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Interaction between tangible and virtual agents on interactive tables : Principles and case study

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Abstract

Interactive tables (tactile, tangible and mixed tables) are mainly used as support of interaction to design applications and value-added services. Indeed, new collaborative applications emerged from theses new supports using classical interaction (through keyboard, mouse and screen devices). Nowadays, new sensory entries enable users using their hands to manipulate different objects. This article is indented to propose a global interaction model that associates multiagent system concepts to interactive table entities. The model proposes two types of entities that can be used simultaneously : virtual and tangible entities. The virtual entities can result from video projection or from screen use on the interactive table. The tangible entities are physical objects that can be manipulated by one or several users. These are detected through dedicated sensors. At the end of this article, a case study is presented. It illustrates the management of a road traffic simulator using the *TangiSense* interactive table. The illustrations show mainly the communication between the different agents. In addition, the simulator presents the advantages of the proposed model in order to facilitate the implied users' decision during the simulation process.

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Keywords: Multiagent System, Situated Agents, RFID, Interactive table, Smart object

1. Introduction

For several years, simulators have been proposed in several application fields. These simulators are used, for instance, in the domains of transportation [1], ecology [2] and medical care [3]. Most of them are based on a standard architecture. This architecture uses mainly the usual sensory entries : <screen, keyboard and mouse > [4, 5]. However, many simulators require experts to be exploited correctly. The simulators can require software complex functioning. To improve the global functioning of the system, indeed such simulation tools have to enable the collaboration between various users (e.g. to exchange on a common objective). In addition, we intend to work further on more interactive approaches (that can allow an intuitive manipulation by persons stemming from different domains and who are not inevitably experts in the complex simulator functioning). These approaches are different from those related to computer use.

As the spectacular evalution of technologies, computers size became smaller and smaller [6]. This leads to new interaction platforms such as PDAs, tablets, smartphones and interactive tables. Then, interaction

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devices can be substituted by the human body movements (mainly fingers). Platform takes too into consideration the manipulation of daily objects. These objects are communicating and/or detected by an interactive table.

Although the users' interaction with the computer is done individually, interactive table interaction can be exploited by several users. The used technology can be intuitive when manipulated by an uninitiated public (e.g. using more natural interactions [7]). The interactive tables use is revolutionized by the new forms of human-machine interaction. This implies to design differently applications.

The reminder of this paper is organized as follows : the first section includes a state of the art about interactive tables and the associated interaction principles. This section covers also technical and software characteristics of these supports. Indeed, we intend to make more intuitive and realistic the applications using more adapted behavior of the used entities (evolving in these interactive support).

Then, we propose a global interaction model through a detailed description of the interactive support entities. The proposed model describes the interaction and communication principles between the various entities and users. This description identifies the sensory entries of the support. Then, it adapts the behavior of the entities/agents of a multiagent system according to the involved environment ((*e.g* tangible [1] and/or virtual for the interactives tables).

Next, a case study is presented. It illustrates how the objects react to the environment modifications and how they can interact together. The application case deals with an application of road traffic simulation. This application is instantiated on the interactive table *TangiSense*. This table exploits RFID technology. This technology enables to detect road signs. These signs are provided with ”RFID” tags. Agents' association with the entities enables the object to interact and dialogue together and with simulated vehicles video-projected on the table surface.

The paper ends with a conclusion as well as the evolution of multiagent system applied to theses supports.

2. Related work

Ambient computing is, nowadays, present in our daily life [8, 9]. The user can interact with several platforms to be connected to the rest of the world. This connection is mainly done thanks to Internet and wireless technologies progress [10, 11]. As these technologies are evolving, new interaction platforms are more used. In this article, we are interested by interactive table as interaction platform. Such tables are considered as innovative interaction support. Indeed, they do not require neither the mouse nor the keyboard to ensure Human-system interaction.

Among the tactile interaction devices, we can cite the ”multi-touch” devices [12]. The interaction through ”Multi-touch” devices enables users to interact with the material entities using several contact points. Interaction can be based also on hearing devices [13]. The user interface can be projected on the interactive table and then can be exploited by several users simultaneously by using digital content. Comparing to traditional interaction platforms, the main advantage of interactive table is mainly to provide the ability of social interaction.

The combination of an interactive table and a tangible user interface (tangible user interfaces make it possible to overlay a virtual model to our perception of the reality) permits new surface, tangible interactive tables [14]. These tables like the ReacTable [15], the SMART Table [2], The Table-robots [16], etc. These tables enable manipulating physical objects on their surface. These objects can be as various forms. Their positions are detected according to the used technology : camera [17, 18], magnetic follow-up [19], weighty detection [20], radio frequency [21], etc. The objects can be identified using different technologies : bar code, image, specific shape, RFID chip, etc.

