that they can be offered by one technology. Both are necessary to process certain services and contain context.
2. Communication. This connects the devices that control the entities through processing and storing.

Although these capacities are essential to the development of the environment that manages the touch interaction, we believe that they almost certainly exist in any environment in which an application of this type would be developed. This is partly due to the fact that the majority of workplaces have them. In addition, touch interaction is ideal for operating electronic and computer devices in today's workplaces.

Both infrastructures comprise the common technology level, which is shared by all applications that make up the ideal smart environment.

4.2 Tagging Context

If tagging involves putting a tag on something and context is any information regarding entities, then *tagging context* could sound incongruous, as it is difficult to label something intangible as context. Thus, the goal of using this paradoxical terminology is to emphasize this concept.

Tagging is necessary for two reasons. First, we must indicate the place where the entity must be touched, and second, we must endow the entity with the capacity to perceive another entity's touch.

The word "context" is used because we endow entities with data needed to deliver the services initiated by touch interaction.

Tagging context requires generic properties in order to be developed, including the perception of touch, the containment of information, processing and communication. These capabilities are provided by different properties, of which all or some of them are endowed to the entities. We define the tagging context as *the endowment of the environment's entities with the necessary properties (including context) to participate in the touch interaction perceived by a system.*

Two properties are necessary to perceive a touch interaction, namely, contact and identification. Because the user initiates the touch, the user must have contact capability. Contact is thus is a way of distinguishing the roles performed by each of the entities that are capable of touch. Identification capability is endowed to other, non-user entities that are responsible for responding to the touch made by the user. In other words, the entity that is touched is the one that identifies the user and then responds to the touch.

For an entity to contain information, it requires memory capability. Although our model focuses primarily on data, memory capability is implicit and necessary. The data have two properties, namely, context and services references.

Context is the information needed to deliver the service and can be of two types, that is, the context limited to the touch interaction, which is the information about the entities involved in the interaction, and the environmental context. The first is included in the same entities as those involved in interaction, and the second is included in the environmental infrastructure.

To deliver a service, some information must be processed. Because such processing could be carried out by a range of entities (that is, the user, the environment infrastructure or a device with processing capability), we decided that instead endowing the entity that is touched with all necessary instructions for processing the data, this entity will contain the necessary *services references*. The services references include all information necessary to process and deliver a given service to the user.

To process the services references, a processing capability is necessary in either the user, the entity that is touched or the environmental infrastructure.

Although we originally hoped that the user and the entity involved in a touch interaction would contain the necessary information for delivering the services, this would be impossible to achieve for all potential services. In other words, it is impractical to save all necessary information in the two entities. Therefore, the user must be augmented with the ability to communicate with other devices in the environment, particularly with those that contain service information. This means that the user must be linked with the environmental infrastructure. In the following table, we have summarized the properties of the concept of tagging context.

Tagging Context Properties	
Contact	Because the user initiates the touch, the user must have contact capacity to carry out the touch interaction.
Identification	This capability is given to other non-user entities, which are responsible for responding to a touch initiated by the user.
Context	This can take one of two types, namely, context limited to the touch interaction, which is the information specifically about the entities involved in the interaction, or environmental context.
Services references	Services references are used so that all information about services need not be stored in the touched entities.
Memory	Although our model focuses primarily on data, a memory capability is implicit and necessary.
Processing	This property processes the services references.
Communication	This links together the entities involved in a touch with the environmental infrastructure.

Table 2: Summary of Tagging Context Properties

4.3 Services

The reason that any device or object appears in an environment is to offer users, as a minimum, an intrinsic service. In order to obtain the service, the user must interact with the object. The object of PICTAC is to offer services from environmental elements by means of touch interaction and, through these services, to deliver others services in implicitly.

The classification established for services is based on the manner in which their execution is originated or the user that has put them. Intrinsic services of the elements in the environment (which can be intrinsic to the item or established by the system) are the *default services* that are received by the user who touches. *Implicit services* are those that accompany intrinsic services and can be received either by the user who touches or other related users. *Optional services* are those created by the PICTAC system that can be received by any user and put in any entity. Table 3 provides a summary of the characteristics of each of these service categories.

