Rigid Haptic Prototyping Demonstrator

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Abstract:

We present here the results obtained with the I-Touch framework in order to create a rigid bodies demonstrator with haptic feedback among multimodal feedback.

Table of Contents

Introduction and presentation of challenges of virtual prototyping

1.1 Interest of virtual prototyping in industry

As previous work has shown, it is obvious that industry (more precisely mainly the car industry as well as the aeronautical industry) is demanding for more virtual prototyping devices and software. The fact that costs can be dramatically reduced by these methods is very interesting for them. For example, the following table illustrate the needs in aeronautic industry [8][9].

Needs	***Information***
• Virtual prototyping • Assembling simulation • Dismounting simulation • Visualization of data • Learning gesture without consequences	• Tactile feedback • Kinesthetic feedback (contact / friction feedback) • Haptic « information » • Sensitive substitute

Table 1: Interest of rigid haptic prototyping

If the interest of the tactile feedback has yet to make its breakthrough, the force feedback one has clearly seduced industrials by its possibility, and the very effectiveness of its implementation. Many forces feedback devices are available on the market for instant use.

The different needs, and the value of haptic feedback is given here:

- Virtual prototyping : In this stage, we are devising or refining a new object. This object can one piece or more (in this case, it is often an assembling). The haptic interface can be used to increase the bond between the user and its prototype. Intuitiveness is what is the most researched here, the interface has to be as « transparent » as possible.
- Assembling / Dismounting of objects : Here, the bottlenecks of assembling or dismounting an object, or inserting an object into another have to be quickly discovered. The haptic interface can remove the need for an actual prototype, and therefore increase the productivity while removing costs (see below).
- Visualization of data : In some case, it is necessary to visualize data. However, this data can be complex and therefore difficult to render only with the visual and/or auditive capabilities. Here the kinaesthetic interfaces can be of help, permitting new « visualizations ».
- Learning gestures : In complex / dangerous situations, the safety of the operator is the most important thing to account for. Therefore, costly process can ensue if real prototypes / situations are used. The haptic feedback can remove theses needs, and increase subsequently safety. Moreover, different learning scenarios can be quickly devised, opposed to creating real tests.

1.2 Cost Analysis

Nowadays, we are assisting to the emergence of a new way to test CADM designed products: virtual prototyping (VP). However, virtual prototyping, for now, often covers only off-line tests such as physical constraints or feasibility tests. Other tests, such as assembling feasibility, are performed only after real prototype creation. Only after this step misconception can be uncovered. A typical flow for traditional prototype creation is shown below.