Then, recognition systems (e.g. TUIO [22] used by IntuiFace and ReacTIVision [18] used by ReacTable) identify and analyze the movements on the tactile surface and/or tangible table. This analysis lists the users'

1. tangible : all that is palpable, perceptible by touch (Source : Center for Textual and Lexical Resources).
2. Smart Technologies. Smart Table. Website, http ://smarttech.com/us/Solutions/Education+Solutions. 2009. (accessible in 2012).

movements possible to occur and that can be recognized by the support. In addition, a processing system can use the received/successful data from the recognition system. They are processed for instance to interpret the users body movements.

Generally, the resulting actions from a recognition system are produced following a state change. For instance, when a pressure sensor detects a presence, it switches on the light. This change does not integrate external factors that are able to alter the object perception (the pressure sensor detects a presence but not if there is enough luminosity in the room, consequently it does not switch on the light). The used systems by interactive tables do not integrate such a concept. The associated actions are related to an actuator (I put the object - I realize an action).

To handle problems related to the majority of interactive surfaces, several systems integrated ”artificial intelligence” concept in order to endow the tables of an intelligent behavior. This behavior is ensured through the manipulated entities. The artificial intelligence is exploited in this case by using software agents. These agents are endowed with behaviors, a processing and communication ability like *Intelligent Table* [3], *the Table-Robots* [16], or still the table *Blip-Tronic 3000* [4]. The Blip-Tronic is a musical instrument to play sounds according to the type of object detected. The tone is varied in dependence on the distance between the objects.

Although many solutions exist, they are generally related to an instantiated application (i.e. for particular interactive tables). The evolving entities do not integrate (or do not enough integrate) the behavior that can be deported to enrich the system intelligence. Furthermore, the entities interact only with the support. We find rarely cases where entities together to exchange the environment data. In order to overcome such limit, in the next section, we propose a global interaction model that can be exploited simultaneously by various virtual and tangible entities evolving on the interactive table surface.

3. Proposition : Global model interactions for interactive supports using agents typology

This section presents our proposition for managing virtual and/or tangible entities. These entities are evolving on the interactive table surface using the agent concepts. These concepts are used to design and implement heterogeneous applications for interactive tables (e.g. applications for colors and numbers learning in education domain [23], games, musical creation, *etc.*). They take into consideration the environment dynamics characteristics. In addition, it considers the heterogeneousness of the entities, distribution of the information, the system complexity, etc. Then, we list the various implied agents as well as their interactions with the interactive support environment.

The proposed interaction model is based on a multiagent architecture. This architecture is completely described in [24, 25]. This architecture illustrates the concepts of instantiated agents through an UML diagram. This diagram defines the agents that are involved in the reception of the sensory entrances from the interactive tables. It defines also the behavior associated to the manipulated entities. This behavior enables the agent autonomy and is represented by a set of roles. These roles apply rules, aims and constraints. To implement the agent behavior, we need to define their typology and the possible interactions between them and the users.

We distinguish three types of agents : tangible agents, situated virtual agents and non situated agents (detailed below). The types form specific groups. For example, the group of the situated agents includes tangible agents and situated virtual agents. The non situated agents group correspond to all the agents types that ensure the good multiagent system continuity (for example, a virtual agents observers).

The tangible agents. A tangible agent is connected to a tangible object (object which can be manipulated by one or several users).The agent association to tangible object is elaborated in order to attribute roles to objects through agents. The tangible agents are agents situated in a plan corresponding to the interactive support detection surface. They react to the environment modifications issued from the objects movements.

3. Panasonic. Intelligent Table. Website, http ://en.akihabaranews.com/7007/household/hdtv-the-interactive-and-intelligent-table-by-panasonic. 2006. (accessible in 2012)

4. Peter Benett, Sean Toru, and Lisa Tutte-Scali. Blip-Tronic 3000. Website, http ://www.petecube.com/bliptronic3000/. (accessible in 2012).

The situated virtual agents. A situated virtual agent is associated to virtual objects that are endowed with a graphical representation on the interactive support. Unlike tangible objects, virtual objects are able to change forms, colors, size and to disappear throughout the application. Every situated virtual agent can reason and have a set of roles that enable it to evolve in an environment. It also has a limited view limited to a perimeter. This perimeter can vary according to its roles according to the instantiated application. In the case of tactile supports, the user has the possibility to directly move virtual objects.

