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Tangible interfaces and dual reality for collaborative problems solving around distributed tabletops

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ABSTRACT

In many domains, the realization of an abstract model implies to cross the valley separating an abstract conceptualization and its actual completion in the physical tangible world. In this paper, we expose our work and domain of researches in tangible interaction and discuss the important aspects of the related domains, such as dual reality. We show next our research methodology followed by the first obtained results. Conclusions and perspectives are then presented.

CCS CONCEPTS

•**Human-centered computing** →**HCI theory, concepts and models**; *Interaction paradigms*;

KEYWORDS

Dual reality, generic tasks, tangible interaction, human-computer interaction.

RÉSUMÉ

Dans de nombreux domaines, la réalisation d'un modèle abstrait implique de traverser la vallée séparant une conceptualisation abstraite et son achèvement réel dans le monde physique tangible. Dans cet article, nous exposons notre travail et notre domaine de recherche en interaction tangible et discutons les aspects importants des domaines connexes, tel que la réalité duale. Nous montrons ensuite notre méthodologie de recherche suivie des premiers résultats obtenus. Les conclusions et les perspectives sont ensuite présentées.

MOTS-CLEFS

Réalité duale, tâches génériques, interaction tangible, interaction homme-machine.

1 INTRODUCTION

Novel HCI-mediated collaborative solutions are required to help users interact efficiently during the lifetime of complex projects, from their preliminary design phase occurring in a conceptual space to the final validation phase occurring in a physical space.

Tangible User Interfaces (TUIs) exploit and take advantage of both simulated and physical environments [17]. They will eventually complete traditional WIMP interfaces (Windows, Icons, Menus, and Pointers). TUIs offer to users the possibility to apprehend and literally grasp the meaning of complex datasets by manipulating insightful tangible representations of these datasets in our physical world. These interaction metaphors are actually bridging both environments: the physical one and the simulated one. A very relevant field of application of TUIs is Interactive Tabletop and surfaces. In such interfaces, the interaction metaphors are directly displayed on the surface of the table, which is also capable of recognizing input gestures as well as tangible objects lying on its surface.

While using an interactive tabletop, multiple users have the possibility to collaborate and solve complex problem together. Interactive tabletops have many fields of application such as acoustic and musical creation, video games, medicine, archaeology, geology, industrial design, and transportation network planning [11][7][16]. When interconnected, interactive tabletops enable users to collaborate remotely while sharing the same collaborative virtual environment [12].

Our research motivations come from the basis that there are no models, to our knowledge, for bridging the dual reality worlds, particularly on tangible tabletops. We aim to design a novel theoretical framework accounting for interaction and representation metaphors that operate in dual reality spaces. These metaphors should faithfully convey the actions of local and remote users as well as users themselves.

This paper is organized as follows: in Section 2 we present the concepts of tangible interaction, dual reality and generic tasks. In Section 3 we discuss our research methodology and its steps. In Section 4 we describe and illustrate our first results obtained this year. Finally, a concluding Section closes the paper by exposing future research directions.

2 STATE OF THE ART

In this Section, we expose briefly the state of the art and some definitions of our research concepts. Also we present the most remarkable conducted works in each field.

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2.1 Dual reality

The concept of dual reality was proposed by Lifton in 2007 in his PhD thesis [14] as "an environment resulting from the interplay between the real world and the virtual world, as mediated by networks of sensors and actuators. While both worlds are complete unto themselves, they are also enriched by their ability to mutually reflect, influence, and merge into one another". In [13], the authors described a system that uses the Dual Reality paradigm: by a plug sensor node, it demonstrates the information flow from the real world to a virtual environment, implemented in the Second Life Online Virtual World¹, where the data sensed from a real object (such as light, temperature, motion, sound and electrical current) influences the corresponding digital representation.

One of the late works is realized by Kahl [8], where he discussed the design of a management tool to monitor smart spaces in which sensors and actuators are installed and exchange data with the accordant services (such systems can be found in smart factories and urban management control stations). The author proposes a generic framework for controlling smart spaces. Additionally, this tool offers the possibility to add virtual services and to run simulations. He developed a two-component management dashboard. The real component, also called physical component, includes the sensors and actuators while the second component includes a virtual counterpart of the first one represented in three-dimensional model. These two worlds are connected and can influence each other according to the Dual Reality paradigm defined in [14].

In another paper of Kahl, co-authored with Burckert [9], the authors proposed an event-based communication infrastructure in order to enable interconnection between different services in an instrumented environment. The given description of the architecture matches the criteria of the Dual Reality Paradigm, defined by Lifton [14], as an interface between both worlds. Many application fields of the dual reality have been stated in several papers such as the management of warehouse and retail [10] and the virtual factory which mirrors a real world chocolate factory² located in San Francisco, USA, by Back et al. [3].