4.3.1 Default Services

All of the environmental elements with which people are surrounded have at least one function (or main use) for which they were designed. The model that we propose is designed so that such use or service will be delivered to the user upon touching the entity. These services are called default services and are delivered to the user automatically whenever the user touches an element.

In a device, the default service is intrinsic to it and is easily identifiable (e.g., the printing of the printer or the display of the monitor).

In an object, default services do not exist because they are not inherently associated with any services that can be obtained through touch interaction (e.g., the desk). An object only contains optional services.

In a place entity, the ideal default service that the user would expect is the opening of a door, but the implementation of this service depends on the available technology; however, touching a place is essential for the user to "enter" or "exit" the application that manages the touch interaction, and should the user fail to enter or ext, it may not receive the desired service.

4.3.2 Implicit Services

The availability of these services is one of the benefits of implementing a PICTAC system. When a system has just been installed (and at other times as well), these services may not be explicitly known by the user who carries out the touch. In other words, they are services under or attached to the default services.

Implicit services are developed to take advantage of the information flow that is generated when a default service is demanded and can be delivered automatically.

All services that are received either directly or indirectly by the related entities and the entities that participate in touch interaction and/or are in the place where touch interaction is carried out constitute implicit services.

Notifications to related users that a user has arrived at a place or comment notifications to users generated automatically by the system or by other users are examples of implicit service.

4.3.3 Optional Services

These services are endowed to entities by the users depending on user requirements; they were developed to take advantage of foreseeable issues that may arise from the daily use of environmental entities.

These services allow elements that do not have an intrinsic service (i.e., the objects) to be regarded as part of the PICTAC system and thus offer services upon touch.

These services thus can be placed in any type of entity, the use of which can be considered structured. For example, when a user reaches its workplace, the user will first touch the door of the building before entering the office; that is, a user visiting to the office must touch the door. Thus, optional services can be placed in the entities to take advantage of such use.

Another example of an optional service is to leave a message for any user (or a specific user) on the door of a building, its desktop or any entity that we can be certain will be touched by a user with which we wish to communicate. We can also, for example, leave a note for a specific user that visits our office in our absence.

PICTAC Services	
Default	Intrinsic services of entities
Implicit	Services that accompany default services
Optional	Services endowed by users to entities that do not have intrinsic services

Table 3: Description of PICTAC services

4.4 Information Flow

Whenever a user touches an entity (i.e., place, object, device or user) an information flow takes place between three PICTAC system components, namely, the user who touches, the entity that is touched and the environmental infrastructure.

Although information flows are similar, the flow in which the user touches the user is distinct in that the goal of this interaction is to offer services in which the environmental infrastructure is not involved. That is, the services offered depend solely on the users participating in the touch interaction, and the services will be offered only to them.