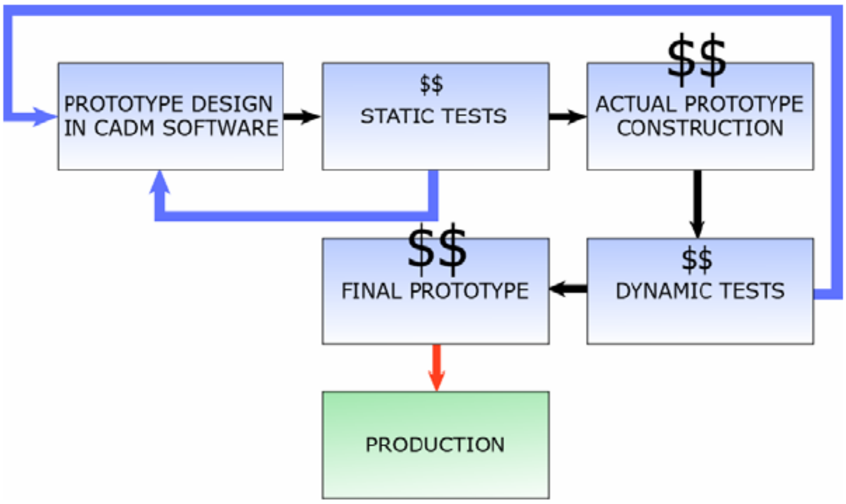

Figure 1: Normal production flow

There is indubitably a market for virtual prototyping: it equals more or less the CADM one. Design areas, from kitchenware to car assembly, could use virtual prototyping in a wide range of applications. The cost of a prototype varies from an application to another, but is generally priced more than \$1000 and can easily reach \$10000. These costs are to be multiplied by the number of prototypes and are far from the cost associated with traditional software. For example, mounting/dismounting car parts are an essential area for car manufacturers, since it has a direct impact on costs. If software could provide a simple and easy way to test such cases before actual construction, it would be more than welcomed by industrials. The cost of such software would be times less than the costs associated with real prototypes. Moreover, a software can be used for many prototypes, while new prototypes in the real world could require new production methods. Even if software upgrade is required, we can easily tell that it is beneficial.

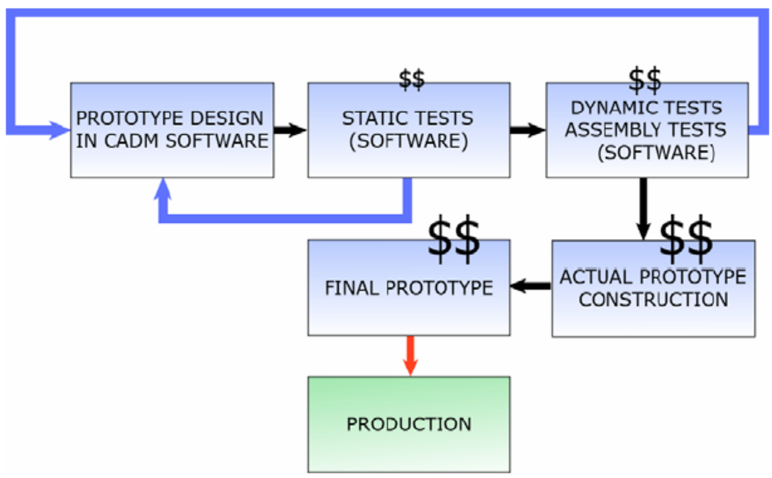

Figure 2: Accelerated production flow.

As we can see, costs associated with physical construction are totally different in this scenario. At the LSC, we are working on such a demonstrator, as part of the haptic framework I-TOUCH. Moreover, another very interesting fact is that timings are accelerated, which reduces time between design and sales.

1.3 Practical examples of industry scenarios

This example illustrate the need to test the feasibility of the insertion/removal of a window motor in a car door. The user will have to test the practical insertion, with force feedback. The force feedback will provide precious information to the user, who will be able to detect difficulty points.

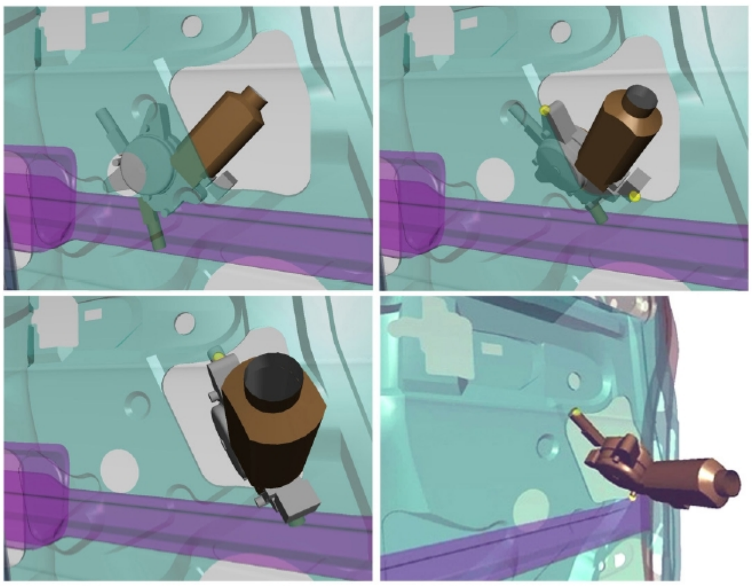

Figure 3: Removal in a car door

We can see the removal can be non trivial due to the dimension of the pieces. The operator can quickly spot problems and incompatibilities with haptic feedback, without the requirements for specials prototypes. However, since the haptic feedback can not completely cover all the haptic information at one time, care must be taken in what information is given to the user from the one available in the simulation. This is why the ability to test many algorithms and methods of feedback is of vital importance.

