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RFID driven Situation-awareness on *TangiSense*, a table interacting with tangible objects

Sébastien Kubicki, Sophie Lepreux, Christophe Kolski

Univ Lille Nord de France, F-59000 Lille, France,

UVHC, LAMIH, F-59313 Valenciennes, France,

CNRS, FRE 3304, F-59313 Valenciennes, France

{firstname.Surname}@univ-valenciennes.fr

Abstract: Interactive tables are increasingly present not only in a research context but also in everyday life. One challenge still has to be taken up concerning interaction with several people around an interactive table. The framework of our research relates to an interactive table named TangiSense which is equipped with RFID technology. The interaction is no longer the result of touching the table, but comes from handling tangible objects placed on the table. The use is closer to the natural use of a table. This technology makes it possible to identify the objects, which can be coupled with the users. Starting from this principle, the article proposes the use of RFID tags to collect the elements of context-awareness in order to adapt the workspaces to the various possible situations around a table (work alone or with several users, on a common or individual space). An algorithm of space division is proposed and evaluations are carried out in order to assess its global contribution. The article ends with a conclusion and some prospects.

Keywords: RFID, table, situation awareness, tangible interactions, user-driven applications

Introduction

Contactless technologies appeared a few years ago in everyday life. They are tools and input/output devices which can communicate without a physical link, for instance, the multimedia data exchange between one mobile phone and another one using Bluetooth technology. Beyond data exchange, Radio Frequency IDentification (RFID) makes it possible to identify or track objects [11]. The RFID technology involves *reader-tags* (also known as interrogators), and *tags* (also known as labels). The RFID tags have electronic chips which store and process information and are linked to an antenna. The reader-tag is generally connected to a computer. Communication between the electronic component and the reader-tag is established by radio waves, the opposite of the barcode with the use of an optical reader. The barcode enables the identification of a product family whereas RFID allows the identification of a tagged object. Moreover, RFID tags can be read over a short distance and concurrently. Many tags can be read at the same time by a reader-tag.

There are several types of RFID tag: passive, active or semi-active [11]. Passive RFID tags have no internal power supply. They use the energy of the radio frequency signal that the reader-tag propagates over a small distance in order to broadcast their identification code (i.e. the Security Identifier SID) and possibly additional data. These tags can have a data capacity of several hundred bits. In general, RFID tags are initially empty and can be initialized with data which cannot be modified. These tags cost less than others and, because of the lack of an onboard power supply, they are quite small (from the size of a postage stamp to the size of a postcard) and have a long life. Active or semi-active tags have a battery. They transmit at higher power levels than passive tags, allowing them to be more effective in 'RF challenged' environments or over longer distances (hundreds of meters). They allow the reading and writing of data. Semi-active tags do not use the power to transmit the information but only to treat the data during use/displacement, etc.

This technology is now commonly used in the fields of transportation & logistics in order to “track” objects, in hospitals to track patients, in superstores for inventory management, in the agricultural area to provide traceability, in passports, in museums, in the field of sports, etc.

Since the first proposals in the 90's, interactive tables have become an active domain of research and development: some specialized conferences are dedicated to these interactive surfaces (in particular: IEEE International Workshop on Horizontal Interactive Human-Computer [12], ACM Interactive Tabletops [31], ACM International Conference on Interactive Tabletops and Surfaces [19]); in parallel many studies concern tangible user interfaces (TUI) and objects ([15],[4],[32]). In this article, we are interested in the contribution of this technology within the framework of new interactive tables, making it possible to work in an isolated way as well as in collective contexts, either requiring collaboration or not. In this case, the users can handle tangible objects equipped with RFID tags. They can thus interact and work on new applications using the tangible objects (e.g. production tasks, collaborative design, collaborative games, etc.) (Figure 1).

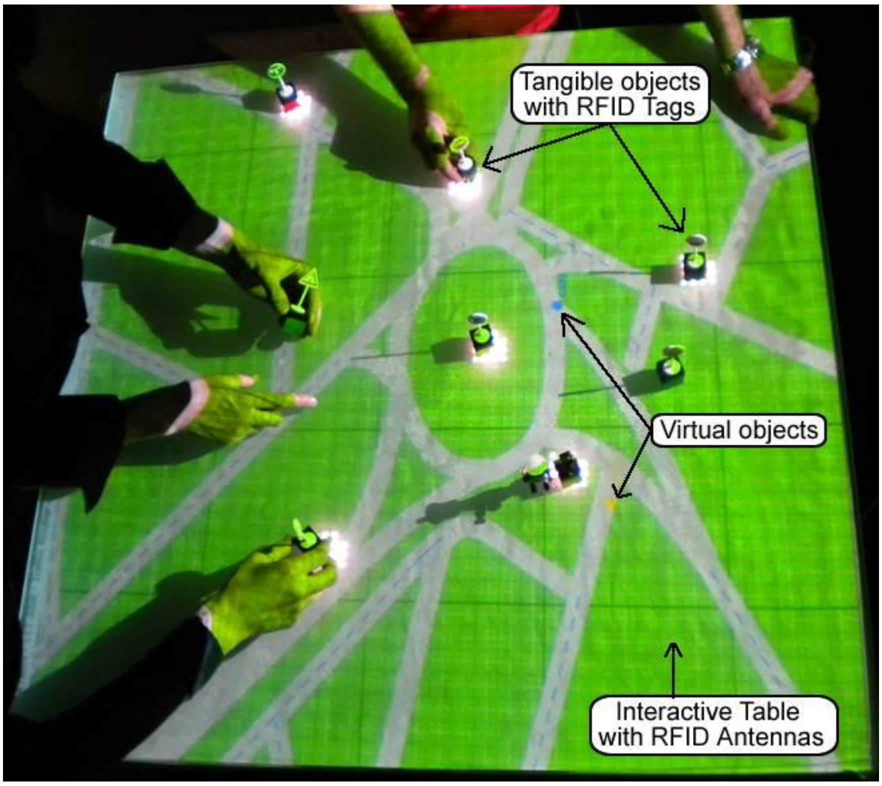

Figure 1. The *TangiSense* interactive table in a collaborative context with tangible and virtual objects; the traffic simulation (represented by virtual objects) evolves according to the displacement of tangible objects. Several specialists (pollution, security…) can simulate different equipment configurations and their consequences.

Section 1 presents the principal capture technologies used by the interactive tables, along with the global contribution of RFID technology for an interactive table and gives details of the tangiSense table, which is the global framework of our research. Section 2 introduces definitions of context awareness and situation awareness, and clarifies how the criteria of context are obtained (with or without RFID). In the section 3 we propose definitions of situation as well as adaptation of solutions concerning Workspace management. To carry out this organization, an algorithm is proposed. Section 4 presents a case study in order to evaluate the global proposition and the algorithm proposed. The article finishes with a conclusion and some prospects.

Framework of work: from interactive tables to TangiSense

The framework of our research work relates to the interaction that takes place around interactive tables. This section initially gives a non-exhaustive selection of examples of existing tables according to the technologies used, in order to have a global analysis of the possibilities in terms of context capture. We will see that the tables equipped with RFID technology make it possible to satisfy the highlighted criteria proposed; other advantages brought by RFID are then provided. This section ends with a description of the TangiSense, an interactive table equipped with RFID technology which is being used as the basis of our work.