The non situated agents. The non situated agents handle the administration of the interactive support and the application progress. Virtual agent's observers are charged to ensure the best operation progress between the various agents (tangible or virtual ones). Their role corresponds to receive and transfer information from other interactive support layers (hardware, middleware or software). They manage also the dynamics of the agent roles and check the coherence of these roles. In addition to that, they contribute to integrate new agents thanks to the environment global view.

The interactions between agents are based on the language FIPA-ACL [26] to exchange information and data. Figure 1 illustrates the principles of interactions between the various groups of agents as well as the interactions between users. The interactive support can be exploited by a user (named U_n).

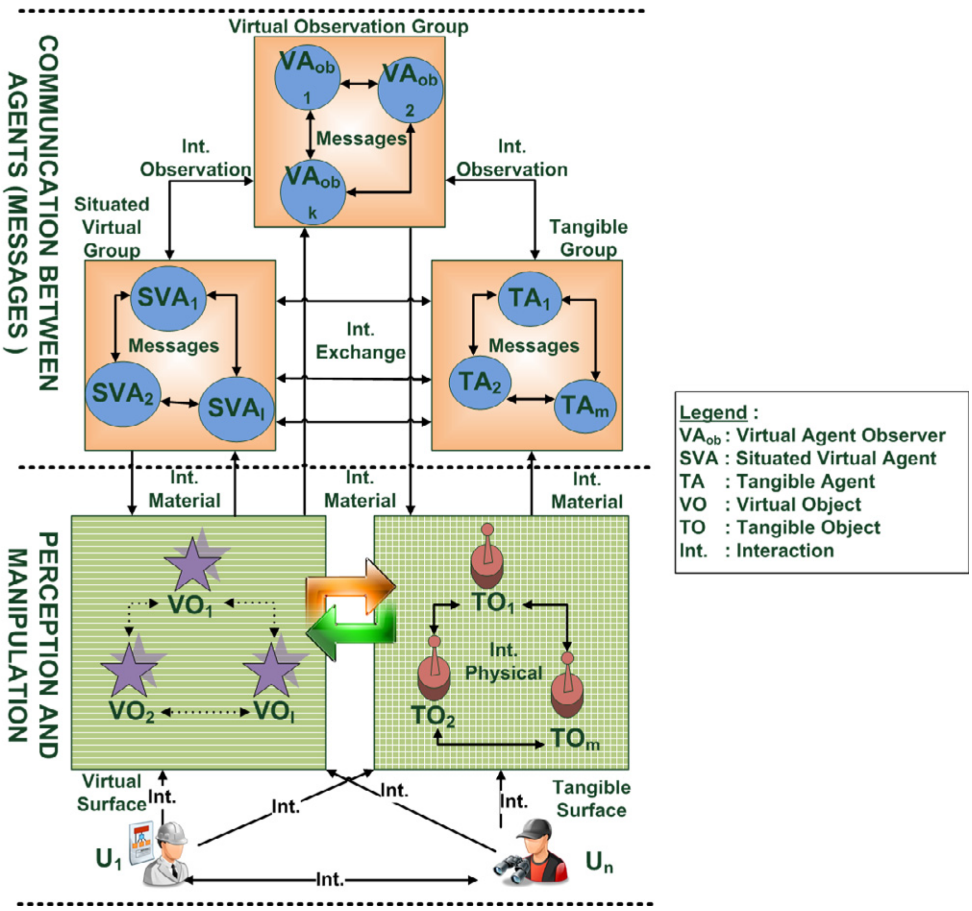


Figure 1. Different interactions on interactive support

The interaction between users and the support results from the manipulation of tangible objects and/or from the manipulation of virtual objects if the support offers this possibility (*e.g.* to manipulate virtual objects, the virtual support must be tactile).

We distinguish several types of interactions in the system : the observation interactions between non situated agents and situated agents. They enable, for example, situated agent to obtain a new role ; the exchange interactions that correspond to the messages sent between the groups of tangible agents and the situated virtual group ; the material interactions that are used to receive the signals emitted by physical environment and to emit notifications in the materials (for example, the LED activation, the sound activation if the hardware permits it) ; the users' interactions that result from the objects manipulation. The user can move tangible and virtual objects (the virtual is movable : either indirectly through a tangible object or directly on the table if it has sensors) ; the strong interactions that result from the subordination of the position of an element according to the position of other one. In this case, we identify the interactions between the agents (tangible or virtual) and between users and agents (tangible or virtual) as illustrated in Figure 2. Then, we deduct for example that a tangible agent can act on the position of virtual agents and not the opposite. In this situation, when the user moves a tangible object, he/she visualizes and modifies the position of a virtual object.