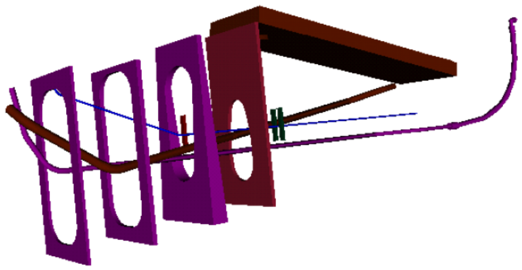

Figure 4: Operation in a plane

Other examples includes the insertion of pieces in a plane. Here, the scales are not the same, but nevertheless the haptic feedback can provide useful information about this process. The haptic interface can adapt the forces/scales in order to provide useful information in regard to the involved task.

1.4 Conclusion

We have shown here that there is a strong need for a rigid haptic demonstrator using the kinaesthetic feedback. The industry is already specialized version in some cases, but lacks a more generalized approach. Moreover, as the hardware part is already there (to some extent), the software part should also be pushed in. The psychophysical part is also behind, so a framework allowing to create test beds for psychophysical measures is also of great importance. All these needs are governing the design of the I-Touch framework.

I-Touch as a rigid body prototyping framework

1.5 The general framework design

The framework is designed along a modular object oriented approach. The basic principle behind this is we create blocks that can be linked together to create the desired result. As far as actual implementation is concerned, please refer to the deliverable D6.8 (which also contains information about collision detection).

The actual implementation is done in object ori ented C++ using an object oriented conception.

