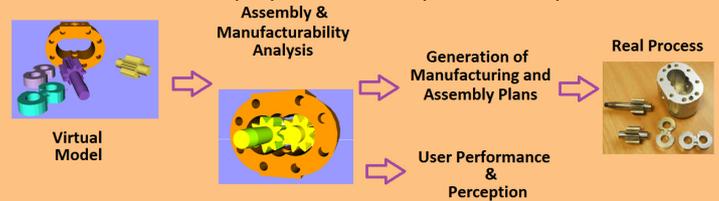


## Introduction

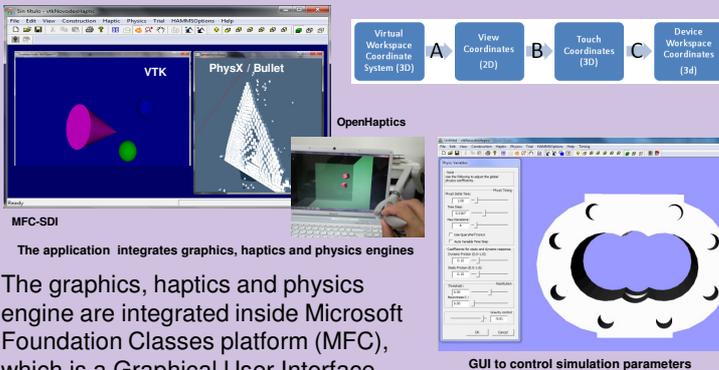
A haptic system is used for rendering shapes, forces, textures, and collisions through a force feedback in a virtual environment enabling the user to feel such effects. A designer with access to a virtual model will be able to accelerate the design process by making changes in the product before it is manufactured. The aim of this project is to analyze the manufacturability and ease of assembly of mechanical components using a virtual reality system taking advantage of the intuitive and interactive properties that haptic devices provide.

The project will be focused on: Assembly simulation of various components, manufacturability analysis for rapid prototyping and generation of manufacturing and assembly plans for real applications. In order to validate the benefits of using such application the user response is measured along with comparisons with standard procedures and results showed in similar works.



## Application Development

A virtual reality application has been developed using virtual reality techniques. The graphic rendering is carried out using the Visualization Toolkit (VTK 5.6.1) that allows the user to see the virtual models on the screen, besides it provides stereoscopic view. Open Haptics Toolkit is the standard platform for programming *Sensible* haptic devices like *Omni* and *Phantom*, the HL API provides functions for control the haptic device, manipulate objects and get force feedback in a virtual reality scene, it also provides functions for create the mapping between haptics and graphics world.



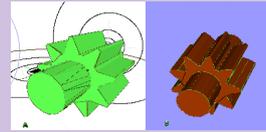
The graphics, haptics and physics engine are integrated inside Microsoft Foundation Classes platform (MFC), which is a Graphical User Interface (GUI) that creates a frame for the graphics scene and where controls are created. The application comprises buttons for camera rotation, pan or zoom, specify a point of view (front, back, left, top, etc), load or insert a new model in the scene; or panels where the user can see or modify simulation parameters like physic's engine time step, gravity, stiffness, static and dynamic friction, etc.



The application allows STL, OBJ and VTK file formats

## Collision Detection & Haptic feedback

When an object is created three models are generated: the graphic model (the one that the user see on screen), the haptic model (the one that the user can touch using the haptic device) and the physic model (the one that gives physical based behaviour and collision detection to the object).



A) Representation of the model in the physics engine  
B) Graphic model

Physical based behaviour provides collision detection and allows the objects to be under the action of gravity inside the virtual scene.

Two physics engines have been implemented in the application, the user can select either of them: PhysX™ engine, by Nvidia corp., and Bullet engine.

PhysX engine shows a more stable and realistic response, however it doesn't allow direct collision detection between concave models, in order to enable it a convex decomposition algorithm is implemented.

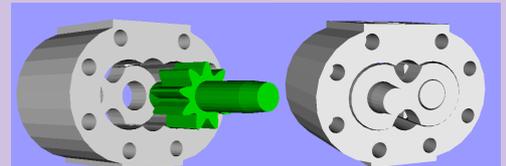
Bullet physics engine has two main advantages over PhysX: It is open source and it supports direct collision detection between concave objects. Collision detection between concave object is essential for virtual assembly tasks.

When a collision occurs a force need to be computed in order to send a haptic feedback to the user, this force is calculated using the spring-mass-damper model:

$$F = k * (P_c - P_o) - b * v$$

where:

- F Force feedback
- k Spring stiffness
- P<sub>c</sub> Cursor position.
- P<sub>o</sub> Object position.
- b Damping.
- v Object velocity.



## Conclusions & Future Work

- The development of the platform has been completed. There exist interaction between objects, haptic manipulation and stereoscopic view.
- Bullet engine seems to be more well adapted for virtual assembly tasks than PhysX engine.
- To implement functions to extract information like object and device position.
- To carry out a study to analyse the influence of the weight of components on virtual assembly operations and user perception and performance.
- A comparative study between the two physics engines to establish which is the most appropriate for virtual manufacturing tasks.
- To implement the manufacturability analysis, generation of assembly and manufacturing plans.