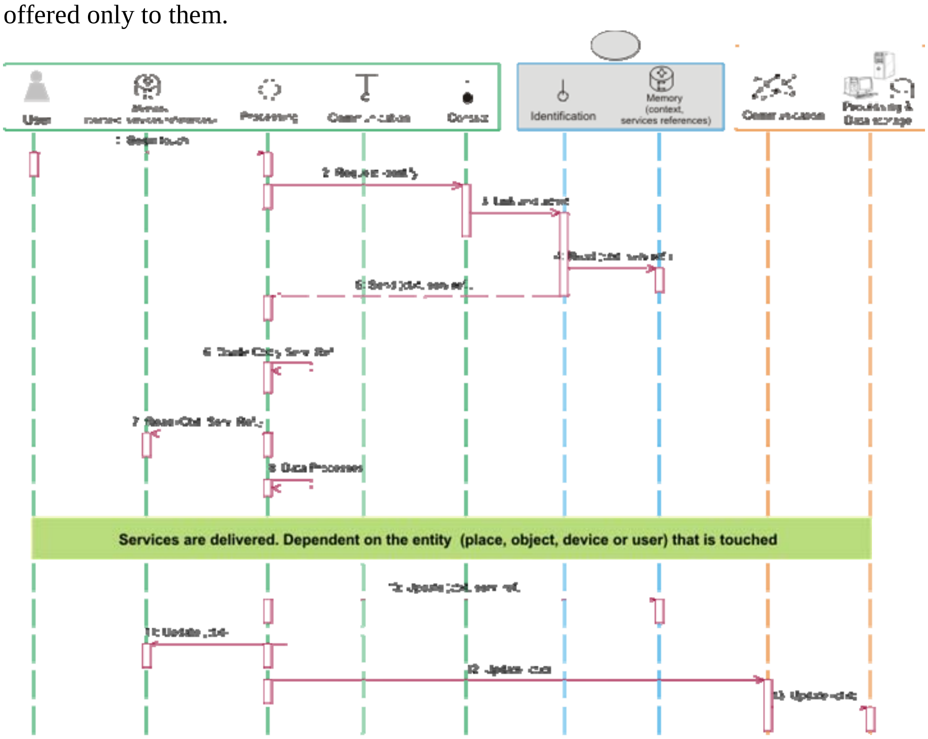

Figure 2: PICTAC Model Information Flow

Whenever the user touches a place, a device or an object, the resulting information flow processes can be divided into three sections. As shown in Figure 2, the first and last types of flows will the same for any of the three interactions (user-place, user-device and user-object), and the second type of flow will depend on the entity that is touched.

When a user touches an entity to obtain services, the first action to be carried out in the contact is the identification and acceptance of the link between the entities. Then the entity that has been touched must deliver the context and references to the stored services, which it will then transmit via its link to the user that has touched the entity. Upon receiving the user-entity information (or its processing property), the entity must process it together with the context and services references that the user carries. After processing, the entity must retain the context and the services references specifically relevant to the interaction.

In the second type of flow (see Figure 2), the services originated by the touch interaction are processed and delivered.

Finally, in the third type of flow (see Figure 2), the context and services references (i.e., the user who touches, the entity that is touched and the environmental structure) are updated.

5 The Relationship between the Model and Technology

The first method used to validate the PICTAC model is to establish a relationship between its properties (see Table 2) and the existing technologies with which the model could be implemented. As some of these properties are related, in this section we decided to consider them according two cases, namely, contact-identification and memory-context-services references. The four categories of the model-technology relationship are explained below.

5.1 Contact-Identification

Automatic identification technologies make it possible to provide environmental elements with contact and identification capabilities. Some of these technologies (e.g., voice, OCR and biometrics) are irrelevant to this model, which is why we decided to analyze only Barcode, Radio Frequency Identification (RFID) and Near Field Communication (NFC).

Barcode technology has contact and identification properties, meaning that it can be used to add these properties to an entity that could be used in a contact interaction.

RFID technology allows two properties (Identification-contact and memory)to be added to the entities and does not even require any interactive user effort because touch is detected as users approach. Unfortunately, the technology’s cost and instability make it an unattractive option.

Near Field Communication (NFC) technology can establish a link when an initiator-reader is within two inches or less of a tag. This short distance gives the impression that the user is touching the tag. Thus, NFC is appropriate for providing these capabilities to entities.

5.2 Memory-Context-Services References

The memory property is essential for storing information in our model because this information contains two key properties, namely, context and services references.

It is important to mention that although technologies exist that by themselves do not provide these properties, they could be embedded in a device that has them. This is why a technology cannot be discarded merely on the basis of it not having these properties. This is also why devices must be examined with respect to whether it is possible to embed these properties. Another important feature is that memory must be re-writeable because context is constantly changing.

The barcode is not an appropriate technology for memory storage because modifying and then saving different information in a barcode is not possible.

RFID and NFC technologies have the memory property by default in the tag.

5.3 Processing

This property must be obtained from the device (or another computational device that controls it) in which the technologies that provide the other properties are embedded.

Processing power determines the complexity of the services that can be offered independent of the environmental structure's processing power.

5.4 Communication

As in the case of processing property, communication must be provided by technologies that are embedded in gadgets that provide other properties. To meet this requirement we considered Bluetooth and Wi-Fi. The major drawback of Bluetooth is that each connection requires user participation, whereas Wi-Fi technology only requires an initial configuration.

In Table 4, we present a summary of the analysis given in the four previous sections, which shows that none of the technologies considered has processing properties (column P in table), which is required of the user' equipment In addition, the appropriate communication properties (column C in table) are only available from WiFi and Bluetooth technologies.

Reading a barcode can identify one entity of environment, but it cannot provide memory because it cannot be modified, so this technology cannot be used.