Principal capture technologies used by current interactive tables

Although there are now many interactive tables both on the industrial market as well as in academic research, the capture technologies employed mainly remain the same. Among these capture technologies, we can quote the use of cameras (Infra-red or not), the touch screen, the magnetic sensors, the electric sensors, and now RFID. Let us note however that the capture technology using a camera is currently the most frequently used technology. Indeed, it has the advantage of being reliable and rapid in the detection of the position of fingers and in the detection and the traceability of objects (which have an image (e.g. code-bar) on their underside). The reacTIVision toolkit for example, proposed by Bencina *et al.* [3] was often used on the first interactive tables and remains a good basic tool as regards the use of the camera as a capture technology.

In Table 1, we present 5 different interactive tables, each one being representative of one of the capture technologies listed previously. Table 1 shows that each capture technology has its own characteristics. The electric sensor or the RFID make it possible, for example, to distinguish the users. It is for this reason that the current interactive tables combine technologies.

In this article, we concentrate on RFID technology and begin with a justification of its advantages for interactive tables.

Advantages of RFID for interactive tables

Although there are currently many interactive tables, very few of them use RFID technology as their capture system. Nevertheless, this technology has many advantages which can allow new uses with virtual objects (videoprojected or displayed on an LCD screen) as well as with tangible ones (placed on the table). Indeed RFID Technology brings certain characteristics which are not provided by other technologies (e.g. camera).

Table 1. Interactive tables using 5 different capture technologies

Capture Technology	Representative example	User distinction	Object detection	Object overlay
Electrical	DiamondTouch [9]	Yes	No	No
Camera	Surface [38]	No	Yes	No
Touchscreen	HDTML [18]	No	Yes	No
Magnetic	Orai/Kalos [16]	No	Yes	No
RFID	TangiSense [22]	Yes	Yes	Yes

One of the main characteristics of RFID technology is the notion of safety. Indeed, as the RFID tag is unique, an object X cannot be detected as being an object Y. It is thus possible to propose an "identifying" object (for example a card) for each user, allowing a payment (e.g. in an interactive bar [28]) directly on the table/bar using a card fitted with a RFID tag. This concept of safety and an individual card would also make it possible to adapt the table interface according to the parameters selected by the owner of the object (e.g. launch the favorite and personal applications of a user such as his/her online accounts or e-mail). RFID technology also makes it possible to superimpose the objects on each other. This is not possible with camera detection because the camera can only detect one side of an object and is not able to detect if one object is placed on top of another one.

Using RFID technology, it is possible to have an object like a “basket”, with a RFID tag of course, in which we could deposit other objects (also tagged). The table is then able to determine the contents of the basket and to define perfectly all of the objects it contains. Lastly, one of the final advantages of RFID is that it **allows** the storage of information directly in the objects. Indeed, RFID tags make it possible to store (a few Kilo Bytes) in the objects. The advantage is to be able to store certain information specific to the users or to a situation, for example, the state of a chess game: the chess pieces memorize their place; if you take the pieces with you to play on another table, it is possible to find the last state of the game thanks to the pieces placed on the new interactive table.

The TangiSense interactive table using RFID has the advantages of this technology. However its capacities are improved thanks to a Multi-Agent System (MAS) associated to the table which brings a certain intelligence not only to the table but also to the objects. We propose to use the integrality of these capacities to allow an adaptation of the interactive tables to the context of use.

The TangiSense interactive table using RFID technology

Description of the table

Designed by the RFIDées company[1], the table is made up of "tiles" of 2.5 cm², each containing 64 antennas (8 x 8), (Figure 2-A), on a surface of 1 m*1 m. Each tile contains a DSP processor, which reads the RFID antennas, the antenna multiplexer, and communication processor. The reading strategies are prioritized and the code is distributed between the processor reader antennas, the processor in charge of multiplexing and the host computer. The table measures one meter square and contains 25 slabs (5 x 5) or 1600 antennas in total. Each antenna contains four RGB LEDs (prototype v4) which enable interaction with the users by displaying/lighting some virtual objects, with a very small resolution of course (Figure 2-B). The tiles are associated to a control interface connected to the host computer by an Ethernet link. The table is operational and its hardware is now in constant evolution (Figure 2-C). Different demonstrators are being developed in several domains such as transport, education, music, etc., using all the capabilities of the table (RFID, LED, video-projection, tangible and virtual objects). Thus, with these objects, the participants around the *TangiSense* table (Figure 1) are able to interact and work in a collaborative manner around applications utilizing physical objects (such as design or production tasks, games, etc.) ([24],[21]).

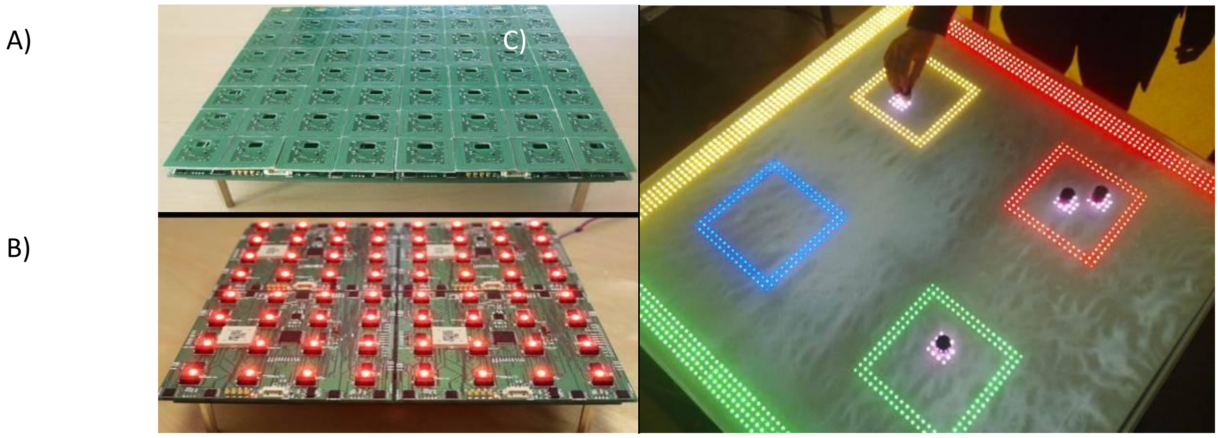

Figure 2. A tile with 8x8 RFID antennas (A), a tile with 1 LED per antenna - prototype v3 (B), The *TangiSense* interactive table with an application using the LED (C)

Description of the objects

As specified before, the objects used on the table can be virtual or tangible, i.e. physically accessible and easy to handle for the users (several tangible objects are visible in figure 1). Virtual objects are the visual objects which are video-projected onto the table (also see figure 1). To do this, there are two technologies available on *Tangisense*: the use of a set of LEDs placed on the

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[1] http://www.rfidees.fr

surface of the table or the use of a video projector. These virtual objects can be handled by the user thanks to a glove fitted with RFID tags making it possible to follow the user's movements [24]. The table is equipped with RFID sensors which make it possible to detect the tangible objects[2] fitted with RFID tags. In these tags, it is possible to store information such as a history of displacements of the object, information on the identification of associated people or objects, etc. At the initialization phase, the application associates the tags to one or several tangible objects.

