6th Sense System Augmented Reality Chemical Plant Supervision System

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Abstract—**This project aims at the realization of a wearable supervision system for chemical installations based on the augmented reality paradigm. Augmented reality improves the perception the operator has of his surrounding environment by overlaying real-time computer-generated images onto the real world. This document describes the work realized from the beginning of this year. The first step was to implement a simplified version of the system to show that such a system is feasible and usable for the supervision of chemical plants. This was done in the prototype α1, which was released in April 2004. Based on knowledge acquired during the design and the implementation of the first simplified prototype called α1, a complete and better version of the system, the prototype α2, is currently being developed.**

Index Terms— **Remote engineering, augmented reality, voice recognition, voice synthesis, wearable computer, embedded system, tracking, wireless communication, supervision, chemical plant.**

I. Introduction

Today's industrial chemical plants are fully automated and managed from a supervision centre. Operators drive these installations from a control room where control screens are located. When a human intervention is needed on a particular part of the installation, an operator must physically go to the required place and has no access more to the control screens and automated commands. Therefore, he needs to be assisted by one of his colleague who still is in the control room. The two operators communicate by radio. The on-site operator gives his orders to the control room operator who executes them. Security problems may arise if the control room operator misunderstands his colleague's orders. [Figure 1] shows the architecture of the test plant and its control system used for this project.

The test installation (labelled "Chemical plant" on [Figure 1]) is a semi-industrial chemical reactor having a capacity of fifty litres. The plant's elements (valves, sensors, etc.) are all connected to a *Siemens S5* programmable logical controller (*PLC*). The *PLC* samples the electrical signals generated by the various elements. The executor and the supervisors are implemented in *LabVIEW™* on traditional personal-computers running *Windows XP*. The executor uses *H1 Ethernet (industrial Ethernet)* to communicate with the *PLC*. The communication between the executor and supervisors occurs through an OPC (OLE for Process Control) interface. This *OPC* link is implemented with the *LabVIEW™ Datalogging and Supervisory Control* (*LabVIEW™ DSC*) module.

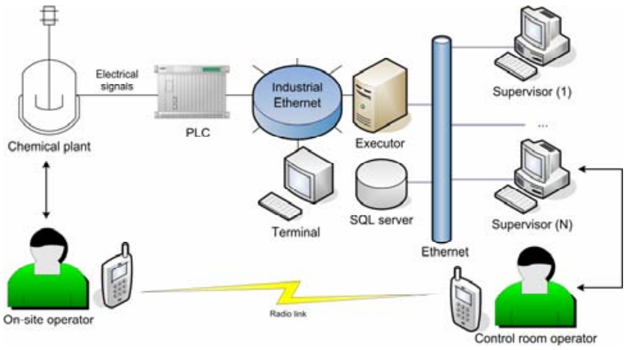

Figure 1 – Test plant's architecture

II. Goals

The aim of this project is to develop a wearable supervision system for chemical plants based on augmented reality. [Figure 2] shows the integration of the *6th Sense System* with the existing control system. The system can be decomposed in three main facets: a supervision facet, an augmented reality facet and a wearable facet.

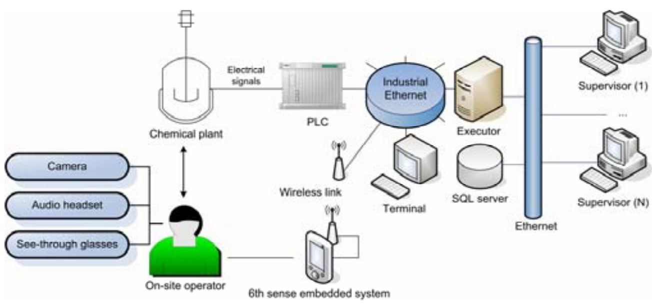

Figure 2 – 6th Sense System's integration

A. The supervision facet

First of all, the *6th Sense System* is a supervision system, meaning it must give to the on-site operator the ability to do the same things as if he were in the control room. To be useful, the wearable supervision system must at least provide the following operations:

- Monitor and change the plant's status (out-of-order, manual, automatic).
- Monitor and change the phases' status (start, stop, hold, restart, abort).
- Monitor and change (forcing) the value of a specific element.
- Plot the evolution of an element's value over time.
- View the list of active alarms and acknowledge them.

