WINDIS Lab

The cyber world that surrounds us

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***Abstract*—The main goal of the *Wireless Networking and Distributed Interactive Simulation Laboratory - WINDIS,* located at the Computer Science Department of Federal University of São Carlos, is to devise solutions that can better support users in their living activities, improving their life quality and safety. For that, methods, techniques and tools have been developed to tackle the challenges of human-computer interaction in a physical world deeply embedded with cyber capabilities. WINDIS main research interests are augmented reality, tangible interfaces, ubiquitous interfaces, natural user interfaces, distributed interactive simulations for training and games, mobile 3D user interfaces, and human-computer interaction in cyber-physical systems. As a member of the National Institute of Technology on Embedded Systems (INCT-SEC), WINDIS Lab research interests also include post-embedded systems generation, known as cyber-physical systems, and its HCI challenges: building flawless and seamless interfaces in the cyber world that surround us.**

Keywords: Augmented Reality, Tangible Interfaces, Augmented Drag-and-Drop, Distributed Simulations, Cyber Physical Systems, Internet of Things.

I. INTRODUCTION

The *Wireless Networking and Distributed Interactive Simulation Laboratory – WINDIS* (former Networked Virtual Reality Lab - LRVNet) of the Computer Science Department at Federal University of São Carlos, SP, Brazil (http://www.dc.ufscar.br/windis) was founded in 1996. The WINDIS Lab has since then been working on two main fronts: models, methods and tools for the creation of distributed simulations (games and training) that are interoperable, integrable and composable; and on the challenges of flawless and seamless human-computer interaction in a physical world deeply embedded with cyber capabilities. The main research interests include augmented reality, tangible interfaces, ubiquitous interfaces, distributed interactive simulations for training and games, mobile 3D user interfaces, human-computer interaction in cyber-physical systems. The mission of the WINDIS lab is to better support users in their living activities improving life quality and safety. The WINDIS Lab is a member of the National Institute of Technology on Embedded Systems (INCT-SEC) with three main ongoing projects: modeling interfaces as seamless and flawless frontiers between the cyber and the physical worlds; advanced interface for command and control of critical infrastructures security (using tangible interfaces and augmented reality); and distributed interactive simulations. The projects are introduced in the next sections.

II. CHALLENGES IN THE CYBER WORLD AROUND US

Cyber-Physical Systems (CPS) can be defined as systems that present a strong combination of physical computational elements in a coordinated way. These systems are used in countless areas, originating a new era of ubiquitous products. CPS are typically designed as a network of interactive elements and not only standalone devices. Advances in the link among the physical and computational elements will provide a myriad of applications that include: intelligent vehicles and vehicle networks (VANETs) that can provide multiple services to the drivers (even while driving) in the safety, comfort and entertainment areas); highly reliable medical systems and devices; smart energy consumption systems that can demand complex configurations from users (e.g., appliances that cooperate among themselves to reduce energy level; appliances that are controlled from the internet); critical operations in highly risk or inaccessible environments (search and rescue; firefighting, deep sea exploration); distributed games, and much more. Among the multiple challenges of CPS, which involves different areas of knowledge, human-computer interface issues, in the frontier between the physical world and the cyber world, are some of the most challenging. These include: seamless and flawless interfaces; anytime, anywhere and anyhow user access to information; ability to deal with several data input and output devices distributed across physical spaces; dynamic and distributed user interface; user experience-aware interfaces; time and space context awareness; dynamic use of devices and resources, among others. Next sections introduce some of the projects related to this topic.

A. Modeling the Interface

The model-based interface design has emerged as an alternative paradigm to the traditional processes of interface building. Instead of programming an interface using a library or a toolkit, developers can write a specification with a high level specialized language, through diagrams, automata or descriptive UML based languages. This specification can be automatically converted on code or interpreted at runtime, building the appropriate interface. Also, model-based design can consider HCI approaches to compose the model to be used. The most common one is the user-centered design, which can take the user tasks as a basis to build the data model. User-centered design is a modern, widely practiced design philosophy based on the idea that users must be the main focus in the design of any interface. Users and developers can work together to draw the needs and limitations of the users and create a system that addresses the real objectives. Model-based and user-centered designs are being evaluated against typical user interface. The goal is to devise hybrid models that can help developers to create seamless and flawless interfaces.

