VisionAir TNA.22

Assembly simulation using haptic devices

General information

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Scientific:
Domain: Material Sciences
Discipline: Industrial Engineering

Period:
Start date: 29.june.2014
End date: 19.july.2014
Duration: 21 days

Summary

Optimization and realistic simulation of the Assembly and Disassembly (A/D) process represent important research themes, considering the important role played by these operations throughout the Product Life-Cycle (PLC).
In recent years, Virtual Reality (VR) technology has evolved to a new level of sophistication. Now it combines several human-computer interfaces in order to provide various sensations and to enable users to become more immersed in a computer-generated platform. Thus, Virtual reality Environments (VE) are frequently used to simulate operations from different domains of activity, one of them being the A/D process. Many of these applications use haptic feedback and are facing (major) difficulties simulating some (detailed) operations – e.g. insertion/extraction.

Objectives

The main purpose of this research was to improve the A/D process simulation through better haptic devices integration. To this end, two objectives were pursued.
The first objective was to evaluate the impact of a mobility module, based on predefined kinematic constraints, able to guide the user's movements, when performing A/D operations simulation, through the intelligent management of the assembly components relative mobilities in contact situations.
The second objective was to find out if it is feasible to create a moderate cost system: hardware plus software, for industrial use. It is important to note that, actually, the price of such a system is prohibitive for many companies and universities. Knowing that the haptic device price represents more than two-thirds from the system price, a rapid way to decrease the total cost would be to use a low cost device, if the simulation quality remains good enough for industrial use.

Experiments

Preparation

In order to meet the stated objectives, the research was split in two phases. Thus, before defining the experiments, the mobility module, able to model contact relations between elementary components of a product and to manage the relative mobilities of the assembly components, was developed. This one can efficiently contribute to the real-time simulation process, when it is performed with haptic devices, by reducing the complexity of the collision detection algorithms and the unwanted effects.
Still in the preparation phase, the target group was defined. It is formed of 20 (twenty) people with the following characteristics:

- □ gender mix: males and females
- □ different ages: 21 ÷ 59 (average: 35)
- □ culture mix: European and non-European
- □ different background: professors, researchers, engineers, bachelor students, master students, PhD students.

Devices

For the second objective, the quality of different immersive simulations was compared. To this end, two 6 DoF haptic devices: Geomagic Phantom Omni – a basic equipment with 3 DoF force feedback (Figure 1.a.), versus Haption Virtuose 6D35-45 – an expensive system with 6 DoF force feedback (Figure 1.b.), whose characteristics are described below, were used for experiments.

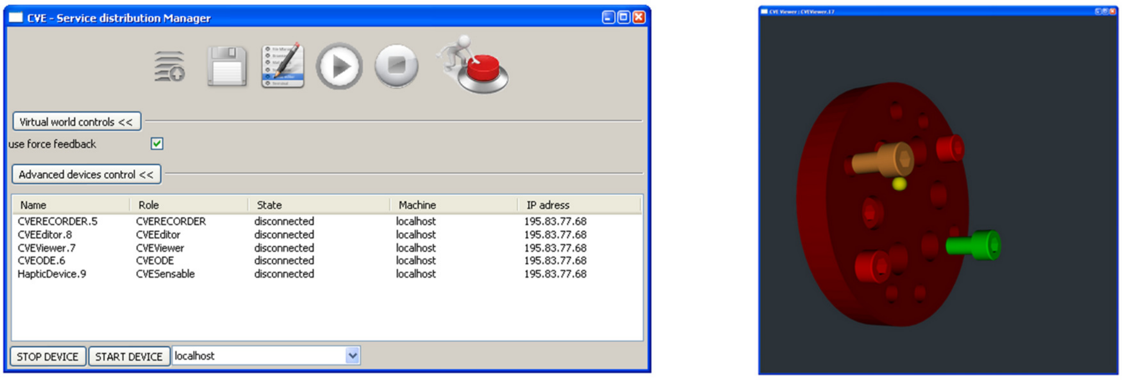
- □ Geomagic Phantom Omni (Figure 1.a.)
  - ○ degrees of freedom: 6 (3 translations and 3 rotations)
  - ○ degrees of freedom with force feedback: **3** (3 translations only)
  - ○ workspace: corresponding to the movements of a **human wrist**
  - ○ maximum force: **3** [N]
  - ○ price: medium
- □ Haption Virtuose 6D35-45 (Figure 1.b.)
  - ○ degrees of freedom: 6 (3 translations and 3 rotations)
  - ○ degrees of freedom with force feedback: **6** (3 translations and 3 rotations)
  - ○ workspace: corresponding to the movements of a **human arm**
  - ○ maximum force: **35** [N]
  - ○ price: high

(a) (b)

Figure. 1. Haptic devices: a) Geomagic Phantom Omni; b) Haption Virtuose 6D35-45

Application

The main application used to fulfill the research objectives was CVE – Collaborative Virtual Environment, developed by the G-SCOP Laboratory. This software can manage the interaction between the virtual scene and human through a stereoscopic display and a haptic device.
CVE is basically an event propagator between several clients (modules) (Figure 2.a.). The clients can be executed on the same computer or on several ones through network connection. Every client is in charge on its own task and does not matter what is executed by others. It just published a shared model which refers in a more or less complex organization a set of concepts which can be evaluated by attributes. Whenever this model is changed the client is in charge to update a local device and simultaneously whenever a local device is activated by the user its new states values must be propagated to any other interested client.