Another example consists of a model of a virtual apartment [15] in dual reality, the user can turn on or off the light of a lamp in the virtual environment. In the real counterpart, the light is turned on or off as well remotely by the software and vice-versa.

2.2 Generic tasks

2.2.1 The concept of generic tasks. The need for generic tasks evolves from the fact that the level of abstraction of much work in Knowledge-Based Systems (e.g rules, frames, logic) is too low to provide a rich vocabulary for knowledge and control. Chandrasekaran [4] provided an overview of a framework called the Generic Task approach that proposes that knowledge systems should be built out of building blocks, each of which is appropriate for a basic type of problem solving. Each generic task uses forms of knowledge and control strategies that are characteristic to it, and are generally conceptually closer to domain knowledge. He follows next in the same paper [4] that the abstract specification of a generic task is:

- The function of the task. What type of problem does it solve? What is the nature of the information that it takes as input, and produces as output?
- The representation and organization of knowledge. What are the primitive terms in which the forms of knowledge needed for the task can be represented? How should knowledge be organized and structured for that task?
- The control strategy. What control strategy (inference strategy) can be applied to the knowledge to accomplish the function of the generic task?

Clancey has also worked on generic tasks and operations, beside knowledge engineering. We find in his famous paper [5] a generic model for operations (tasks) that we can do to or with a system. Figure 1 and Figure 2 summarize hierarchically these generic operations. Operations are grouped in terms of those that construct a system and those that interpret a system, corresponding to what is generally called synthesis and analysis.

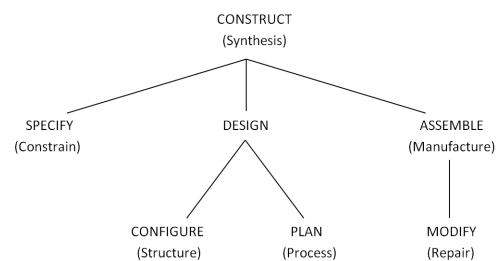


Figure 1: Generic operations for synthesizing a system.

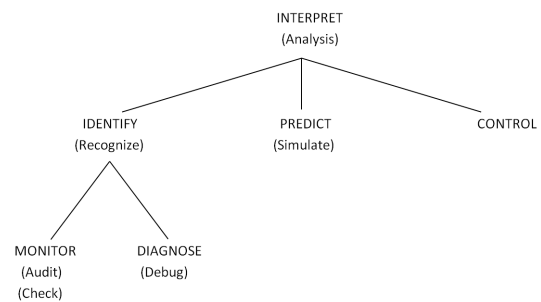


Figure 2: Generic operations for analyzing a system.

Clancey describes that the terms between brackets are common synonyms of the generic operations (in capital letters). He also explains in [5] that INTERPRET operations concern a working system in some environment. In particular, IDENTIFY is different from DESIGN in that it requires taking I/O behavior and mapping it onto a system. Whilst PREDICT is the inverse, taking a known system and describing output behavior for given inputs. Moreover, "Simulate" is a specific method for making predictions, suggesting that there is a computational model of the system, complete at some level of detail. For the CONTROL, not often associated with heuristic programs, takes a known system and determines inputs to generate prescribed outputs [18]. Thus, these three operations,

¹<http://secondlife.com>

²TCHO VENTURES, INC. <http://www.tcho.com>

IDENTIFY, *PREDICT* and *CONTROL*, logically cover the possibilities of problems in which one factor of the set input, output, system is unknown.

Further explanations are given in [5], when the author notes that *MONITOR* and *DIAGNOSE* presuppose a pre-existing system design against which the behavior of an actual, running system is compared. In the case of *MONITOR*, one detects discrepancies in behavior (or simply characterizes the current state of the system). In the case of *DIAGNOSE*, one explains monitored behavior in terms of discrepancies between the actual (inferred) design and the standard system.

The Design is taken to be the general operation that embraces both a characterization of structure (*CONFIGURATION*) and process (*PLANNING*). *DESIGN* is conceptual, it describes a system in terms of spatial and temporal interactions of components. Therefore, The idea of "executing a plan" is moved to the more general term *ASSEMBLE*, meaning the physical construction of a system [5]. Also from the same reference, *SPECIFY* refers to the separable operation of constraining a system description, generally in terms of interactions with other systems and actual realization in the world (resources affecting components). Of course, in practice design difficulties may require modifying the specification, just as assembly may constrain design (commonly called "design for manufacturing").