RFID technology is a good option for implementing the PICTAC system, as it provides memory, identification and contact properties; unfortunately, costs make the technology unaffordable, although certain trends indicate that costs will fall. If this becomes the case, it will be possible to reconsider this option.

NFC technology is an excellent option for the PICTAM system, as it provides two of the four categories of properties, namely, contact-identification and memory-context-services references. In addition, it can be embedded in a gadget such as a NFC-enabled cell phone, which may include additional memory, processing and, if it has Bluetooth, communication. NFC Technology can also address the drawbacks associated with Bluetooth technology, as it enables an automatic link via Bluetooth.

	Properties				
Technology	I	M	P	C	Interaction technique
Barcode	✓	×	×	×	Touch
Passive RIFD	✓	✓	×	×	Not necessary
Active RFID	✓	✓	×	×	Not necessary
NFC	✓	✓	×	×	Touch
Bluetooth ≈ ZigBee	✓	×	×	✓	Not necessary
Wi-Fi	✓	×	×	✓	Not necessary
Infrared	✓	×	×	×	Movement

I=Identification/Contact M=Memory/Context/Services References
P=Processing C=Communication

Table 4: Property-Technology Relationship

6 PICTAC Visualization

To formalize the relationships and elements that have been explained in previous sections that comprise the PICTAC model, we use UML class diagrams.

In the conceptual PICTAC model shown in Figure 3, the largest element is the smart environment that contains the PICTAC system, the normal environment, the communications infrastructure, processing, data storage, context and intelligent interfaces.

The intelligent interfaces are those involved in user interaction with environmental elements. The environmental elements include objects, places and devices, which together with the user comprise the PICTAC model entities.

When tagging entities, we add capacities associated with participating in a touch interaction perceived by the PICTAC system, which may include contact, identification, memory (which contains the context and services references), communication (to link with the environment's communication network infrastructure) and processing.

A system that perceives touch interaction through tagging context consists of tagging entities in which a user touches the tagging entity for the purpose of obtaining services. This contact is perceived through properties that obtain and process the data necessary to deliver the service. This information and processing property may be contained in gadgets that can deliver services without needing the environmental infrastructure. However, the quality and quantity of these services depend on the technical characteristics of the technologies used to provide the properties. Within a communications infrastructure, processing and data storage are essential if the goal is for the PICTAC system is to form part of an intelligent environment.

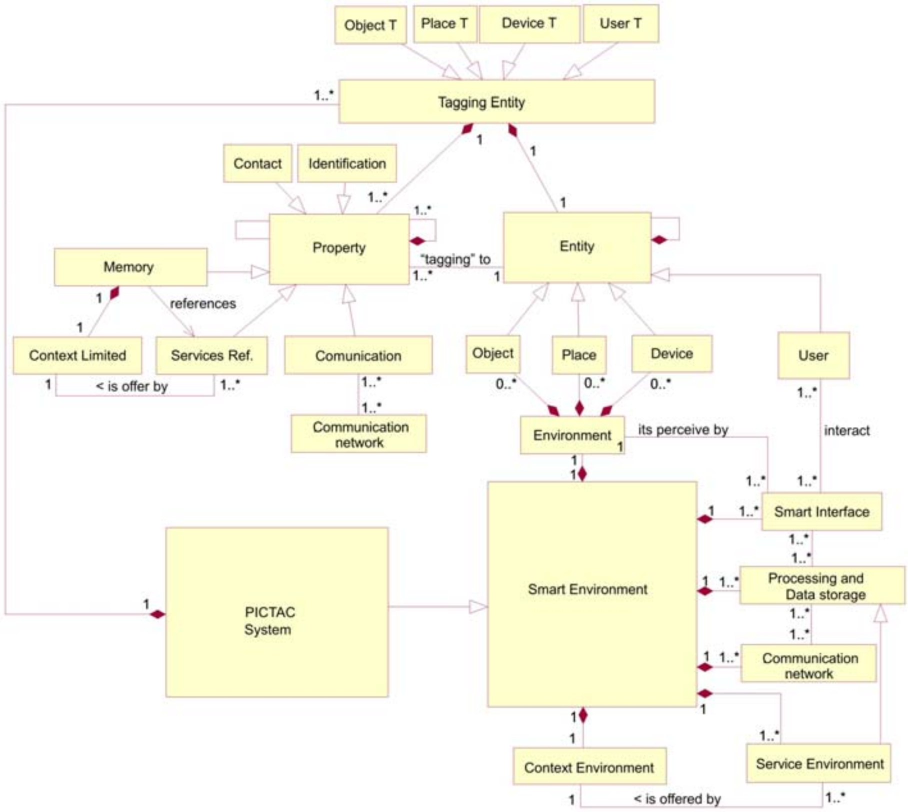

Figure 3: UML Description of the PICTAC Model.

