

SimHaptics: a Coupling Library for the *Force Dimension* Haptic Devices and the *20-sim* Modelling and Simulation Environment

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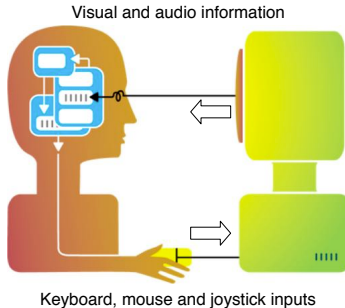
Summary

- 1 Introduction
- 2 Bidirectional Coupling Architecture
- 3 Simulation Results, Conclusion and Future Work

Human-Computer Interaction

Historical perspective:

- Human-computer interaction is based on one-directional channels of information;
- In this information loop there is no kinaesthetic energy flow to the operator because the sense of touch is not involved.

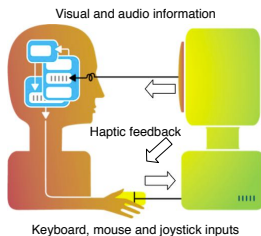


No kinaesthetic energy flow to the operator

Motivation Factors

The sense of touch:

- touch is one of the most reliable and robust senses, and is fundamental to our memory and in discerning;
- to provide the user with additional and intuitive information, haptic technology can be employed^[1,2].



- [1] Yuki Yokokura and Seiichiro Katsura. "Adaptive motion-copying system based on real-world haptics". In: *Proc. of the 36th Annual Conference on IEEE Industrial Electronics Society (IECON)*. 2010, pp. 1228–1233.
- [2] Filippo Sanfilippo and Kristin Ytterstad Pettersen. "XBee Positioning System with Embedded Haptic Feedback for Dangerous Offshore Operations: a Preliminary Study". In: *Proc. of the MTS/IEEE Oceans '15 Conference, Genova, Italy*. 2015.

COTS Haptic Feedback Devices

Nowadays, different commercial off-the-shelf (COTS) haptic feedback devices exist.



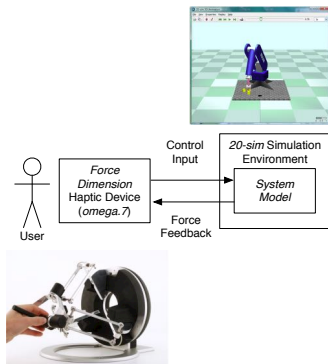
Essentially two ways to access these devices:

- device-specific low-level application programming interfaces (APIs) written by the manufacturer;
- generic high-level libraries developed by either third parties or manufacturers.

However, the integration of these devices still requires significant programming skills:

- a tedious and time-consuming task, which may prevent developers from fully focusing on the application logic necessary to achieve the core task;
- most of the currently available APIs do not offer flexible tools for modelling, simulation and analysis of multi-domain dynamic systems.

A Coupling Library between a COTS haptic device and a general purpose modelling and simulation environment



An open-source library for coupling the *Force Dimension omega.7* haptic device with the *20-sim* modelling and simulation environment:

- compatible with all the different haptic devices produced by *Force Dimension*;
- it allows users to focus only on the core task;
- tracking the user's motion, detecting collisions between the user-controlled probe and the virtual objects, computing reaction forces in response to motion or contacts, and exerting an intuitive force feedback on the user.

[3,4]

[3] Force dimension. "*omega.7*". 2015. URL: <http://www.forcedimension.com/products/omega-7/overview>.

[4] Controllab Products B.V. "*20-sim*". 2015. URL: <http://www.20sim.com/>.

Force Dimension omega.7



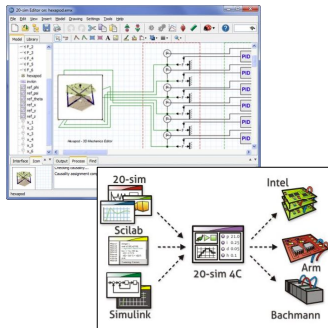
When choosing the haptic device, several aspects were considered:

- High dexterity to provide haptic capabilities to various systems with different specifications;
- High performance to provide the user with a realistic experience;
- These guidelines were provided by the *Force Dimension omega.7*, which is probably the world's most advanced desktop 7-DOFs haptic device.
- Even though the *Force Dimension* software development kit (SDK) offers great advantages, the integration with external modelling, simulation and analysis environments still requires advanced programming skills.