Architecture

From a software point of view, an architecture including several layers was adopted (cf. Figure 3) ([21],[22]).

1. The *Capture and Interface* layer detects tangible objects which have each been fitted with one or more tags and passes on information to the traceability layer.

2. The *Traceability* layer handles events associated with the objects and communicates the modifications of position of the objects to the application layer.

3. The *Applicative* layer manages the specificities of the applications associated with the table. It is used as an interface with the user. This layer is made up of two parts:

    a. The part integrating the *Multi-Agents System* (MAS) which brings a reasoning feature. The MAS has an overall view of the virtual and physical objects (tangible) which form its environment. The hierarchical organization [1] between the agents allows not only the intelligent management of the objects but also the allocation of roles to them [25].

    b. The *Human-Computer Interaction* (HCI) part which is given the responsibility of communicating with the users and which enables the transmission of virtual information (for example the displacement of a virtual object by the user).

Our work is focused on the HCI layer in which we use RFID technology to make adaptations to the situation. In order to use the MAS, the JADE platform [2] is used to develop interactive applications.

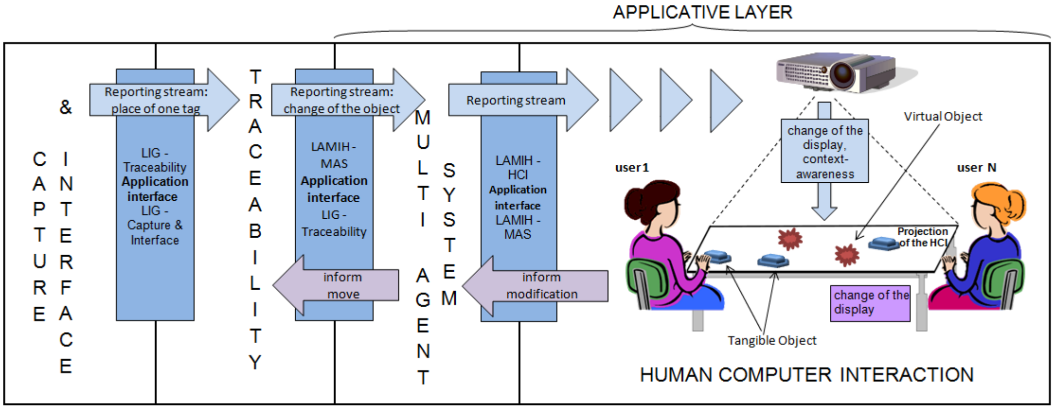

Figure 3. Software architecture of *TangiSense* in three layers [22]

In this section, we have described our framework of study and shown that the TangiSense table has potential advantages for the capture of context and the adaptation of the Human-Machine Interface of the table. The following section aims at presenting the context we wish to take into account in the adaptation and shows why we are working towards a more global adaptation to the interaction situations.

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[2] The TAC (Token and Constraints) paradigm proposed by Shaer *et al.* [35] could be used to provide a specification of the tangible objects but it is not the object of this article.

From Context awareness to Situation awareness

Related Works

In 1994, Schilit *et al.* [34] introduced the context-awareness concept and associated it with a mobile system (ParcTab) in which localization ("Where are you?"), the identity of the people ("Who are you with?") as well as the proximity of the resources ("What resources are nearby?") make it possible to study the context. They describe how the applications can react to changes in the physical environment or the user. Some applications should allow user participation and permit some interaction between users and devices, but especially when these applications react according to the context. In a fundamental article, P. Dourish has explored in depth the context concept and suggested different directions for design [10]. Ward *et al.* [39] interpret the context using the localization of the user and the state of the environment. They also consider the localization of the objects. Pascoe [29] defines the context-awareness concept and more particularly defines the context according to four contextual generic capacities: perception, adaptation, discovery of resource, and the contextual augmentation. Dey *et al.* [8] add a precision to these entities. They define the context as a set of elements of information making it possible to characterize the situation of an entity; an entity can be a person, a place or an object which can intervene on the interaction between the user himself/herself and the application. At the same time, Thevenin and Coutaz [37] define the concept of context of interaction (let us note the change of term), which is connected with the definition given by Dey. The environment becomes a triplet <Object, Person, Event> of entities associated with the current task. Calvary *et al.* [6] present the plasticity concept and the user interface adaptation. The adaptation is modeled as two complementary properties: adaptability and adaptivity ([5],[20]). Adaptability is the capacity of the system to allow the users to adapt their system starting from preset parameters; adaptivity is defined as being the capacity of the system to improve the adaptation automatically without action of the user. In 2004, the context became the context of use: Calvary *et al.* [7] propose the adaptation of the Human-Machine Interfaces to their context of use, seen as a triplet: <user, platform, environment>. The user is representative of the public concerned, the platform corresponds to the material and software structure underlying the interaction and the environment refers to the physical environment accommodating the interaction. Pascoe *et al.* [30] add the concept of *social context*; they specify the biometric signs, the history, the emotions and the status of people as well as their mood. Terrenghi *et al.* [36] show that new social contexts can be associated with multi-person-display ecosystems. Hervas *et al.* [17] have proposed a model to link contextual information to augmented elements, with the goal of enhancing the services offered to facilitate the user's activities.

The other concept which is more global than context is situation. This difference is illustrated by D. Haghighi [14] in an example: "in a smart room scenario, rather than monitoring sensed context from light, noise and motion sensors individually, this information can be used to reason about situations, such as "meeting," "presentation" or "study," which provides a better understanding of the environment". The notion of a situation is then defined as being a meta-level concept over context, which is inferred from contextual information. Situation-awareness provides applications with a more abstract view of their environment, rather than focusing on individual pieces of context.

Context information specific to interactive tables

We have proposed a model of the criteria composing the context by a class diagram [23]. This classification is based on the triplet <User, Platform, Environment> proposed by Calvary *et al.* [7]. The users can be characterized by competences, capacities, as well as emotions and habits depending on their culture; the preferences could be also integrated here. The environment integrates the localization, the type of environment (social, professional, cultural or family), the resources available in the vicinity, information on the external environment (local characteristics) and the possibility of using communication technologies. Finally, the characteristics of the platform can be taken into account for the adaptation. The platform proposes a surface of display (or interaction). This surface can be tactile or not. The modeling suggested is sufficiently generic to be adapted according to particular needs. It can be easily extended according to the developments as well as to the uses. We have enriched it with new cases of context generated by the use of interactive tables [22]. One of the characteristics of interactive tables compared to the usual platforms (PC, portable, PDA) is that they can be **multi-user**. This generates the fact that there can be several users of the application. These users will certainly have relationships which will modify their manner of collaborating and thus of interacting.

Here, the applications are adapted according to the environment and to the users but also to their physical **position relating to the table**. Indeed, we estimate that in a context of use of an interactive table, the position of the user is very important and influences the platform *display* itself. Indeed, the context will not be the same if the user is positioned on one side of the table or on the opposite one. An adaptation is necessary, allowing the user to work correctly according to his/her position at the table. We can find these adaptations during an individual or collective use of an interactive table. Each user must be able to work on his/her own allocated space or on a common space. A criterion of the environment which could be added, in the particular case of interactions using the table, concerns the classification to know if the environment is **collective**. This collective environment can be distinguished through two characteristics which will influence the interactions: either (1) the users use common parts of the table, the workspace is then common; or (2) they use different parts of the table, each one having his/her own workspace, in this case the workspace is individual.