$$\begin{array}{rcl|l} SVA & \Longrightarrow & SVA & \\ TA & \Longrightarrow & SVA & \quad \textit{Legend} \\ TA & \Longrightarrow & TA & \quad \Longrightarrow : \textit{act on the agent location} \\ U & \Longrightarrow & TA & \\ U & \Longrightarrow & SVA & \end{array}$$

FIGURE 2. Interaction between agents and users

From this modeling, we suggest applying the various agents' typologies as well as their interactions in the following section through an application for road traffic simulation. This application is applied on the interactive table *TangiSense*. It enables the manipulation of tangible objects using RFID technology.

4. Case study : agent-based simulation on interactive table

In this section, we propose to implement interactions between the agents presented in the previous section (Section 3) on the interactive table *TangiSense*. The *TangiSense* table integrates RFID technology allowing detecting the position of objects through the provided tags.

According to existing simulators and their related problematic (described in section 1 such as use difficulty, lack of collaboration, etc.), we show the interest of a simulator dedicated to the management of transportation network.

The simulator of road traffic proposed is a network composed by links (roads, highways, etc.) and nodes (crossroads). Thus, it is a set of roads. The simulator is intended to be used by experts in security, architecture, transportation and also by non expert like local elected member to obtain agreement on road or infrastructure modifications.

The Figure 3 illustrates example of road traffic simulation. The network is visualized through a video projection on the *TangiSense* table. Tangible objects are used for road sign (traffic lights, no-entry sign, one-way street, etc.). They are manipulated by the users and they interact with other virtual objects. These objects are equipped with RFID tags to be able to modify the network structure by modifying the crossraod type or by reducing the limit speed, etc.

Other crossroad objects are used by being moved, by enlarging the map, by showing the street name, etc. These objects are associated to a tangible agent and used to facilitate the interactions between the users and the table. According to computer use, the actions are more intuitive and can be multiple (according to the number of persons and objects used simultaneously).

The simulator aims to test hypotheses of waiting time reduction in the crossroad, crisis situations management (accidents for example) and infrastructure modifications. Other objectives concern the consideration

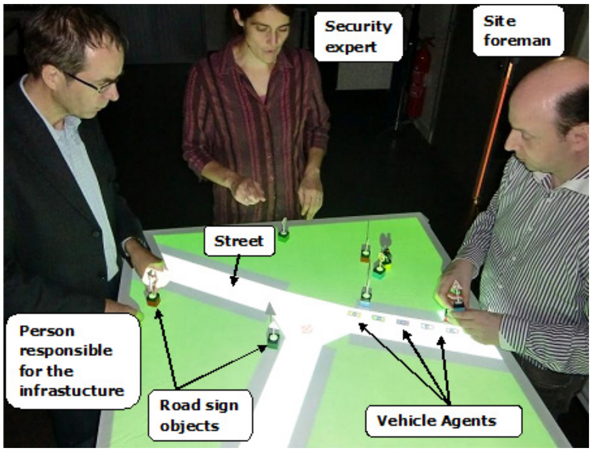
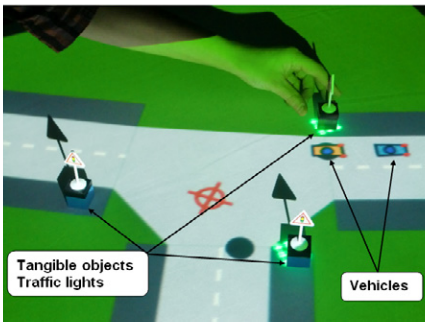


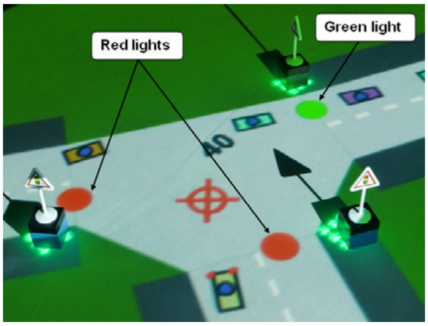
FIGURE 3. A road traffic simulation on the *TangiSense* interactive table

of the user actions on the application while validating the principle of association of virtual agents and tangible agents.

