Network Force-Feedback Applications for Hospitalized Children in Sterile Room

Nicolas Tarrin
Research Engineer
Teamlog - France Telecom R&D
+33 622 18 82 24
nicolastarrin@yahoo.fr

Grégory Petit
Human-Computer Interaction Trainee
France Telecom R&D
+33 680 03 05 84
gregory_petit_ihm@yahoo.fr

Denis Chêne
Ergonomist
France Telecom R&D
+33 4 76 76 43 85
denis.chene@francetelecom.com

ABSTRACT
This paper describes the development of 3D network applications with force feedback for and with hospitalized children. These applications are built on an innovative multimodal platform which includes networked 3D graphics, sound and force feedback. One goal of this research is to improve the life quality of children isolated in sterile rooms during their stay in the hospital by providing them the ability to physically interact with other people and to enjoy themselves. Another goal is to elaborate a haptic design methodology where users are involved in the design process.

Keywords
Multimodal, Haptic interaction, Hospitalized Children, Accessibility.

INTRODUCTION
Children in sterile rooms are extremely isolated, separated from their family, having very few contacts with other people in general. This comes at a time when they have to deal with the difficultes of severe treatments, as these children suffer from serious diseases such as cancer.

In hospitals such as CHU Brabois, Vandœuvre-lès-Nancy’s children hospital in France, the sterile rooms are beginning to be equipped with phones, a local video network, and/or laptops with internet access. This facilitates as much external contact as possible.

However, these children still very rarely have physical contact with other people, whereas touch is an essential sensation for human relationships. One of the primary functions of the sense of touch is to communicate emotionally with another person or other living thing [3]. The hand, our major touch organ, is an important communication organ [2].

Our staff mainly does research into the use of haptic modality in new network services. “Haptic" is defined as the sense of touch (using the skin), and the perception of self-position and self-motion (using the inner ear, tendons, and muscles). This project is 60% technical innovation and 40 % design process.

Main Objectives
The main objective of this research is to provide children in sterile rooms a new technology that will do three things: allow them to interact with people outside of their room using the sense of touch, to provide physical activity, and be entertaining.

The first section of this paper will describe the software platform which integrates our research with 3D interaction technology, force feedback, gesture transmission over a network, and new technologies for accessibility. In the next section, we will introduce how we dealt with the constraints of co-design with the children and the hospital staff. We will then introduce our first results that include network force-feedback game prototypes. Finally we will conclude with our perspectives.

TECHNOLOGY DESCRIPTION
The haptic modality is challenging in terms of technical issues and applications. As we described in the introduction, it is very important for communication. However, applications that make use of haptic interaction are still very rare.

Technical issues around haptic modality are directly linked to one of its important characteristics: the threshold of perceiving a haptic sensation varies between people, but in general it is 10Hz-400Hz. According to the Nyquist-Shannon sampling theorem, we decided to use twice this maximum frequency plus a tolerance to arrive at 1 kHz.

Moreover, haptic modality is an action/perception sense. Haptic interaction feasibility over the network depends heavily on the network delay: a good network interaction for grasping would approximately require a 15ms-delay.

We are studying the network constraints, especially with regards to the gestures transmitted between two people. Haptic signal transmission quality is under study regarding network delays and packets loss. Different experimental conditions are being explored: high data transfer rate with few errors in a local network to low and unreliable transfer over a distant network.
This research will contribute to a software platform that can be used by our entire research staff.

Platform Description

This platform is composed of distinct elements, each of which provides answers to specific needs and can be easily combined.

Force feedback modules provide an interface to various force feedback devices (Sensable™’s Omni™, PHaNTom® Desktop™ and 1.5, Force Dimension’s Delta3D). These devices allow user to touch and manipulate virtual objects.

Network modules integrate specific protocols and tools for gesture and images transmission. A special module manages the network delay. It is used to predict the position of the distant elements if the network delay is too long. Then, the force feedback is extrapolated as a function of these estimated positions in order to provide a better haptic sensation.

Interface modules play sounds and render graphics. A specific module also integrates a physics simulator for correct mechanical simulation of virtual objects (weight, friction, collision detection…). For rapid 3D scene creation and modification a classical 3D editor uses a plug-in that adds mechanical characteristics to objects in the scene and they are imported into the physics simulator using a file conversion pipe.