B. Multi Layer Interfaces to Command and Control

The surveillance of critical infrastructures is one of the applications being developed at the WINDIS Lab as part of the INCT-SEC project (integrative applications group). A layered interface is provided for different levels of command. The objective of the system is to increase efficiency and effectiveness of the existing standard military protocol for the security of critical infrastructures. The seven created layers are Topographical, Personnel Control, Intelligence, Operations, Logistic, Public Relations and Configuration Layers (as shown in figure 1). These layers are configurable using a tangible collaborative command table (Table-Top interface). Figure 2 shows one of the layers in more detail.

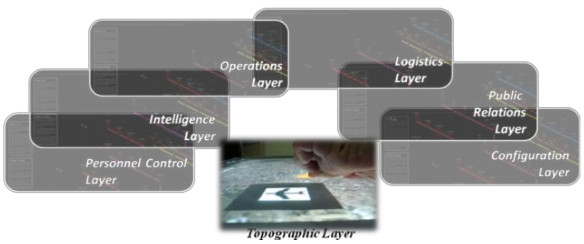

Figure 1. Multi Layered Command &Control Interface.

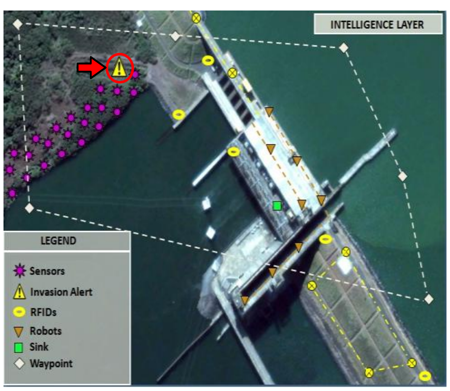

Figure 2. Layered Interface: Intelligence Layer.

III. COLLABORATIVE TANGIBLE INTERFACES: TABLE-TOP

A Table-Top multi-touch tangible device was built at the WINDIS Lab that allows multiple users to collaborate on a common surface using touch and tangible objects (physical objects that have a digital representation, which can be controlled by physically handling the object). Two prototypes were built - Figure 3 shows the latter. This device has been very useful as a visualization tool to our current projects and for the development of new interaction techniques.

Figure 3. Windis Table-Top/Version II-a.

A. Modelling Tangible Interfaces

At WINDIS a high level model to describe both embedded interface characteristics and user actions for table-top tangible, multi-touch interfaces using diagrams and record tables has been devised. The model highlights the whole set of interface elements, composing a more intuitive product for the implementation phase. Our specification model to develop advanced Table-Top Tangible User Interfaces is based on a descriptive language and proposes a simple manner to organize and classify data, where the composing elements are the core of the study to build a new interface and reach the directives of model-based design. The approach is based on an interface record consisting of unique tables. These tables expose the several components of the interfaces, and highlights the interaction factors adding an essential part of the user interface development: the dimension "how", which refers to the way the interaction is done. This approach shows the developer the whole organization of the interface elements and variables close to the final shape that is ready to be implemented (a fragment is shown in figure 4).

Interface	Interface Element	Owner ID	Element Description: Usage	Element Description: Operation
1	Waypoint	1	The waypoint is used as a route for the unmanned air plane	Waypoint is created using a token. Altitude may be changed. It's possible to check its position and remove it.
Requirements				

Part ID	Part Name	Part Type	Part Description	Part Usage
Parts				
1	Core	Button	Flag that represents the core of the waypoint	A tap selects the waypoint. Two taps opens the highlight menu
	Draft			
	Interactions			
	Interaction ID	Interaction Type	Interaction Action	Orientation
	1	Gesture/Tap	Selects the core	-
	2	Gesture/Double Tap	Opens the halo highlight menu	-
Part ID	Part Name	Part Type	Part Description	Part Usage
2	Halo	Image	Halo containing the waypoint menu	A single tap in one of the options will open the option part
	Draft			
	Interactions			
	Interaction ID	Interaction Type	Interaction Action	Orientation
	3	Gesture/Tap	Open the touched option part	-

Figure 4. A fragment of the Table-Top Tangible interface model.