(a) (b)

Figure. 2. a) CVE main window – Service distribution manager; b) CVE Viewer module

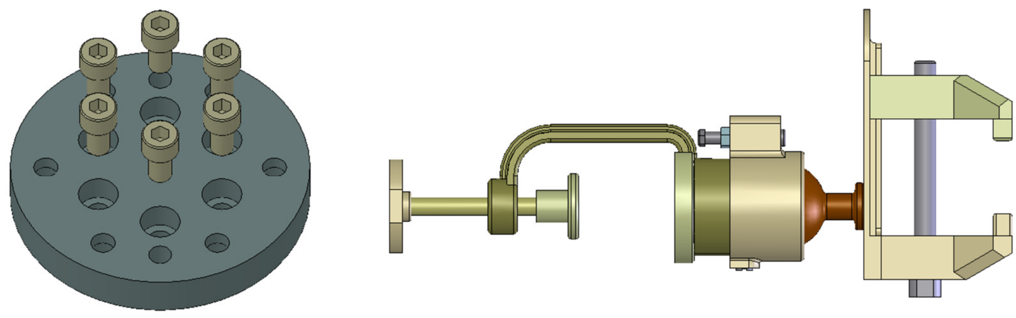
In this version, CVE can manage four types of joints (links): Anchorage (ANC - ENC), Planar Fit (PLF - APP), Cylindrical Joint (CLJ - PVG) and Spherical Fit (SPF - RTL). The first joint is a special type and it describes a fixed component in space. It is important to note that, in order to be able to create an assembly, a fixed component is always required. The last three types of joints are basic type links defined by functional surfaces of the same type, e.g. Cylindrical Joint formed by cylindrical surfaces.
CVE handles the components' movement through a real-time management of collision detection and kinematically constraint guidance. A simple typical assembly situation is represented in Figure 2.b. The color code is the following:

- □ red - the component is fixed and cannot be moved;
- □ green - the component can be moved or oriented free in space;
- □ orange - the component has reached a particular position in space where it can be assembled using a constraint guidance;
- □ blue - a subassembly constructed from the code (supplementary).

Models

The main purpose of the experiments was to assess the assembly application features and to compare the simulation quality when different haptic devices are used. In this regard, two types of assemblies were deployed: Mounting Flange (Figure 3. a.) and Standard Vise (Figure 3. b.).

- □ Mounting Flange
  - ○ type of assembly: simple
  - ○ number of components: 7
  - ○ number of interfaces: 12
  - ○ target: accommodation
- □ Standard Vise
  - ○ type of assembly: medium
  - ○ number of components: 16
  - ○ number of interfaces: 41
  - ○ target: testing



(a) (b)

Figure. 3. Test assemblies: a) Mounting Flange; b) Standard Vise

Protocol

In order to have relevant data, several scenarios were created to carry out the tests. Thus, in the first place, an accommodation stage was performed on the flange assembly (Figure 3.a.). The participants were asked to mount the six screws into the base part. The main part has 14 holes (6 + 8), the user being free to choose any of them. It is obvious that this was an easy and repetitive task to perform. Then, all the vise components (Figure 3.b.) were loaded in the VE, in a predefined position, and the participants were asked to perform the assembly (or disassembly) operations. Considering the higher number of components and the medium complexity of the vise product, mounting the whole assembly is not a trivial process.
All persons have performed the mounting operations using, by turn, the two haptic devices. However, to properly assess all situations, half of them started with the basic equipment – Geomagic Omni, and the other half started with the expensive system – Haption Virtuose 6D.

Achievements

In order to have a meaningful evaluation, different types of assessments were deployed:

- □ Real-time quantification:
  - ○ number of assembled components (3 DoF vs. 6 DoF)
  - ○ average time for a component assembly (3 DoF vs. 6 DoF)
  - ○ average number of clicks for selection (3 DoF vs. 6 DoF)
- □ Questionnaires:
  - ○ pre-activity
  - ○ post-activity questionnaire (3 DoF and 6 DoF)
  - ○ final questionnaire

Each test session was recorded. Thus, three types of elements were measured (extracted) in real-time. This data will be concatenated with the questionnaires results.
The main part of the questionnaires was based on a standard Likert scale: 1 – absolutely not to 5 – absolutely. Thereby, the questionnaires answers provided a fast evaluation of the users' satisfaction when using the application: ease of use, usefulness of stereoscopic view, utility of the haptic cues etc. and a comparison of the two haptic devices: Haption Virtuose 6D and Geomagic Omni.

In the near future, more details, relevant data and conclusions will be presented through different scientific articles.