2.3 Tangible user interfaces - TUI

Ullmer and Ishii in their paper [17] say that "tangible interfaces give physical form to digital information, employing physical artifacts both as representations and controls for computational media". They add that they (TUIs) "couple physical representations (e.g., spatially manipulable physical objects) with digital representations (e.g., graphics and audio), yielding user interfaces that are computationally mediated but generally not identifiable as "computers" per se".

On tangible user interfaces, the interactions are done using a tangible object on the surface (of the tabletop for instance) [6]; this last is not considered as a simple display screen, but well as a space for manipulating objects, as a system input function.

Tangible tabletops are interactive tabletops that use tangible objects to manipulate data and communicate with the digital world. Among these, we cite the TangiSense which allows interactions with virtual objects (using LEDs or an overhead video projection) as well as with tangible objects [2], the *Symbolic Table* which allows to manipulate tangible objects without a digital display on the surface [1].

3 RESEARCH METHODOLOGY

Our research methodology consists of having a solid literature basis on both tangible interaction and dual reality first. Second, getting familiar with the tangible tabletops (we use TangiSense tabletops, see Figure 3) development environment and tools. In fact, we have already reappropriated an existing software library of the TangiSense (designed by the Rfidees company), to be used for developing applications, and also developed an application to remotely control dynamic tangible objects on the TangiSense tabletop, equipped with RFID technology. Third, we aim to write and

publish articles all along with developing adequate demonstrators to the context. Beside of this, implementation, tests and evaluations are required for each demonstrator and will be conducted on at least two connected interactive tabletop systems. For the time being, an article we wrote and submitted recently has been conditionally accepted in IHM'17 conference, in Poitiers.

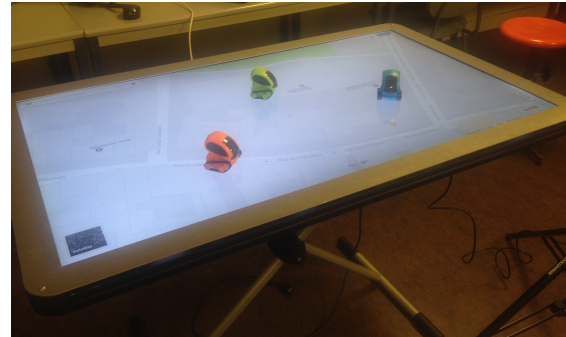


Figure 3: The TangiSense tabletop

Other researches and work will be conducted in DFKI³ in Saarbrücken in the Ubiquitous Media Technology Lab⁴, on other systems than Tangible tabletops, starting from next year and for several months. These researches will be subject to several papers.

4 FIRST RESULTS

We have recently worked on a paper entitled "Reformulating Clancey's generic tasks for bridging both sides of dual reality" [19]. It proposes a generic model based on Clancey's ontology of generic tasks and the dual reality paradigm. This model aims at bridging the real and the virtual sides of dual reality in the generic context of task/project realization, in a way that interactions in one world are duplicated in the other world. This generic model shown in Figure 4 for mapping between the two worlds and ensure a generic manner of interaction from and towards real and virtual worlds.

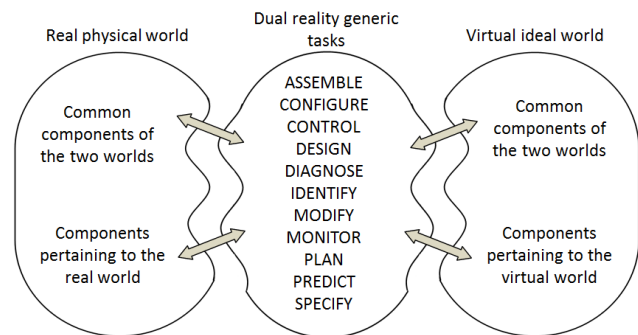


Figure 4: Generic bridging model between the real and virtual worlds.

³German Research Centre for Artificial Intelligence

⁴<http://umtl.cs.uni-saarland.de/>

Ongoing work is about implementing this model in a dual reality application for crisis management, which consists of controlling robots on field using the TangiSense interactive tabletop and mobile tanks (toys). Any action in one world (be it real or virtual) will be duplicated and performed in the other world to maintain the similarity between these two worlds.

5 CONCLUSION

In this paper, we have seen a brief state of the art on dual reality, tangible interaction and generic tasks. We have also presented our research methodology and our vision for the coming years of this PhD thesis. We exposed our first results in this domain and how we intend to improve them and do further researches.

The ongoing work is part of the perspectives of our paper related to Clancey generic tasks model reformulation [19]. It should demonstrate several tasks and should allow to do serious evaluations and tests. The development of a first demonstrator of dual reality application is also in progress.

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