B. Augmented Reality integrated to Table-Top Tangible Interfaces

Since the input in the table-top can be done through tangible objects, there was a problem to be solved when the map (or the interface in general) was zoomed or panned. In these cases the tangible object would lose its position reference. To solve this, Augmented Reality (AR) was added to the system, to represent the tangible objects, so that they only had to be used as a stamp (put and remove) to define their position in the map. After removal, they are represented virtually, in 3D, by using AR (it is necessary to have an HMD or cellular to view the AR). Figure 5 shows a demonstration of an application with AR, where there is the table-top with markers (to track the table position for AR), the application interface with the map, and the AR objects (airplane and tank).

Figure 5. AR representing tangible objects.

C. *From the Table-Top visualization to Anywhere visualization*

To extend the visualization currently obtained with our table-top multi-touch tangible device, large screens can be installed, for instance, in a command and control room to allow a larger number of people to follow eventual emergency operations controlled from the command table. Likewise, mobile devices can also be the visualization vehicles to whatever is shown in the command table. For that, software solutions are being devised for *"drag"* and *"throw it there"* operations.

IV. WEB-AWARE AUGMENTED REALITY

An underexplored challenge within the Augmented Reality area is the use of data and information from the WWW in the real world. Although there is a large volume of information from the web that is used every day by users, when a user needs information from the web to apply in an activity or task in the real world s/he typically does that by searching, filtering, studying, memorizing and even printing this information. Examples include manuals (e.g., changing a shower resistance, growing a garden or assembling equipment) and e-commerce (selecting a sofa in a web site and trying to visualize it at the living room). Although a manual can have in-depth details, the pictures in it can be hard to understand, especially the geometry of the object. In such cases, the use of "web-aware" Augmented Reality can directly project instructions from manuals in the web on the equipment in the physical world (where pieces fit and how they fit), i.e., it can bring a knowledge that was in the Web to the real world. These examples show that there is a gap between the information displayed in the WWW and its application in the physical world, i.e., there is a lack of solutions that allow the transition from the web directly to the real world – this transition currently has to be done by the user. Although there are some tools that started to deal with this issue, such as Layar Reality Browser or Wikitude, these are limited, providing only specific data types, usually based only on geo-localization. Our aim is to devise solutions that can integrate AR and Web, allowing a designer to define which content should be transposed, how it will be shown in AR, what are the possible interactions with the virtual object in AR, and how the object respond to interactions.

A. *Towards Seamless Interaction From the Web to the Physical World*

In [1] it is presented a system developed by a post-doctoral of the Computer Science Department in collaboration with WINDIS lab, in which objects selected via browser, from e-shops in the web, are deployed on the physical world. All the interactions occur via a web browser. The user can drag an object out of the browser to the real world – when the edge of the monitor is reached, visualization switches from the web shop to an AR view. Figure 6 shows a user selecting different appliances using a Wii pointing device and placing them on a desk of the physical world.

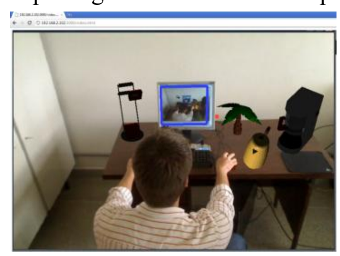

Figure 6. User selecting objects from the web to the physical world [1].

V. DISTRIBUTED INTERACTIVE SIMULATIONS

The complexity of creating different simulation scenarios is a challenge for the area of training simulation. Composing, interoperating and executing distributed existing models are important features to architectures that support and facilitate the creation of these simulations [2]. An innovative system to support creation, management, control and human performance measurement of distributed training simulations is being developed at the WINDIS laboratory [3]. It has aspects of semantic interoperability (using High Level Architecture (HLA) and ontologies), composability (using linear list, logic fuzzy or deterministic finite automaton component) and reuse (of models and components). A set of distributed simulations on different devices in different places (federates), compose a federation. A federation is implemented in three layers: presentation (2D and 3D interfaces), behavior (components) and communication (HLA and RTI), as can be seen in Figure 7. This abstraction layer allows the reuse of components and the creation of different graphical interfaces for use on different devices (desktops, mobile phones, etc), as can be seen in Figure 8 and 10. Because the components are generic and standardized, different training scenarios can be customized for each component (using metadata). Game engines are integrated in the architecture to render the 3D graphics, simulate the physical phenomena, support collision detection and animation, among others. As proofs of concept, training scenarios related to fire fighting are being implemented, with 2D and 3D interfaces, for workstations and mobile phones, as shown in

Figures 8, 9 and 11.