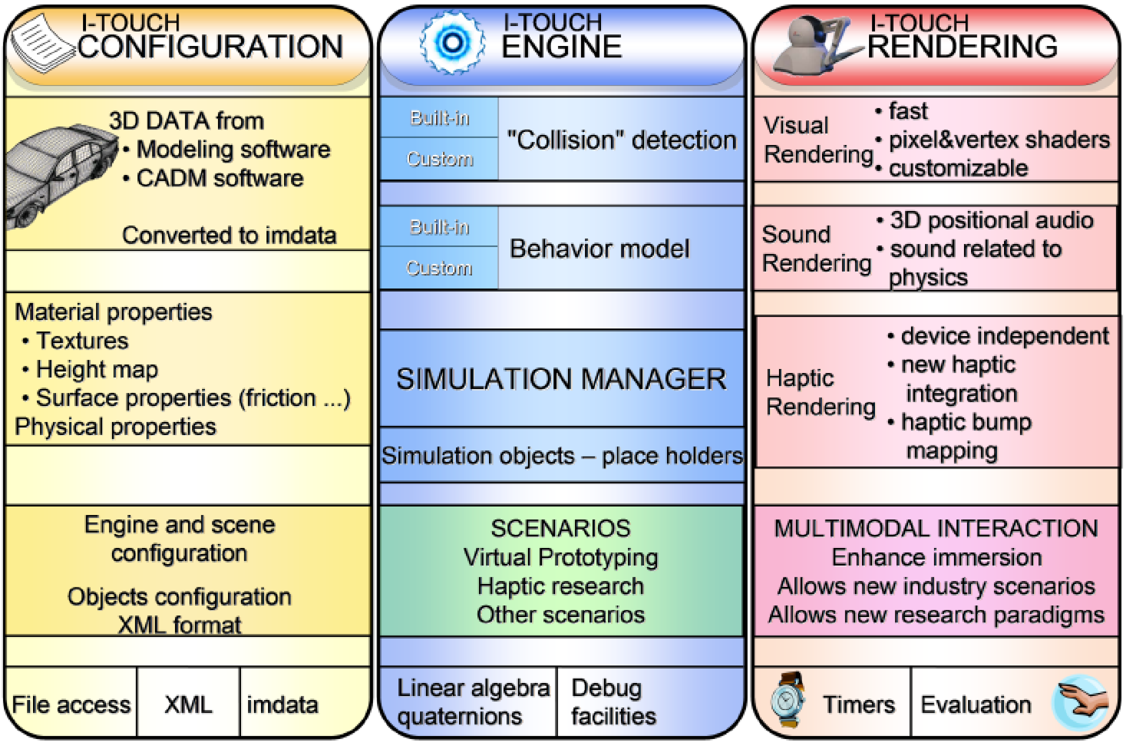

Figure 5: the overall layout of the framework

The I-Touch engine is for responsible for internal behaviour of the scene : it is the place where appropriate physics for rigid body dynamics take place. Another place of importance is the haptic rendering, where the haptic feedback is handled and haptic input is forwarded to simulation. This haptic feedback should also be tailored to meet the rigid body prototyping case requirements. In fact, it may be required that a special device has to be attached to the simulation (for simulation a special tool, for example). In this case, the extension capabilities of I-Touch will allow for fast integration. Moreover, is the device is of 6-dof force feedback type, there will be very little code required to add support for the device.

1.6 I-Touch ability to create a stand alone virtual prototyping application

We are currently developing a virtual prototyping case, which uses our built-in collision detection, behavior model and haptic proxies. Steps required to create such a program are the following:

1. *Identify the virtual prototyping tasks and involved objects.*
   The main effort is placed here on assembling/dismounting case, that is a dynamic case (as opposed to a static case, where only the fitting would be tested, with collision detection for example). We can start by creating a new scene with specific task display. This can be easily done by deriving from existing scene, in order to leverage from existing code.
2. *Import/export 3D models of these objects from industry internal format (CADM software).*
   I-Touch use an generic internal format for its 3d data. This allow for independence from modelling software. The format is really easy and well documented. Moreover, importer/exporter have been already written in C++, C# and in 3dsmax script.
3. *Configure objects.*
   This step can be done here, or after the whole software package has been devised, as necessary. For the most part, it involves editing XML[15] files (which have the corresponding XML schema – for easy structure analysis). A basic editor, written in .NET, allows for visualization and editing of basic properties of objects.
4. *Bind a haptic interface (PHANToM, Virtuose, etc.) to the manipulated virtual object.*
   This step is closely related to the step 3. The haptic device is bound to an object in the simulation. This allows easy feedback / input from / to the simulation. If necessary, inherit a new haptic interface[2] from generic existing one, and use it in the framework.
5. *Use default or specify algorithms for physics and collision detection.*
   The great flexibility in the choices of the algorithms is here of vital importance. The fact is that for a virtual prototyping task, a constraint based method[4][5] is probably the best, although is it more a case by case decision. Basic engine switch support is already, without recompilation of the software. This switch system should be extended to allow for further customization needs.
6. *Perform VP tasks within I-TOUCH.*
7. *Measure whatever must be benchmarked.*

To allow for greater immersion, all the recent techniques in visual and auditive rendering are used[1]. While breakthrough are made in the haptic rendering, it remains a difficult exercise, and the perfect algorithms are yet to be found. Nevertheless, the flexibility of the I-Touch rendering allows tailoring of haptic feedback for certain scenarios.

These steps can be done not only with virtual prototyping scenarios, but also with other haptics scenarios. Moreover, the framework allows the creation of test applications in the domains of rigid bodies coupled with haptics. We show below some of theses test cases.

Scenarios

1.7 *Virtual prototyping scenario*

The VP scenario consists in mounting/dismounting a window-winder motor in/out of a car door (the 3D models are kindly provided by RENAULT car industry and the CEA (French nuclear authority)). The operator can test if the window-winder does really fit and if it is possible to put it in place, taking the shape of the door car into account. What is gained here is the intuitiveness of the operation. The CADM engineer disposes a powerful tool that allows him quick changes of CAD models. Moreover, compared to a real world creation of a prototype, and through scale conversion, it is a very inobstrusive solution, as we can see there, onmy a desk and a relatively small device are required, to compare to a full length dedicated room.