RFID: from a capture technology to a context capture technology for situation-awareness

In the research literature, the most common cases of context-awareness intervene during changes of platform (in general restricted) when the user leaves his/her personal computer and uses a PDA or another mobile platform. In this article, the situation-awareness is not focused on this platform adaptation since the interactions will be centered on the use of the *TangiSense* interactive table with tangible or virtual objects. The context information (1) is detected by the table or (2) is given by the user as requested by the table or (3) is read directly from the RFID tags stuck on the objects. For example, a user is detected by the table via an RFID Tag initialized with an *IDUSER*.

In the specific case of tables fitted with RFID antenna, we study whether each piece of contextual information can be captured by RFID technology. In this case, the RFID technology makes it possible to drive the application adaptation and to decide if the contextual information can be useful in the adaptation of the table. This information can be provided by the RFID tags and if this proves to be the case, this is how it happens.

Table 2 provides means to use the RFID to capture the context. The second column enables one to know if the information can be obtained without RFID technology. The RFID can be used to store data and in this case, no details are given but just a “yes” indication is mentioned. If the RFID plays another memory role, the detail of the use is given as for the user-position criterion which is deduced from user tag positions. Criteria such as Environment-communication Technology, Environment-resources and Environment-location are not needed in the table because the tables are static; so this information about environment does not change. Similarly, the software of the platform (i.e. the *Tangisense* table) does not change so this criterion is not taken into account. The information on three criteria: cultural, competence and ability characteristics of the user can be saved in a database so they can be mobile via the memory of RFID tag or saved locally by the table.

The advantage of putting the user-related information in the RFID tags is that it can be updated by systems other than the table (mobility), whereas if the information is saved by the table database, it will not be mobile and cannot be updated by another system. Some parts of this information are not changeable such as cultural information, whereas competence and ability can evolve.

Table 2. Means to capture the context - RFID role in the interactive table

Capture means / Context criteria	With RFID	Without RFID
User/Position	The position of the RFID tag allows to deduce the position of user	By tactile interaction if possible
User/Emotion	The permanent emotion (character i.e. anxious) can be saved in the RFID tag. In the future, sensors can be coupled with RFID tag…	Not for the moment
User/Cultural information	By the RFID tag content	By interaction
User/Competence	By the RFID tag content	By interaction
User/Ability	By the RFID tag content	By interaction
Environment/ Local Characteristics	If RFID tag is coupled with sensors	Sensors can be integrated in the table. The mobile aspect of RFID tag is not an advantage.
Environment/Resources	Table is network connected so RFID is not useful	By network
Environment/ Collective	The number of users detected with their tags enables deduction of this information.	No
Environment/Collective/Type Of Space	The user(s) position can be deduced following the RFID tags location	No
Platform/Screen	On table, positions of tags allow to know the necessary workspace of a user.	Platform without RFID do not adapt the workspace
Platform/Objects tangible	Yes	Irrelevant
Platform/Objects virtual	Yes	By default
Platform/Software	Irrelevant (note: Each platform knows its software; this criteria is used to adapt application to platform)	Irrelevant

The fact of taking into account the context or more generally the situation of interaction must lead to providing the user(s) with the best interaction possible.

Proposal for a model of situation-awareness on an interactive table equipped with RFID technology

The situation is more general than the context and can be viewed as a set of contextual information elements. We focus on Human-Computer adaptation, so only the interaction situations are studied. We used the classification of context adapted to the table to define the interaction situation. Moreover, there are two levels to adapt applications on a platform. Either the adaptation is made by the system/the application, or the adaptation is made by the platform. In our case, the analysis is independent of the application but specific to the platform (table), so we choose to make the adaptation by the platform. For that, the table is fitted with MAS which allows applied defined rules.

Proposal of Situation definitions

We propose to define four situations from interaction with the table: *standby*, *alone*, collective on *individual* space, collective on *common* space. The collective situations can be collaborative or not [33].

Let us note S for Situation.

$S_{Standby}$ = {#User = 0}

In this case, there is no User detected by the table. Only information on the platform and platform environment is given.

S_{Alone} = {#User = 1, Environment.collective=False}

In this case, only one user is detected by the table. The context information filled in concerns this user (his/her preferences can be provided by the database integrated in the table or by the RFID tag used for identification), the platform and the platform environment.

$S_{collective.IndividualSpace}$ = {#User >1, Environment.collective.TypeOfSpace = individual}

The interaction situation is collective if more than one user is detected by the table. However, as the users are working on distinct spaces, the workspace is individual. The context information filled in concerns these users, the platform and the platform environment.

$S_{collective.CommonSpace}$ = {#User >1, Environment.collective.TypeOfSpace = common}

The interaction situation is collective if more than one user is detected by the table. However, as the users are working on the same space, the workspace is common. The context information filled in concerns these users, the platform and the platform environment.

Situation capture from Position RFID tags

One difficulty in the user interface on the table is to correctly orientate this user interface. For PC use, the screen is vertical and the interface has one orientation (from top to bottom). With a smartphone, the interface can follow two orientations (in a horizontal or a vertical position). On a table, the interface can follow several types of orientations: 4 orientations if the interface is parallel to the table sides, 8 if the interface is oriented following the cardinal points (N, S, E, W, NE, NW, SE, SW), etc. At this time, one of the first interactive tables proposed in 2001 by Dietz and Leigh [9] is able to distinguish the users. For that, some capacitive sensors are used and linked to the user's chair. Each chair corresponds to one user. Even though the capacitive sensors are able to distinguish the users and determine the position of the fingers, unfortunately the table is not really able to know the real relative position of the users and so to adapt its interface to their position(s) (i.e: display). For that, the position of the RFID tag is a lead.

In effect, each tag is detected by the table via antennas, so its (x,y) position is known. The average of the x and y position gives an idea of user position but not exactly the side from which he/she is interacting. For example if the table is represented by a 10*10 grid and if the average of x is 4 and y is 7 then the user follows the South side (cf. Figure 4, crosses). In another case, the average of x is 2 and y is 2, so we cannot conclude if the user is on the North side, on the West side or at the NW corner (cf. Figure 4, square).

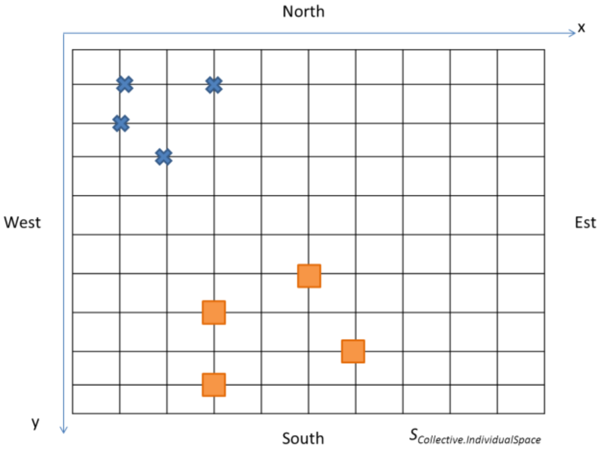

Figure 4. Table presentation as 10*10 grid and RFID tag positions; two users are considered in the $S_{\text{Collective.}IndividualSpace}$.