[5]

[5] Filippo Sanfilippo, Ottar Laurits Osen, and Saleh Alaliyat. "Recycling a Discarded Robotic Arm for Automation Engineering Education". In: *Proc. of the 28th European Conference on Modelling and Simulation (ECMS), Brescia, Italy. 2014*, pp. 81–86.

20-sim modelling and simulation environment



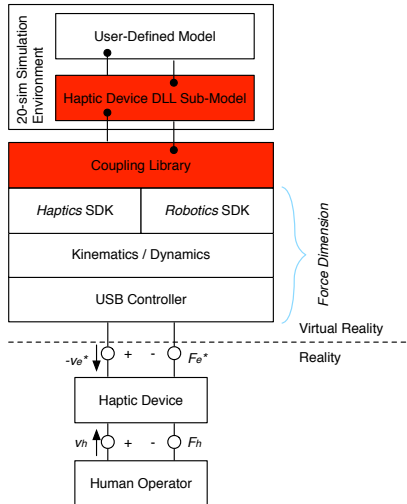
When considering the simulation environment, different aspects were taken into account:

- modelling of multi-domain and complex systems;
- modular approach;
- physical interaction. The possibility of developing controllers for embedded software and the creation of virtual prototypes for use in hardware-in-the-loop (HIL) simulations are crucial requirements;
- the 20-sim modelling and simulation environment was adopted to be coupled with the selected haptic device.

[6]

[6] Filippo Sanfilippo et al. "Flexible Modeling And Simulation Architecture For Haptic Control Of Maritime Cranes And Robotic Arms". In: *Proc. of the 27th European Conference on Modelling and Simulation (ECMS), Aalesund, Norway*. 2013, pp. 235–242.

Bidirectional Coupling Library

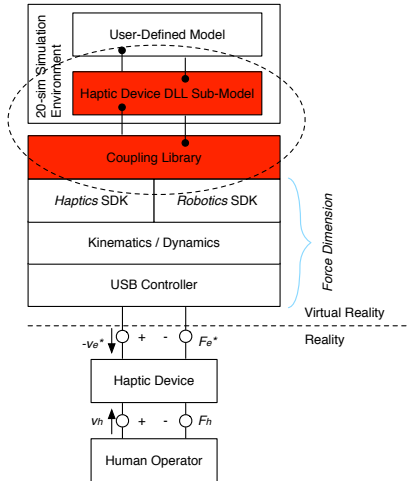


- The proposed coupling library is built on top of the *Force Dimension* SDK stack layers.

Starting from the lowest logic level, the native SDK provides the following layers:

- a real-time Universal Serial Bus (USB) controller, which is responsible for the communication to the physical device through the serial channel;
- the kinematic and dynamic model of the adopted haptic device so the latter can be controlled in both haptics and robotics mode;
- the *Haptics* SDK and the *Robotics* SDK. The former offers all the basic functions to read positions and to program desired forces. The latter offers an advanced set of real-time routines to precisely control the position of the device.

Bidirectional Coupling Library



- The proposed coupling library works as an abstraction layer for all the methods provided by the *Force Dimension* SDK.
- The library is implemented as a dynamic link library (DLL), which can import the two main interfaces corresponding to the *Haptics* SDK and the *Robotics* SDK, respectively.
- In this way, all the native low-level methods provided by *Force Dimension* are accessible.