Figure 4(a) illustrated that roads and vehicles are initialized and shown when launching the application. Roads are generated from OpenStreetMap [5] cartography (a free map that enables to simulate the road traffic of any city). Vehicles are associated to virtual agents and generated from an XML file. This file contains their starting point. The XML file concerns also if vehicles move randomly or toward a set of objectives to achieve. Every crossroad is associated to a virtual agent which manages all the entries with roles. To modify a crossroad, the user has to put a tangible object on the road. When the object is detected by the support, we choose to light LEDs beneath it to indicate to the users the taking into account of the object by the system. The agent in charge of the crossroad validates the user action when entrances are affected (Figure 4(b)) and executes the entrance behavior. In the case of a crossroad with traffic lights, vehicles move then according to the lights state.



(a) Establishment of road sign objects at a crossroads



(b) Management of road sign by an agent

FIGURE 4. Changing the virtual agent environment using tangible objects

During the simulation, the virtual vehicles/agents dialogue with the tangible objects/agents put on the table by the users. Figure 5 represents the curve of immediate speed in km/h of a vehicle for a duration of four minutes.

This curve is established from 8000 values that correspond to the vehicle movements. The vehicle starts in the initialization point of the map and accelerates gradually up to 30 km/h (zone of launch) before arriving

5. http ://www.openstreetmap.org/. (accessible in 2012)

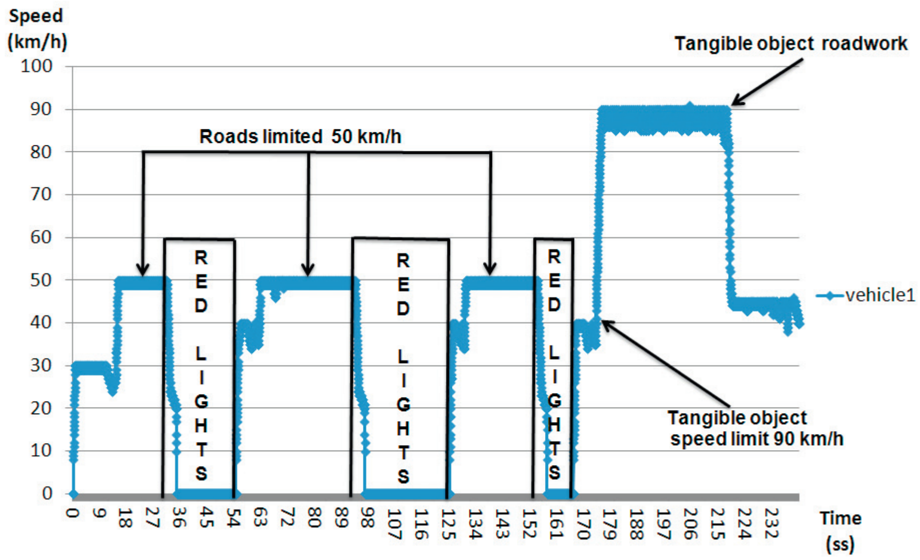


FIGURE 5. Instantaneous speed of a vehicle based on the road signs.

to the road limited to 50 km/h. During the simulation, the vehicle respects the road sign imposed by the users and accelerates its speed according to the light state (red, green or orange). When the light communicates its state to the vehicle agent, the waiting time of the vehicle is more or less long and varies according to the light transition time. For example, when the first light is red, the waiting time is approximately 20 seconds while the second and the third time are respectively of 28 and 8 seconds. The speed limit objet or roadwork object put by users shows the impact on the speed of the vehicle.

Accordingly, we validated such representative example, the principles of agent to tangible and virtual entities operating at the surface of interactive tables. We showed the combination of agents behavior in order to achieve a set of roles during the simulation but also for their interaction/communication during the simulation.

5. Conclusion

In this article, we presented new concepts for managing interaction platforms (such as interactive tables exploiting agents). We propose a solution that handles some existing problems using interactive tables. The complexity of these platforms results from multiple technologies related to object detection and display. It integrates also new forms of interactions such as : multi-user, tactile, etc.

We suggested modeling the interactions between various agent from the proposed typology that represent the tangible and/or virtual entities. These entities are evolving on the interactive table surface. The entities have to be able to interact between them and also with users. The personalization of these entities, virtual or physical, will allow them through their intelligence to realize a set of actions and to adapt themselves to different environments.

Then, we validate the various agent typology on the *TangiSense* interactive table. They interact with both virtual and tangible objects. We highlighted all the elements and the concepts proposed throughout this article to enrich the objects behavior by communication/interaction between them or with human beings using interactive supports.

We intend to expand our work by using several interactive supports (interactive tables, tablets, smartphones, etc.) simultaneously. These supports can be connected through local area network using Internet. The objective is to distributed solutions for solving problems concerning crisis. These problems require strong coordination of actors that can be performed locally (on the same device) or remotely through a set of devices.

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