The RFID tag position makes it possible to deduce the interaction situation the user(s) is/are in. The situation $S_{standby}$ is deduced if there is no RFID tag on table. In this case, there is no user so no adaptation is needed. The situation S_{Alone} is deduced if only one user is interacting with objects on the table. This case is illustrated in Figure 5 (A) in which only the RFID tags belonging to the same user (crosses) are detected by the table. The situation $S_{\text{collective.IndividualSpace}}$ is shown in Figure 4 where two users are interacting on the table but each one in a workspace. The interaction is driven by each user's RFID tags. The application can be different or the same, collaborative or not (e.g. each user does his/her drawing with an editor, not a common drawing). Figure 5 (B) shows a possible configuration of Situation $S_{\text{collective.CommonSpace}}$ using the *TangiSense* Table. The RFID tags of the two users concerned are mixed on the total surface.

Proposal of workspace adaptation rules according to situation changes

On the basis of situation definitions given before, this section provides an example of possible adaptations focused on the workspace (WS) management of the interactive table. Here the workspaces of another platform are not treated because each platform can have its own logical adaptation.

Table 3 has to be read from source situation (vertical) to target situation (horizontal). The variable N in the table represents the maximal number of users.

For example, if the source Situation is $S_{\text{collective.IndividualSpace}}$ and becomes S_{Alone} after the exit of users (n-1), then the workspaces which were dedicated to these n-1 users are closed.

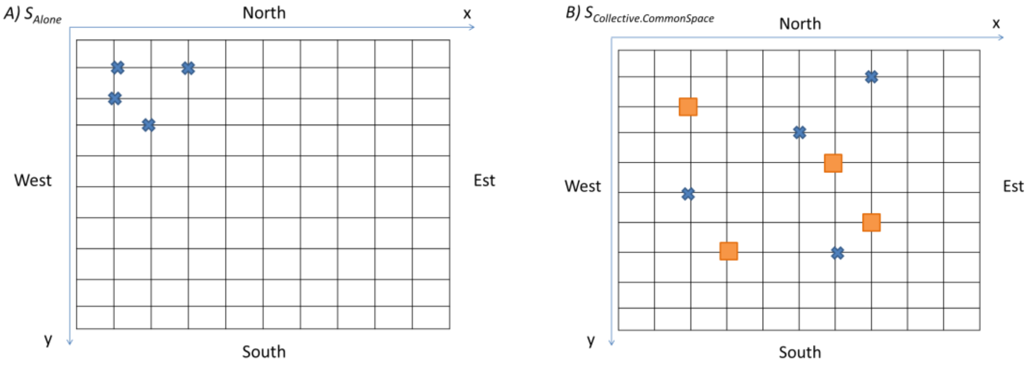

Figure 5. RFID tag positions on *TangiSense* table represented as 10*10 grid A) one user in S_{Alone}, B) two users in $S_{\text{collective.}CommonSpace}$

On the other hand, if the source situation is S_{Alone} (only one user) and other users (n-1) begin to interact, the situation becomes $S_{\text{collective.IndividualSpace}}$ - so the initial workspace is reduced and n-1 new workspaces are created for the new users.

Work on the composition/decomposition of user interfaces ([13],[26],[27]) could be used to achieve this aim.

Table 3. Workspace (WS) adaptation according to situation change

Situations source (v) → target (h)	$S_{Standby}$	S_{Alone}	$S_{collective.IndividualSpace}$	$S_{collective.CommonSpace}$
$S_{Standby}$	—	1 WS is opened	N WS are opened	1 WS is opened
S_{Alone}	WS is closed	—	The Initial WS is reduced and N-1 WS are opened	No change
$S_{collective.IndividualSpace}$	WS is closed	N-1 WS are closed	—	N-1 WS are closed
$S_{collective.CommonSpace}$	WS is closed	No change	Initial WS is reduced and N-1 WS are created	—

Implementation

An application has been developed with JAVA and is running. The scenario is the following: first, only one user is working. Then, when a second user comes, the table detects the change of situation. The system adapts to the new situation and separates the workspace into two parts. This scenario is the same until four users are simultaneously present around the table in order to provide a workspace sufficient for each user.

The proposed *Split_Workspace* algorithm is visible in Figure 6. In input it considers N, the number of users interacting with the table. The minimum number of users is 2 (N>1). First the algorithm takes into account the set of virtual objects composing the workspace of each user initially around the table (N-1 users). The virtual objects of the new user are instanced with a JAVA object and initialized in coherence with the already existing objects (note that they are not yet displayed). The following sequence aims at analyzing the workspaces in order to estimate the ratio and the necessary axes of reduction, according with the new configuration (i.e. allocation of the zones to the users[3]). Each object of the N users is reduced, positioned and displayed in the workspace allocated to the considered users.

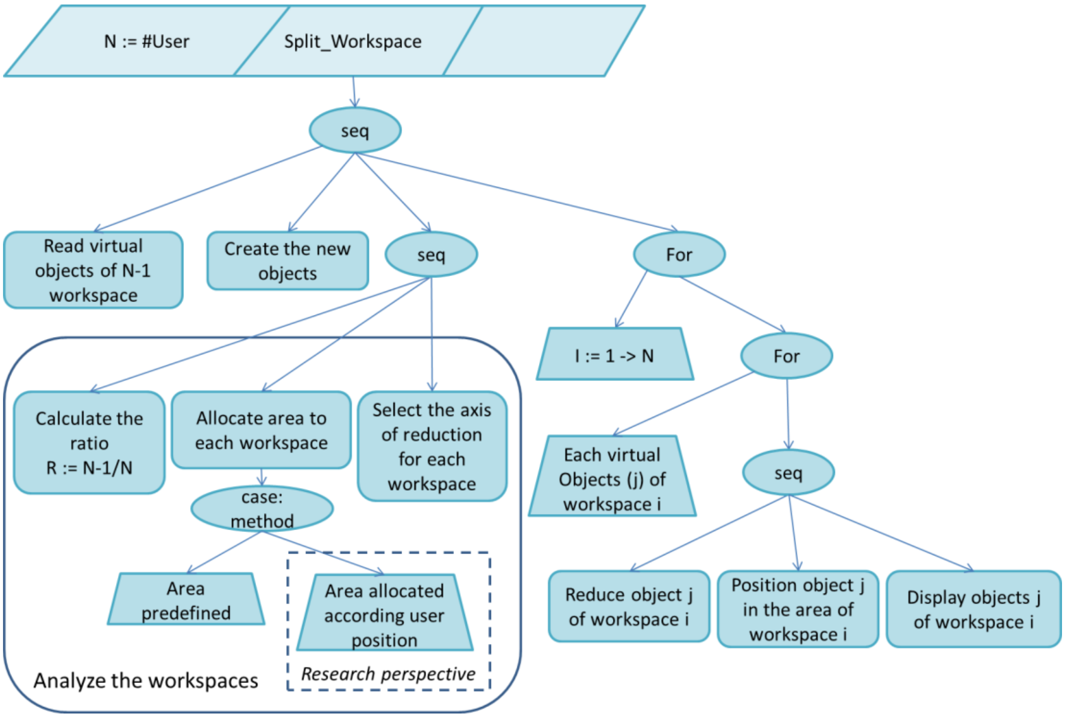

Figure 6. *Split_workspace* algorithm

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[3] An alternative would be an allocation in real time when a user changes his/her position around the table; this idea is the subject of a research perspective.