7 Technological Suitability of the Model

To adapt the PICTAC model to combine different technologies for its implementation, we divided it into two main areas, namely, the tagging context and the infrastructure environment.

The technology already associated with the gadget used to implement the tagging context endows entities with the properties necessary to participate in the touch interaction perceived by the PICTAC system, including contact, identification, memory (which contains the context and services references), processing and communication.

NFC technology is embedded in mobile phones through two gadgets, namely, a NFC-enabled mobile phone and NFC-tag. Together, they offer all properties mentioned in the previous paragraph. NFC technology provides contact, identification and memory properties, and cell phones also offer different communication alternatives (i.e., some models have Bluetooth, GSM, SMS, MMS, XHTML, SMTP, POP3, IMAP4 EGPRS and/or GPRS), processing and a large memory up to 2 Gb.

The PICTAC model uses the computer technology (and its respective communication, processing and storage properties) that can be found in most workplaces. This is the so-called “infrastructure environment” that is established as a requirement for environmental infrastructure in the PICTAC. This component is divided into two parts, namely, processing-storage and communication.

The communication component allows entities to link with processing and storage infrastructure in the environment. This property is satisfied by installing WiFi in the all places and LAN in the computer devices that control object, devices and places.

Processing and storage are offered by computer devices that control objects, devices and places. They also take on the function of a so-called “services server” by processing some services and containing the context.

Figure 4 show the tagging context as a blue circle that surrounds all entities with its properties. The color green represents the communication that envelops the devices in order to connect them with processing and storage infrastructure.

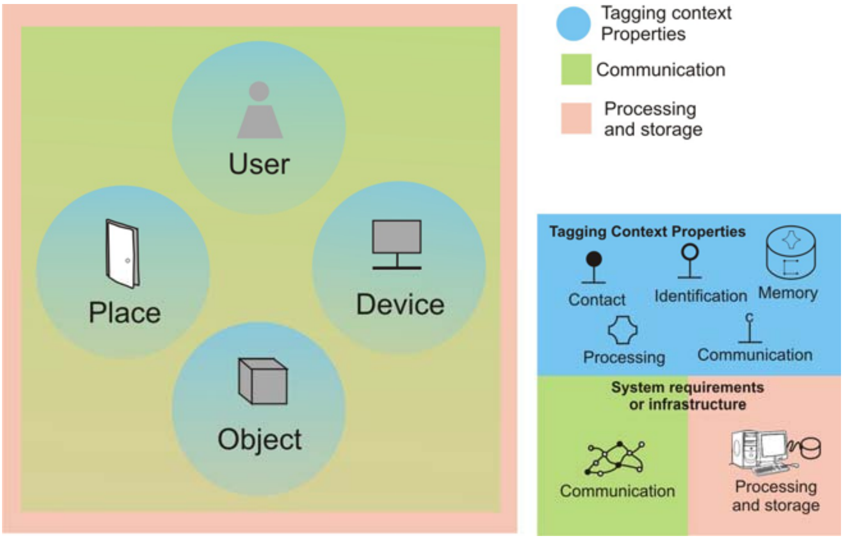

Figure 4: Technological Components of the PICTAC Model

8 Conclusions

The investigation conducted here was made possible by various technological innovations that are currently available; however, technology itself does not necessarily take into account the innovative uses addressed by our research.

When implementing a managed system with the PICTAC mode, note that touch interaction benefits not only the user involved in the touch interaction but also all users of a smart environment.

NFC technology is an excellent tool to provide services through touch contact, with the real prospect of easier integration with the environmental infrastructure (owing to the fact that an NFC mobile with WiFi is being developed).

The incorporation of contextual information in the tag and the offer of various services is the main difference between our research and that of others working with NFC technology.

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