

The Virtual Factory:

Exploring 3D worlds as industrial collaboration and control environments

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ABSTRACT

This project investigates practical uses of virtual, mobile, and mixed reality systems in industrial settings, in particular control and collaboration applications for factories. In collaboration with TCHO, a chocolate maker start-up in San Francisco, we have built virtual mirror-world representations of a real-world chocolate factory and are importing its data and modeling its processes. The system integrates mobile devices such as cell phones and tablet computers. The resulting "virtual factory" is a cross-reality environment designed for simulation, visualization, and collaboration, using a set of interlinked, real-time 3D and 2D layers of information about the factory and its processes.

KEYWORDS: 3D applications, virtual worlds, x-reality, mixed reality, remote collaboration, remote monitoring, remote control, data visualization, collaborative tools, cross-reality, sensors, pervasive computing, simulation, mobile computing.

INDEX TERMS: H.5.1 [Multimedia Information Systems]: Artificial, augmented and virtual realities; H.5.3 [Group and Organization Interfaces]: Computer-supported cooperative work; I.6.3 [Simulation and modeling]: Applications.

1 INTRODUCTION

To understand appropriate uses of cross-reality [1] and virtual reality technologies in industrial settings, we have teamed with TCHO [2], a real working chocolate factory in San Francisco. To aid this kind of collaboration, we import real-world sensor data (such as temperature and machine state) and multi-camera imagery from the real factory floor [3]. For example, inside the virtual factory world, you can visit a machine to read its sensors' status, or move closer to it to trigger an inworld video overview of its function. This multi-user collaborative space can be used for tasks like remote factory observation, virtual inspections, customer visits, education/training of employees, process monitoring and inventory tracking. On the mobile side, an experimental iPhone app provides mobile laboratory monitoring and control. In the chocolate development lab, where intricate processes are developed to bring out the best in each bean, accurate tracking of time and temperature are essential. The app allows a real-time view into the lab via pan-tilt-zoom steerable camera and individual control over machines and sensors. Data from the lab is also represented in the 3D virtual world. Finally, a network of high-definition cameras installed around the chocolate factory streams live video to web, virtual world, or iPhone displays. These systems were deployed at the real-world factory and lab in late 2008 and 2009, and are now in beta development.

Through this mashup of mobile, social, mixed and virtual technologies, we hope to create industrial systems for enhanced collaboration between physically remote people and places – for example, factories in China with managers in Japan or the US.



Figure 1. An avatar in the Multiverse-based Virtual Factory, top, and a photo of the real factory floor under construction.

1.1 Mirror worlds and data layering

For the Virtual Factory project, we expect to build out a number of applications, based on a virtual teleoperation, simulation, visualization, and collaboration environment. We currently have two: a 3D multiuser world, and an integrated iPhone app. The information environment itself is a complex set of interlinked, real-time 3D and 2D layers of information about TCHO and its processes, with collaborative/social network functionality as well for multiple users. We can switch between layers of views or mini-apps designed for specific purposes.

Data layers are designed for particular user types, and include recorded HD video (for tours and training), live multi-camera feeds, imported sensor data from a MySQL database that tracks and controls factory machine states (for operators and managers),

animations of machine interiors (for tours and training), and import and display of documents (such as doc, ppt, pdf, and xls). These data layers show up inside a realtime, multi-user 3D world (we have built several versions of the Virtual Factory so far on different platforms: in Multiverse[4], Wonderland[5], RealXtend/OpenSim [6] and Qwaq Forums/Teleplace[7]). Because the world is multi-user, people can talk with each other; local and remote groups or communities can develop, or mirror those in the real world.

1.2 Collaborative applications for different users

One of the ideas behind the Virtual Factory project is to create 3D information environments that enable a number of different collaborative applications, depending on the type of user in the virtual world. These collaborative applications are aimed at specific tasks performed by specific types of users. At the TCHO factory, we have identified seven potential types of users, with subsets of each:

Managers (though the CEO and the operations manager need different information and level of detail)

Operators (technical, mechanical, maintenance – some with expertise on different machines)

Trainees (learning each machine's processes and getting an overview of the whole multi-day chocolate process)

Tour guides (for real-life tours, and virtual world tours – or both at the same time)

B2B clients (technically knowledgeable, more interested in process and product reliability)

Suppliers and sources (cacao farmers and producers, suppliers of other materiel)

Consumer customers (real-life, point-of-purchase in the TCHO store, Web-based virtual world online)

For these different user types, collaborative applications can be used for tasks such as remote factory observation, machine monitoring, process/workflow monitoring and analysis, virtual inspections, mobile/virtual teleoperation, b2b customer visits (augmented reality), education and training of employees, visitor tours, and inventory tracking.

1.3 Virtual Factory deployment

The Virtual Factory building and machines were modeled from blueprints, hand measurements, and photos, and tested on several virtual world platforms. As a first deployment, a large display (a Samsung 56" LCD screen) and a client/server computer running the Multiverse version of the Virtual Factory were installed on the real factory floor. An animated tour in the virtual world moves an avatar from one machine to the next, showing HD video on the function of each machine. However, this is still a full-featured virtual world – a user can choose to break away from the automated tour, and to use normal inworld features such as text chat, audio chat, etc. with other inworld users. This system is currently in daily use on the factory floor by TCHO personnel for general and business client tours.

2 MOBILE MIXED REALITY: IPHONE MONITOR AND CONTROL APP FOR THE TCHO DEVELOPMENT LAB

Integrating mobile with virtual and mixed reality systems is a logical extension for industrial smart environments. With this in mind, we have built an experimental iPhone app that provides mobile laboratory monitoring and control. In the TCHO lab, where intricate processes are developed to bring out the best in each bean, accurate tracking of time and temperature are essential.

The iPhone application gives the user a real-time view into this lab (via PTZ or Pan-Tilt-Zoom steerable camera) and imports real-world sensor data as well.

The tasks on the main factory floor differ from the tasks in the smaller TCHO development lab, where cacao beans from different growers and geographic areas are analyzed and new recipes developed for them. The mobile system is integrated with both the multi-camera surveillance system and the database underlying the virtual factory worlds. Using the iPhone, machines can be turned on/off, temperatures and timer settings can be read and changed, and lab environmental controls can be changed. The iPhone app provides greater accuracy and transparency for the people operating the TCHO Lab, and runs via a database that allows accurate tracking over months of the myriad combinations of cacao bean selection, treatment, and recipe development.



Figure 2. Screen shots from the iPhone app for controlling and monitoring machines in the chocolate development lab.

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- [7] Teleplace: <http://www.teleplace.com/>