Case study: Scenario of Situation-awareness

In this article, the platform adaptation concerns the interactions, centered on the use of the *TangiSense* table according to a situation change. The goal of this study is to evaluate the *Split_Workspace* algorithm (Figure 6). In this part, we initially present the generic application exploited within the framework of the study. The protocol implemented is explained; 24 subjects were implied in this protocol. The results are then presented.

Generic application made up of basic elements which are reusable in various applications

The application used for the study can be seen in a generic way, inasmuch as it consists of basic elements which are reusable in various applications on an interactive table. Indeed, the concepts of workspace, separation of workspace, placement zones, passive objects (not triggering a particular action; for example, being able to be classified), active objects (for checking or calculation) can be used in classification applications, in the broad sense of the term[4].

Here, one to 4 users place themselves where they wish around the table in order to perform an individual task in a context which can be common or not (according to the situation). This task consists in placing objects in corresponding areas (i.e. connected with the object concerned). The split algorithm was applied on this application, with several groups of adult subjects.

Protocol

The protocol uses the following elements: (1) the TangiSense interactive table showing four colored areas (blue, red, green, yellow); (2) a set of passive tangible objects (8 per subject) for the subject to replace in the suitable colored area (4 colored areas per workspace); (3) 4 active tangible objects given the role of verifiers. (4) a video camera to film the central zone of the table; (5) a camera providing an overall view of the scene; (6) questionnaires intended for the subjects.

Subjects

Six groups each composed of four adults (24 subjects in total including 13 men and 11 women) took part in this study. Their average age is 34.5 years; they are all between the age of 22 and 56. There can be up to 4 users with the TangiSense table in the $S_{collective.IndividualSpace}$ because the table has a surface area of 1m*1m. With more than 4 users, the workspace allocated to each user would be too small to use this application in sufficient technical and ergonomic conditions.

Differentiation between "common space" and "individual space"

For each group, two sets of working conditions were used, corresponding to the $S_{collective.IndividualSpace}$ and $S_{collective.IndividualSpace}$ situations: *common space* condition and *individual spaces* condition. The same task was to be carried out in each situation. Each group was examined under the two conditions at intervals of approximately 15 minutes, each one starting randomly with one or the other of these conditions. The *common space* condition consists in not cutting up the workspace. The application displays 4

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[4] For example, starting from these generic and reusable elements, we proposed an application allowing the recognition and the learning of colors by children. The scenario is based on the French teaching syllabus for nursery schools. In collaboration with a nursery school teacher, we proposed a simple application in which the aim of the users (i.e. the children) is to place objects represented as a black and white picture in the corresponding colored area (e.g. a sun in "black and white" should be placed within the yellow color area). For that, the child has a set of objects (small cubes each carrying a black and white image). The child must then determine what the image represents, associate the suitable color and place the object within the corresponding colored area on the interactive table. A special object which looks like a wizard is used in this application to check results. When the child has finished, he/she puts an object representing the wizard in his/her workspace. The application checks each colored area to see if the objects placed in this area match the color and announces any errors or correct answers to the children. This application was tested in a real situation in a nursery school with common space only (without using the "Split" algorithm proposed in this article).

colored areas on the total surface of the table. There is only one verifier object for all of the users. The *individual spaces* condition consists in cutting the workspace into two, three or four sections according to the number of users. The 4 colored areas are placed on each workspace. There is one verifier object per workspace/user. The four renders of the table associated to these 4 possible situations are shown in Figure 7.

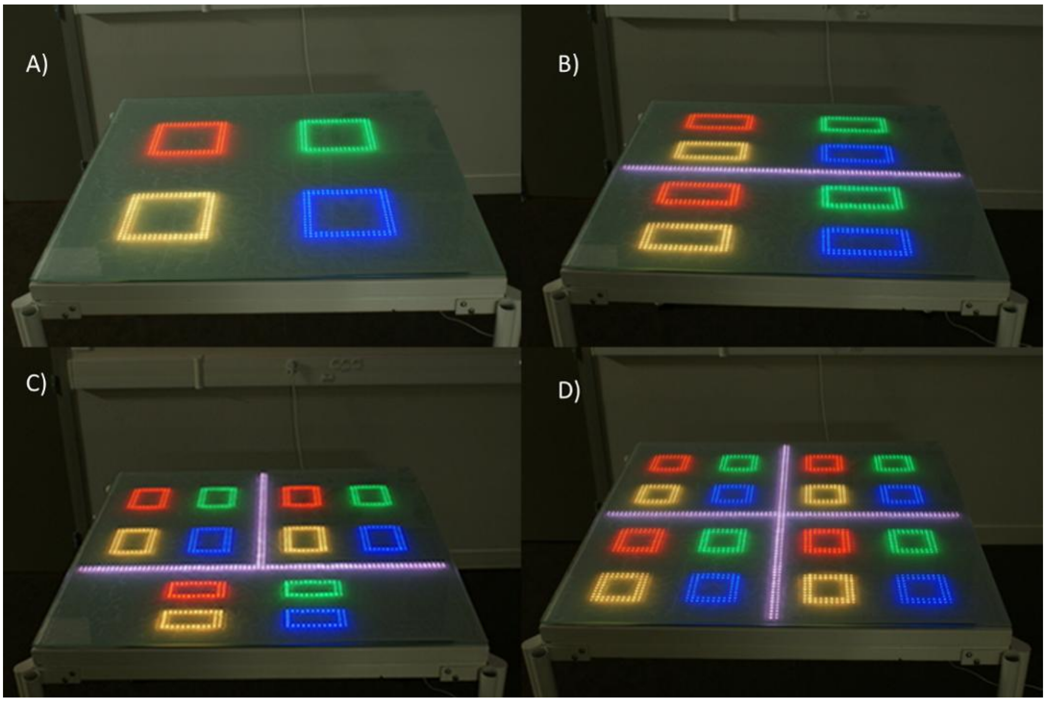

Figure 7. Splits of workspaces in the case of situation adaptation:
A) S_{Alone} (one user) or $S_{Collective.CommonSpace}$
in $S_{Collective.IndividualSpace}$:
B) two users
C) three users
D) four users

Overall procedure for all the groups

Firstly, we carried out a preliminary methodological control involving 8 people separated into two groups (G1 and G2). These subjects worked on the table alone. Groups G1 and G2 therefore correspond to tests groups making it possible to validate the protocol and its components. They make it possible to highlight possible errors in the protocol, in its progression as well as in the instructions given and the questionnaires to be completed. Let us note that no major technical or methodological problem was highlighted. Only one minor problem was detected and corrected concerning the filling in of the questionnaires; indeed, one question was considered not to be very clear and had to be reformulated.

For G1, the workspace was initially configured in common space: it covered the totality of the table. Then, it was configured in individual space (cut into four zones); the workspace then occupied a quarter of the entire surface area of the table. The 4 following subjects (G2) followed the same protocol but the 2 sets of working conditions were permuted (initially work on individual space, then on common space).