This scenario covers the basic of rigid bodies haptics: we have a non convex car door, in which is a window-winder motor, which itself is not a convex object. This scenarios customize more specifically the step 6 and 7 given above. Special care is to be taken in regard to the physics algorithms, because the complexity of the test case.

Figure 6: Virtual prototyping with two different haptic devices.

We can see here that different devices can be used transparently in the simulation. For now, the devices have the same functionality in the scene, but we could imagine that each device represent a different tool. We could even use the two devices at the same time (or more than one device of one type), to recreate the sensation of having more than one tool. The same principle can be applied to objects: we could have more than one object (in case of a two object insertion, for example). This is important, in the case in which only one haptic device is not sufficient for handling all the haptic data that should be forwarded to the user. In this case, a two device approach can solve the problem. More generally, since the human being has two hands, and use them in a coordinated manner, we should not restrict him to only one hand when dealing with haptics.

Further applications following the same model could be devised, for example, stacking applications, screwing applications... could use the same model.

1.8 Virtual scribble

In the virtual scribble application, we want to investigate a natural way of using a haptic device. In this case, that was the fact that an Phantom haptic device can be handled the same way as a pen. So we tried to mimic the look and feel of a pen. In this scenarios, the physics can be trivialized with simple plane test for collision dectection. Since the I-Touch framework allows easy replacement of collision detection and physic algorithms, we did it. This allows to give more attention and time to the rendering, which is very important in a more 'mainstream public' application as this one.

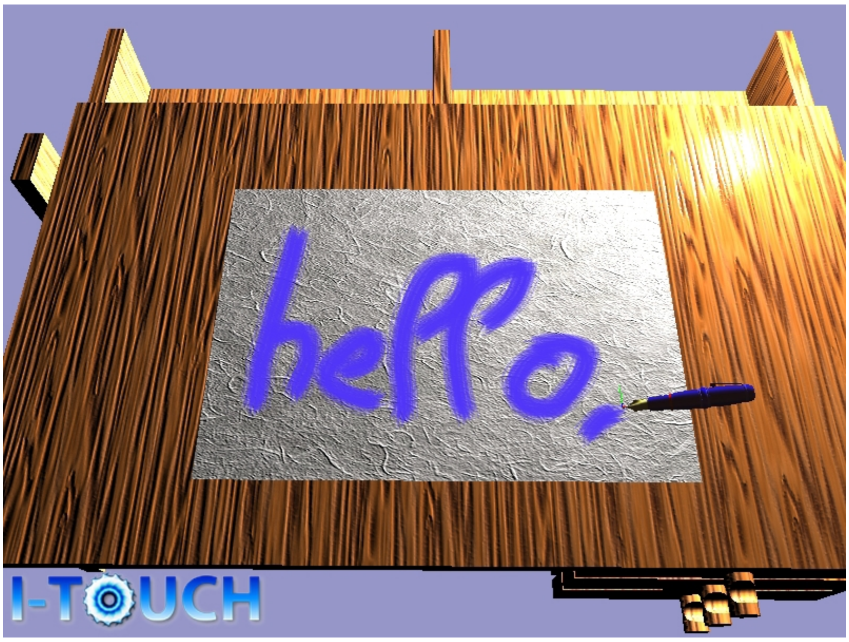

Figure 7: Virtual scribble application

As it can be seen, more details are available to the user. All rendering are done with pixels and vertex shaders. A parallax mapping with bump mapping shader is user for the table wood and the the paper, and a metal looking shader is used on the pen (hard to see in the picture). The writing are simply textured quads streched along the direction of the writing.

Moreover, 3d sound[12] related to the speed of writing is also provided. As in the real world, the 'striching' sound is higher pitched when the movement is faster.

This application proved itself very intuitive to the user, and widened the understanding of the haptic applications along the assistance.

Conclusion

We have shown here a generic rigid bodies framework with multimodal, and therefore haptic feedback, which has been used to create a rigid haptic prototyping demonstrator. We have also detailed the steps required to create such a framework, and how to customize it to reach certains needs. We are searching for future enhancements, in the domains of physics and multimodal feedback, along with an even easier way of creating applications, to widen the use of this framework in the haptic community.

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