Bidirectional Coupling Library

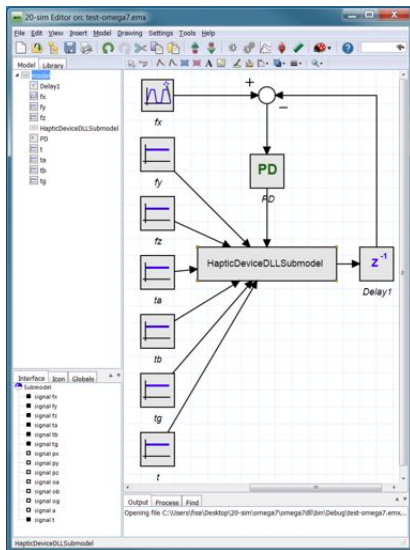
```
//imports the Haptics SDK interface
#include "dhdc.h"
DLLEXPORT int omega7(double *inarr, int inputs,
    double *outarr, int outputs, int major) {
    if (major) {
        // set force and torque
        dhdcSetForceAndTorqueAndGripperTorque(inarr
            [0], inarr[1], inarr[2], inarr[3],
            inarr[4], inarr[5], inarr[6]);
        // get position and orientation
        dhdcGetPositionAndOrientationDeg(&outarr[0],
            &outarr[1], &outarr[2], &outarr[3], &
            outarr[4], &outarr[5]);
        // get gripper angle
        dhdcGetGripperAngleDeg(&outarr[6]) < 0);
    }
    return FUNCTION_OK;
}
```

The pseudo code of the DLL main class that imports the Haptics SDK interface

The pseudo code for the 20-sim static DLL sub-model.

```
parameters
    string dll_name = 'omega7.dll';
    string function_name = 'omega7';
variables
    real dll_input[7], dll_output[7];
code
    // prepare the DLL function inputs with desired
    forces and torques
    dll_input = [fx;fy;fz;ta;tb;tg;t];
    // invoke the DLL function
    dll_output = dll(dll_name, function_name,
        dll_input);
    // read the DLL function outputs containing
    position and orientation
    [px;py;pz;oa;ob;og;a] = dll_output;
```

Case Study

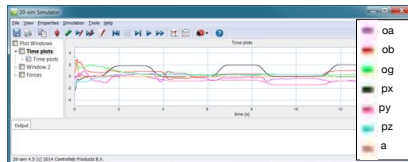
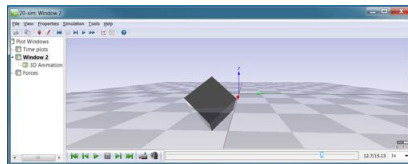
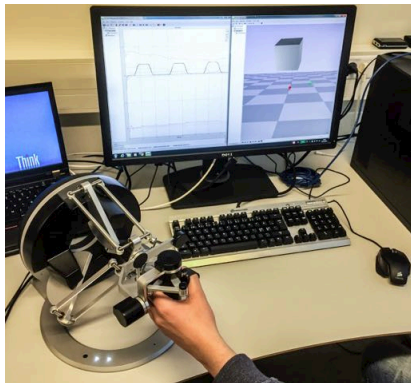


To add haptic capabilities to the system to be designed, the user needs to simply follow the following steps:

- import and drag the haptic device static DLL sub-model from the *20-sim* library of block diagram elements to the *20-sim* editor;
- store the DLL library in the same *20-sim* project folder.

Constant source blocks are used to generate all the input forces and torques, except for the force input along the x-axis which is given by the output from a proportional-derivative (PD) controller. The actual position and orientation flows first to a delay block with one sample interval delay. This block is a discrete-time operator. The input of the PD controller is the difference between the delayed output and the signal coming from a motion profile block.

Simulation Results



Conclusion and Future Work

An open-source library that allows for establishing a bidirectional coupling between the *Force Dimension omega.7* haptic device and the *20-sim* modelling and simulation environment:

- compatible with all the different haptic devices produced by *Force Dimension*;
- enables developers to easily add haptic capability to their systems;
- fully exploits the flexible and intuitive tools for fast-developing offered by *20-sim*.

Future work:

- the possibility of exposing haptic devices physically connected to remote computers;
- new features can be logically layered without modifying the presented library.

Thank you for your attention



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- [1] Yuki Yokokura and Seiichiro Katsura. “Adaptive motion-copying system based on real-world haptics”. In: *Proc. of the 36th Annual Conference on IEEE Industrial Electronics Society (IECON)*. 2010, pp. 1228–1233.
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