Following on from this, the 4 subjects of each group (G3, G4, G5 and G6) did not work alone on the table but simultaneously. They either integrated the interaction on the table (G3, G4), or left it (G5 and G6), always in a gradual manner. Another user came/exited when all of the preceding objects had been found and validated by the active checking object. Upon each user arrival, the table cut up the total space of the table according to the number of users (i.e. individual space) or not (i.e. common space). Each workspace contained 4 colored zones; a set of objects to be placed (a different set each time) was given to each subject. Figure 8 summarizes the order of the subjects (users U_a^b, with *a* being the number of the user within the *b* group) and the context in which they are: (1) the dark parts having a undivided representation of the table correspond to the common spaces condition (2) the clear parts having a divided representation of the table correspond to the individual spaces condition.

Group		1st condition					2nd condition				
G1	Q1	U^1_1 ☐	U^1_2 ☐	U^1_3 ☐	U^1_4 ☐	Q2	U^1_1 ⊞	U^1_2 ⊞	U^1_3 ⊞	U^1_4 ⊞	Q2'+Q3
		S_{alone}	S_{alone}	S_{alone}	S_{alone}		S_{alone}	S_{alone}	S_{alone}	S_{alone}	
G2	Q1	U^2_1 ⊞	U^2_2 ⊞	U^2_3 ⊞	U^2_4 ⊞	Q2	U^2_1 ☐	U^2_2 ☐	U^2_3 ☐	U^2_4 ☐	Q2'+Q3
		S_{alone}	S_{alone}	S_{alone}	S_{alone}		S_{alone}	S_{alone}	S_{alone}	S_{alone}	
G3	Q1	U^3_1 ☐	$U^3_1+U^3_2$ ⊟	$U^3_1+U^3_2+U^3_3$ ⊞	$U^3_1+U^3_2+U^3_3+U^3_4$ ⊞	Q2	U^3_4 ☐	$U^3_4+U^3{}_3$ ☐	$U^3_4+U^3_3+U^3_2$ ☐	$U^3_4+U^3_3+U^3_2+U^3_1$ ☐	Q2'+Q3
		S_{alone}	$S_{collective.IndividualSpace}$				S_{alone}	$S_{collective.CommonSpace}$			
G4	Q1	U^4_1 ☐	$U^4_1+U^4_2$ ☐	$U^4_1+U^4_2+U^4_3$ ☐	$U^4_1+U^4_2+U^4_3+U^4_4$ ☐	Q2	U^4_4 ☐	$U^4_4+U^4_3$ ⊟	$U^4_4+U^4_3+U^4_2$ ⊞	$U^4_4+U^4_3+U^4_2+U^4_1$ ⊞	Q2'+Q3
		S_{alone}	$S_{collective.CommonSpace}$				S_{alone}	$S_{collective.IndividualSpace}$			
G5	Q1	$U^5_1+U^5_2+U^5_3+U^5_4$ ⊞	$U^5_1+U^5_2+U^5_3$ ⊞	$U^5_1+U^5_2$ ⊟	U^5_1 ☐	Q2	$U^5_4+U^5_3+U^5_2+U^5_1$ ☐	$U^5_4+U^5_3+U^5_2$ ☐	$U^5_4+U^5_3$ ☐	U^5_4 ☐	Q2'+Q3
		$S_{collective.IndividualSpace}$			S_{alone}		$S_{collective.CommonSpace}$			S_{alone}	
G6	Q1	$U^6_1+U^6_2+U^6_3+U^6_4$ ☐	$U^6_1+U^6_2+U^6_3$ ☐	$U^6_1+U^6_2$ ☐	U^6_1 ☐	Q2	$U^6_4+U^6_3+U^6{}_2+U^6_1$ ⊞	$U^6_4+U^6_3+U^6_2$ ⊞	$U^6_4+U^6_3$ ⊟	U^6_4 ☐	Q2'+Q3
		$S_{collective.CommonSpace}$			S_{alone}		$S_{collective.IndividualSpace}$			S_{alone}	

Figure 8: progression for the six groups

Progression for each group from G3 to G6

On arrival, the subjects filled in a first questionnaire (Q1) concerning their opinion on interactive tables, tablets or new interactive supports. The instructions of the task were given to them. They knew their objective (to place the objects in the colored areas) and they knew that they would work in an individual or common context (Figure 9). At the end of this first use, they filled in a second questionnaire (Q2) concerning their reaction on the use of the table and on the position of the colored areas in their interaction. They were then given the instructions concerning the second set of working conditions. Thus, approximately 15 minutes after the first use, they used the second set of conditions (depending on the set used first with their group and visible in Figure 8). Once the 4 users had completed their task, they again filled in a questionnaire identical to the previous one (Q2'), along with a further questionnaire enabling them to give their preference between common space and individual spaces (Q3). Our results are based on the analysis of these questionnaires, along with elements provided by the videos.

Results

Our analysis is focused on the data resulting from the situations, with common or individual space (Figure 9), involving groups G3 to G6.[5]

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[5] Let us recall that the groups G1 and G2 were used for preliminary methodological control. The data associated with those groups is therefore not considered in this article.

Figure 9. Situation with (A) 1 user, in *common space*, (B & C) 2 & 3 users in *individual space*, (D) 4 users in *common space*

Given the way the tests were performed, the questionnaire was filled in three times individually: before the use of the table, after the first use (common case or individual case), after the second use (opposite case to the previous use). Let us specify however that the results are interpreted by working group, and not in an individual way. This made it possible to highlight interesting developments concerning the perception of the various work situations by the groups of subjects.

Figure 10 (A) refers to the evolution of the question “Do you feel it is appropriate to work with several people on a common workspace on an interactive table?” The results show that, before use of the table, the groups have a favorable *a priori* (averages between 7 and 8). After a first use of the table (using the common or individual space condition), the *a priori* were consolidated for 3 of the 4 groups. However, for the G6 group which started using common space, the average decreased because of the very low mark of one of the subjects who underlines “[it is appropriate] only if one needs to communicate”; however the videos show that the subjects needed to communicate at various times during the session. After the second use, the results are good (averages between 7 and 9), except for the G3 group (average of 5.5) which started with an individual space and finished with a common space; this last situation affected the results since one of the subjects brought up the issue that "certain persons do not want to cooperate”. This result raises the interest of algorithms like the one proposed above (Figure 6), but also the importance of taking into account the concept of context in order to adapt the workspace to the desired situation.