B. The augmented reality facet

Augmented reality (AR) is a way to improve someone's perception by overlaying real-time computer-generated graphics onto real world objects. "Instead of diving the user into a synthesized, purely informational, environment as it is done in virtual reality (VR) based systems, the goal of AR is to augment the real world with information handling capabilities" [2]. AR offers a new paradigm for human interaction with computers. There are two essential components to make an augmented reality system work:

1. *A head-mounted display (HMD).*
   The operator will be equipped with optical see-through glasses [Figure 3]. Optical see-through glasses are devices through which the user can view the real world as well as computer-generated graphics projected on top of that world. The HMD is the core of an AR system, because it is the device allowing for actually augmenting the real-world with computer-generated graphics.

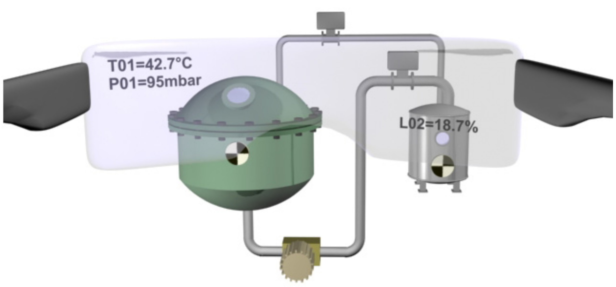

Figure 3 - Optical see-through glasses

2. *A tracking system.*
   To be able to deliver contextual information to him, the computer must know where the operator is located and where is looking to. This implies that the system must precisely track the user's position and head's orientation in real-time. The idea is to use an optical tracker system, which uses a camera to detect artificial landmarks in the surrounding environment and computes the camera position and orientation by calculating the inverse projective transformation from the projective plane (the image) to the projective space (the real world).

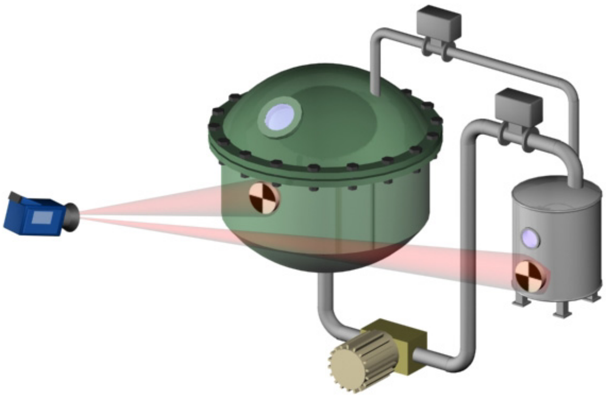

Figure 4 - Optical tracker

C. The wearable facet

The system must be "wearable", meaning it should be worn like a piece of clothing. The camera, the audio headset and the see-through glasses are attached to the operator's helmet and a processing box is attached to his belt. The system must provide a hands-free user interface and respond to some wearability constraints so an operator can efficiently and comfortably work with it.

Figure 5 - Helmet prototype

In order to work properly and efficiently on the plant, the operator's hands have to be totally free. The operator must be able to give commands to the system without any cumbersome input device such as a keyboard or a mouse. This is achieved by a voice recognition module which listens to the operator and translates his voice into commands. Using voice recognition allows the operator to work totally hands-free. He can give commands to the system in the most intuitive way, i.e. natural language.

The system must also be able to give the operator a feedback of some sort. This can be achieved through voice synthesis or through reality augmentation. The feedback mechanism will not use only one or the other way, but a clever combination of them. The challenge is to combine voice synthesis and augmented reality so that, on one hand, the user will not be annoyed by too long or too repetitive vocal messages and, on the other hand, the user's field of view will not be too restricted by irrelevant information.

The vocal interface allows the user for hands-free operations, that's great but not enough to make the system wearable. The wearability issues, both technological and ergonomic, will not be discussed here. They will be solved in a later development cycle during the next year.

III. System Overview

This chapter presents an overview of the whole system as it is at the time of this writing. The system is divided into several task-oriented modules. A module is a set of objects and/or sub-modules providing a particular functionality. The modules are designed as stand-alone processes exchanging information through a communication network. All modules have the same structure and the same communication interface. [Figure 6] shows the conceptual architecture of the system.

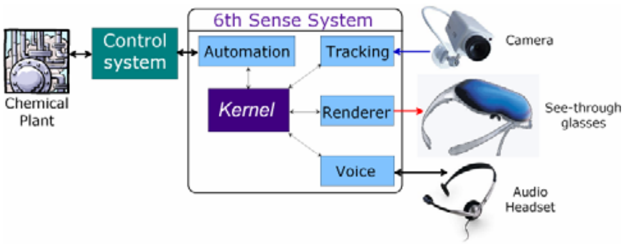

Figure 6 – 6th Sense System's conceptual architecture

A. The "Kernel" module

The kernel is the core module responsible for establishing the communication links between the various modules. The communication between modules is based on a messaging architecture. Such architecture is described in [4]. The kernel is implemented in *LabVIEW*™.