Networks

A high bandwidth local network has been installed in the hospital from the children's rooms to the outside and connecting each of the children's rooms. A high bandwidth connection has been set up between rooms in different hospitals and a standard ADSL network has been set up between each child's room and their parents' home. Then we will be able to test several impacts of the network delays and dead reckoning using force-feedback display shared through the network.

CO-DESIGN PROCESS

We are following a co-design process that takes into account qualitative and quantitative data from usage analysis. Creativity, human-computer interaction, innovation and gameplay adjustments can be made using qualitative data. Ergonomics validation, network studies and non-regression development can be made using quantitative data. We will collect the data using the methods described by John and al. [1].

The first step of the co-design process is a qualitative one. We wanted to evaluate the children's acceptance of force feedback applications in these extreme situations where the users are very isolated. The goal of this research is to bring people together with technology. Will our technological solution be a sufficient substitute? Will it be accepted as a relationship strengthening or as a "just another medical tool"?

Co-design Plan with Children in Sterile Rooms

As Norman said: "It is time to insist that the machine is developed for humans; we have to remove from the technologists the responsibility of conceiving the product"[4].

We have decided to follow an iteration prototype process to develop this multimodal application. In this case, we had particular constraints to take into account. The sterile environment and possible contamination carry important technical risks. The availability of the children is also quite limited. This does not allow as much interaction with the children as we would like.

We first met the hospital staff to establish how to present the project to the children and how to observe their reactions. This staff is composed of educators who take care of the everyday life of the children. We asked the children to explore several haptic applications (the writing, geometry and game prototypes described above). The
hospital staff agreed that these kinds of applications have to be tried directly by the children.

![Figure3: Air Hockey demo](image)

The first step was to present in the internal hospital television show some of the well developed applications as well as the early 3D game prototypes with force feedback (see Air Hockey Figure3).

Then, in order to collect ideas from the children, it has been decided to install applications and devices early on so they can all try out the new modality and what it can offer and evaluate its different features. Interviews of the children and their educators will come afterwards.

We decided to make a video in our work place in order to present both the applications and how they are made to the children. The aim of this video is to show them that they can be involved in the design process even if they are locked inside their room. This video will be periodically broadcasted on the internal television channel of the hospital.

The next and most important part of the co-design phase with the children is composed of several meetings with them so that we can collect new ideas and feelings about the applications. We will also take advantage of these meetings to install new versions of the applications. Finally we will be able to identify the advantages of the force feedback network interaction with regards to improving the communication between isolated children.

We will repeat this process by integrating the children's ideas into our software. Bit by bit the children will be able to see their design choices affecting the applications that they are testing with us.

At the end, we should be able to organize collaborative meetings with several children in order to validate the applications’ performance with more than two users.

**Co-design: First Qualitative Meeting**

In order to introduce ourselves to the children and to show them demos with the haptic device we participated in a show on the internal television channel of the hospital. This channel was the best way to have a first contact with the children.

Two hospitalized children of age 11, who were not restricted to sterile rooms, were present to test the demos. It was important for us to know how they would react to a device they had never touched. Two other children watched the presentation on TV from their rooms, with the possibility of asking questions by phone.

The purpose of this first meeting was to gather comments and reactions from the children in an informal way. We wanted to identify their main needs. The following results were gathered from this first demonstration to the children.

**RESULTS**

Our first exchanges both with the hospital staff and with the children have been extremely rewarding. The generosity, involvement and open-mindedness of Vandœuvre-lès-Nancy’s hospital staff help the children forget the difficulties they encounter every day. While keeping the welfare of the children their first priority, the staff made important steps toward innovative technological solutions built around the children, and they have drastically facilitated our work.

Laptops and a high-speed network have already been installed in the sterile rooms, and tools such as videoconferencing software, chat clients and video games are a part of the everyday life of the children and their parents. Most of the children miss playing physical games and the sensation of touch. They did not realize that their sense of touch was so important when they were in good health.

They really liked to use the force feedback device and were very enthusiastic about sharing their ideas about how to improve the demos. We discovered that they were eager to contribute to the application design and that the co-design activity by itself meets everybody needs: improving communication inside and outside the sterile rooms.