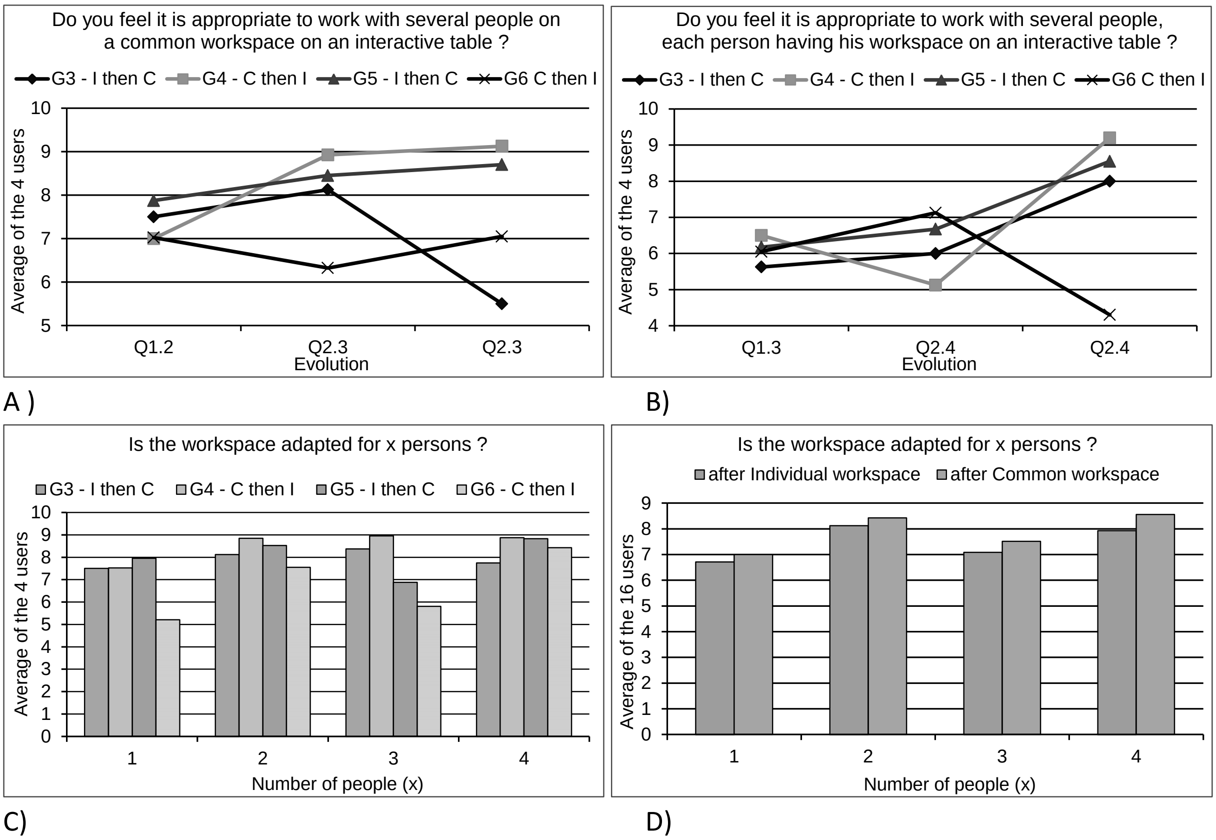

Figure 10. Results with the questionnaires filled in by the subjects

Figure 10 (B) refers to the evolution of the question "Do you feel it is appropriate to work with several people, each person having his workspace on an interactive table?". At the beginning, the averages of the opinions for the 4 groups all ranged between 5.5 and 6.5. At this level, we estimate that the subjects could not think how they would be able to work individually on an interactive table; their a priori seems however rather favorable. After the first use of the table, the two groups which started to work on individual space (G3 and G5) increased their average slightly. It is also the case for one of the two groups (G6) which started with common space; however the other group (G4) lost 1.5 point (without justification or any particular remarks). After use of the 2 types of space (common and individual), three of the groups have a very positive opinion (ranging between 8 and 9.2); the fourth (G6, having finished with individual space) was not really in agreement (with an average of 4.3), because two people (out of 4) in the group did not at all appreciate working in this individual configuration: the video shows a disagreement between the subjects concerning the placement around the table; we voluntarily did not impose a place for the subjects, they were able to choose their own place around the table. In fact, the two subjects who gave a low mark were in fact disturbed by one of the other subjects who wanted to impose certain places around the table. It is an interesting result from the point of view of improving the proposed algorithm: a prospect could be to directly take into account the preferences of the users (in terms of placement) highlighted during previous sessions.

Figure 10 (C) gathers the results for 4 questions "Is the workspace adapted for X persons?" (the number X of persons varies from 1 to 4 and is represented in X-coordinate). The average is given for each value of X, for each of the four groups; each average considers all three questionnaires (before use, and after use of the 2 types of space (common and individual)) filled in by each of the 4 subjects of the same group. The results are the following:

- Case where X=1: for groups G3, G4 and G5, the results are very positive and vary little (from 7.5 to 8). For the group G6, remarks were made systematically on the fact that the table is too large for only one person and led to an average of 5.2.
- Case where X=2: no remark was made, all of the groups express a positive opinion (all the averages are above 7.5)
- Case where X=3: for groups G3 and G4, the results are very positive (respectively 8.4 and 8.95). For the group G5, the results are good (6.9), a remark having been made: "the division into three « rectangles » is perhaps not optimal". For the group G6, the video shows that two of the subjects got in each other's way during the positioning around the table, standing on

the same side (whereas a positioning opposite each other was possible); the results are thus not as good (5.8) (let us note that there is convergence with the opinion formulated with the Q2.4 question of Figure 10 (B) by this same group).

- Case where X=4: all of the groups express a positive opinion (all the averages are above 7.75). An interesting remark was however expressed by a subject: "The size of the interactive objects is limited compared to the size of the colored zones", but without influence on the results.

Concerning Figure 10 (C), the results remain overall positive and consolidate the fact of using an algorithm for workspace division like the one proposed. An additional prospect for the algorithm, due to the remarks voiced, would be to make positioning suggestions for novice users.

Like in Figure 10 (C), Figure 10 (D) refers to the question "Is the workspace adapted for X persons? " (With X varying from 1 to 4). However it aims this time to compare the average of the opinions after having worked on an individual space (questionnaire Q2 filled in after the first use of the table for groups G3 and G5, Q2' after the second use for groups G4 and G6) with the average of the opinions after having worked on common space (questionnaire Q2' filled in after the second use for G3 and G5, Q2 after the first use for G4 and G6), cf. Q2 and Q2' on Figure 8. Even though a slight difference can be noticed on this figure in favor of the common surface, the results are very positive for the 2 types of surface (average always higher than 6.7), which is very satisfactory compared to the algorithm proposed.

Conclusion

In this article, we have shown the increasing interest in contactless technology and interactive tables. The context-awareness principle was generally presented and then applied to the use with interactive tables. The advantages of RFID technology for the capture of contextual information while using the *TangiSense* table were studied and compared to information capture without these wireless technologies. This part of the study concluded that RFID can be used to drive applications and therefore applications can be user-driven via RFID technology. RFID technology was used as a support to propose definitions of situation to be taken into account when adapting the interfaces. The contribution of the RFID in detecting the current situation has been given.

A case study has been presented. An experiment has been performed involving 24 subjects; several situations have been tested, particularly with individual and common spaces. It allows us to validate the proposed and developed algorithm.

Future works could consist in taking into account the content of RFID tags to adapt the system. For the moment, the feasibility of this has been demonstrated but not yet used. Only the position of tags is used within the framework of this article for the detection of changes of situation in order to adapt the interfaces.

Another prospect aims at improving the algorithm proposed and the manner of using it (according to the suggestions made in the results section). It would also be possible to determine the positions of the users according to the position of their tangible objects in order to facilitate interaction and thus refine the process of adaptation to the situation.

The use of other platforms linked to the *TangiSense* table has not yet been studied in detail and should be the subject of a future article; it will also be possible to study other situations in which distant collaborations become possible (using new types of individual and collective spaces).

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