B. The "Automation" module

The automation module is the interface to the existing control system. The role of the automation module is to hide the details of the existing control system behind a well-defined interface. With such an abstraction, the other modules have access to the control system without knowing the details of its implementation. In addition, the automation module can be adapted to different control systems without modifying any other parts of the system. The current version of the automation module is implemented in *LabVIEW*™.

C. The "Tracking" module

The role of the tracking module is to give the operator's position and head's orientation in real-time. The augmented reality system must be aware of the user's position to deliver contextual information to him. There are several possibilities to realize this task. We chose to use artificial landmarks and a head-mounted camera to detect them. The tracking principle is as follow [3]:

- Artificial landmarks with unique IDs are placed at known locations in the real world.
- A head-mounted camera captures live video of the real world and sends it to the computer.
- A vision software on the computer searches through each video frame for any known landmark pattern.
- If a landmark is found, the computer extracts its ID and calculates the camera's position relative to the landmark.
- Knowing the ID of the landmark, its position in the real world can be easily retrieved and used to compute the absolute position of the camera in the world.

D. The "Renderer" module

This module is responsible for presenting the information to the user. The graphical user interface is projected in optical see-through glasses, on top of the real-world and registered with it. An example of what can be seen through the glasses is shown in [Figure 7]. At the top is the main status bar. This bar displays the current plant's status (Out-Of-Order, Manual or Automatic), the current's system status and the current time.

One of the needs of the supervision facet is to be able to monitor the value of one or more specific plant's elements. This is achieved by the monitoring bar located at the bottom of the screen. The monitoring bar displays a box for each element to monitor. Each box shows the name of the monitored element followed by its current value and physical unit.

When the information to render is too large and will dramatically obstruct the operator's field-of-view if displayed on the whole glasses' screen, a virtual screen is used. A virtual screen, as indicated by its name, does not exist in the real world. It is located at a defined position in the virtual world. The operator must look at the corresponding position in the real world to actually see the screen. [Figure 7] shows two virtual screens. The left one is a landscape mode screen dedicated to trends. The right one is a portrait mode screen used to display the list of active alarms or the list of phases. The operator can chose which information is displayed on this virtual screen.

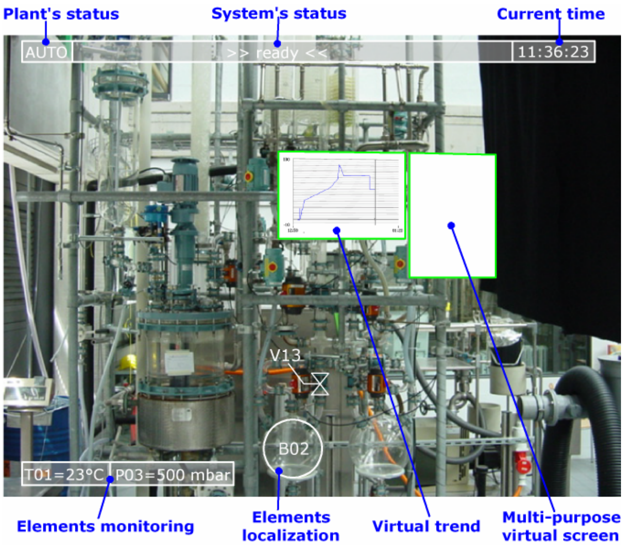

Figure 7 – Rendering example

E. The "Voice" module

The voice module is made of two distinct and independent sub-modules:

1. The voice recognition sub-module, which is able to translate what the user says into a string of characters.
2. The voice synthesis sub-module, which is able to translate a string of characters into spoken words.

This module is currently implemented in *LabVIEW*™ and uses the ScanSoft's *Dragon Naturally Speaking* recognition and synthesis engines. The engines are both accessed through an *ActiveX* interface. Unfortunately, due to performance and reliability issues, we have to switch to another recognition engine (*ScanSoft's VoCon3200*) better suited for the project's requirements.

IV. CONCLUSION

The aim of this project is to develop a wearable supervision system for chemical plants based on augmented reality. With the prototype α1 the project's feasibility has been proven from a technological point of view. The prototype α2 has to demonstrate the usability of augmented reality in real working conditions. Besides, it allows us acquiring the knowledge and experience necessary to move to the next development step which will lead to the release of the prototype α3. The prototype α3 will essentially address the wearability issues of the system.

The development of such a system is quite challenging because it involves emerging technologies, for which there is no standard solution to a given problem. This project also is a challenge from a human point of view because it implies a radical change in the working method of the operators. Our role is also to convince people that such a system can really improve their work.

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