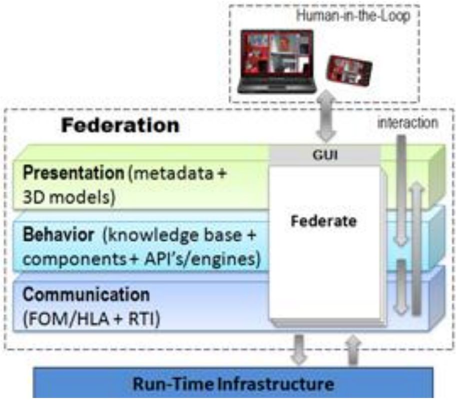

Figure 7. Overview of layer architecture.

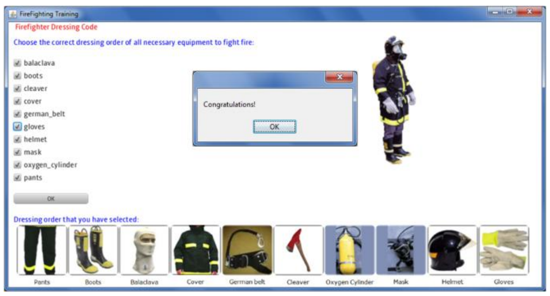

Figure 8. 2D interface for firefighter training in workstation.

Figure 9. 3D house plan for firefighter training in workstation.

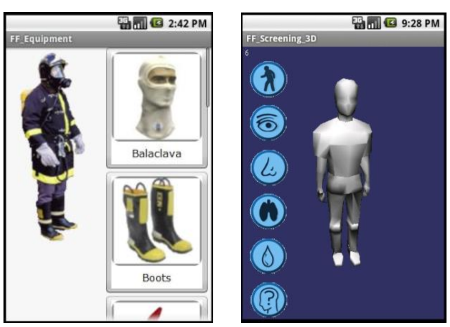

Figure 10. 2D and 3D interfaces for firefighter training in mobile phone.

The mobility of cell phones provides trainees with access to training simulations anytime anywhere without specific infrastructure requirements. Despite cell phones´ resource limitations, they can be successfully used in simpler simulation scenarios as both complement and supplement to more complex simulations running on high-end workstations. At the moment 3D models are being integrated with audio, character animation and physics engines to the simulation scenario. A Human Performance Evaluation Tool is being implemented, that can improve training, and will be integrated to the training simulation system. A 3D fire fighting simulation is being modeled that can interoperate with simulations running on different devices, with the Portico RTI API. The trainee will be trained to manage the Fire Truck's control panel (setting of flow and pressure exerted by the water pump, controlling the amount of available water, among other activities). These flow and pressure are sent to firefighter federates, interacting from notebooks or other devices, that control the hoses, as shown in Figure 11. Although the scenarios described above are on firefighting training, our system can be used for any interactive simulation for the teaching of practical skills in different competences.

Figure 11. Distributed simulation that integrate cell phone and workstation.

VI. Final Considerations

The mission of the WINDIS lab is to better support users in their living activities improving life quality and safety. This paper describes several of the projects in progress at our lab. WINDIS receive students from the computer engineering, computer science, physics engineering, information systems (UFSCar/Brazilian Open University) and electrical engineering courses. Today there are eleven undergrad students, three MSc and six PhD students working on the presented projects. WINDIS lab has collaborations with PARADISE Lab (SITE, University of Ottawa), S Carlos Engineering School Aeronautics Department (EESC/USP) and the Institute of Math and Computer Sciences (ICMC/USP).

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