Among the different demonstrations presented, we noticed their strong interest in games or competitive situations. Indeed, the hospital educators had them play games together, such as dart challenges, using a webcam to compare their scores.

**Games**

During the live show at the hospital, we demonstrated difference pieces of software in order to collect children's impressions. The ones which were controlled by the haptic device were the "Air Hockey" demo (Figure3), the "Badaboum" demo (a demo where you have to build a tower using several geometric objects), and the writing software (see "Platform Description" section).

We also presented mouse controlled software that uses the same physics simulator that our demos use. We wanted to show other ideas to the children and ask them if they prefer using a mouse to the haptic device. For example, we showed them a Jenga demo (a tower composed of blocks which you gradually take away without allowing the tower to collapse).
One demonstration was game oriented, providing 3D graphics and force feedback interaction, but what attracted their attention as well were basic timed writing exercises, such as an activity in which the children jump hurdles using the haptic device. They were very interested in having their performance for a particular task scored. Indeed, they rapidly improved their scores in the hurdle game even if, at the beginning, their performances were low.

When we observed them playing, we noticed that they really liked games that allowed them to build and destroy things.

The children really enjoyed games in which they have a real opponent in front of them whom they have to defeat. The Air Hockey game was a good example of this.

Ergonomics
We have to take into consideration many ergonomic criteria, such as usability, the ease of manipulation, navigation and action and design for all (see further).

The quality of the hands-on experience must be as good as possible. To accomplish this, it is especially important to identify the optimum settings of a good haptic interface, and to provide a good haptic sensation through precise computation and transmission. The underlying technical challenges are very important for the end user's experience.

Adaptability for different ages must also be taken into account. Indeed, some games were not suitable to the user's age. Some exercises of the reading and writing software were too difficult for eleven-year-old children. They had to write an Arabic letter, the first time with haptic help, and then rewrite it on a white paper without reference. The cognitive memory needed for this task was too heavy for young children.

Graphics
One of our demonstrations had poor graphical aspects (the game prototype). We noticed that the presence of force feedback could reduce the importance of graphics compared to classical video games. This might be explained by the fact that children just discovered the force feedback sensation, but this must be studied further.

Creative Activity
We asked the children what they liked to do when they were not at the hospital. One child liked to play djembe (an African percussion instrument). Making an application that appeals to the creativity of the children, such as a game in which the children can build things, would be a good way to stimulate the children.

Music applications, like an interactive drum with force feedback, or cooperative building (or destroying!) games, where users feel each other through the network and could unite their efforts to succeed, would be interesting applications to develop. For example, they could coordinate their movements to lift up various objects in order to build a structure. The touch sensation would be felt by the children.

Accessibility
One of the children had to protect his eyes against strong light, and thus wore dark protection glasses. He was not able to read the score of the hurdle game for example. Children we will meet may have very different needs in terms of accessibility, depending on their condition. One important point is to be able to provide a means of interaction as complete as possible. Our platform should answer these needs. In this example, providing an auditory timer could be easily implemented. It seems that we cannot get away from a "design for all" approach.

CONCLUSION AND PERSPECTIVES
Our main goal was to involve the children in the development of this project in order to make haptic applications that they would enjoy. They took this role to heart are already enjoying the co-design aspect of this project. The medical staff was won over by the project.

At the moment we are in the co-design iterative process with the children. We will focus on two games that permit haptic communication with an external person. One of which will have very complicated shared gesture interaction in order to test different network parameters and the other application will have less restrictive gesture interaction in order to be sure that we can offer a functional game to the children. Finally, pedagogical content must be approved by the medical staff.

Then we will develop some games at various difficulty levels and we will have further meetings with the users in order to quantify gameplay, ergonomics, network performance, and social impact. For this last point, we would like to compare benefits associated with each modality in the communication between people: simple visual elements of the game plus haptic interface, the same with added sound, the same plus webcam and audio conference, or just a video and audio link. We acknowledge that all of these elements are necessary for social interaction.

ACKNOWLEDGMENTS
We thank the children and the staff of CHU Brabois, Vandœuvre-lès-Nancy's hospital in France, especially Marie-Hélène Petit and Aline Albiné.

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