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Deliverable D4.1 Virtual Testbed Concept

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Abbreviations used in D4.1

CWM Central World Model
RBS Rigid Body Simulation
ROS Robot Operating System
VTB Virtual Testbed
WP Work Package

Executive Summary

Regarding modeling and simulation, the seamless integration of the developments and results of all project partners is the first step towards a fully immersive CENTAURO representation in a virtual environment. The deliverable aims at collecting and evaluating the requirements and needs of a fully functional Virtual Testbed and a general concept of interfacing with the associated modules of the robot and the telepresence equipment.
D4.1 "Virtual Testbed Concept" is conceptually based on the following major points:

- Central World Model
- Virtual Testbed for early, continuous integration
  - Input
  - Modeling
  - Interfaces
  - Integration
- Virtual Testbed for Prediction Mode demonstration
  - Real-time Rigid Body Simulation
  - Mode of Operation
  - Visualization

Based on the Virtual Testbed Concept, ongoing developments in the project can be seamlessly integrated and continuously updated towards a fully operational demonstrator for the CENTAURO project.

Contents

1 Introduction

Figure 1: Render image of the project vision: CENTAURO robot in its prospective working environment.

In the first six months, the project CENTAURO focuses on requirement analysis and concept development, e.g. the Virtual Testbed and Central World Model, documented here as the **Virtual Testbed Concept**. The Virtual Testbed Concept aims at providing a fully functional virtual model of the CENTAURO robot (see Fig. 1), which can be operated with the help of force feedback. This Virtual Testbed will also be used to – early and continuously – integrate modules from other project partners and finally interface with the real robot.

Using a Virtual Testbed for integration and operation is a central aspect of the CENTAURO project [4]. Thus, all partners should benefit from the development of the Virtual Testbed for CENTAURO in terms of interfaces and integration. The implementation of the Virtual Testbed is mainly carried out in work package WP4 ”Modeling and Simulation” by the Institute for Man-Machine Interaction (MMI) at the RWTH Aachen with the input from other project partners concerning their ideas and needs for interfaces and integration with the simulation. The objective of this first report in WP4 is to provide a basis for the project partners for contributing and working with the Virtual Testbed.

In the following, the overall project plan of WP4 is documented in Sec. 1.1 before the foundations of the Virtual Testbed approach are recapitulated in Sec. 2 and Sec. 3, whereas in Sec. 4 the progress beyond the state-of-the-art in CENTAURO is presented. More specific information (see Sec. 5) and particular implementation concepts (see Sec. 6) concerning project partners finally yield in a series of concrete implementation steps for the Virtual Testbed (see Sec. 6.2).

1.1 Work Package 4: Modeling and Simulation

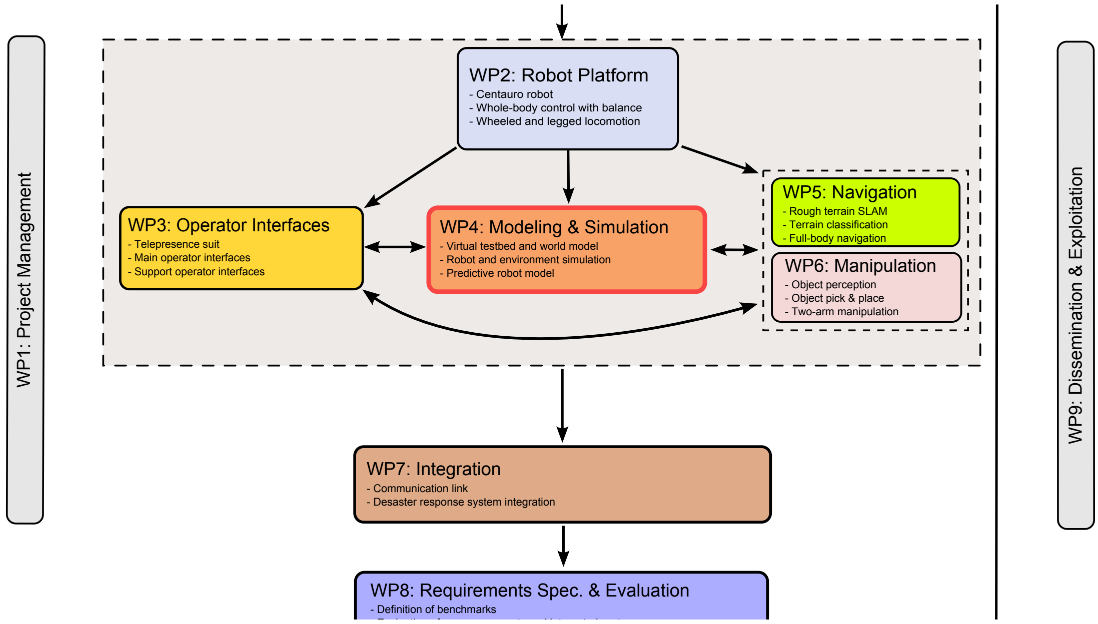

Figure 2: Overview: CENTAURO Workpackages with WP4 marked.

In work package WP4 (cf. Fig. 2), the key element is the modeling and simulation of the CENTAURO robot using the Virtual Testbed (VTB) approach. Within this work package a Virtual Testbed has to be developed compromising all relevant system components – summarized in the Central World Model (CWM) concept. After the conceptual phase of developing a Central World Model, and thus a simulation model of the environment, the next step is the development of a CENTAURO robot model to enable early integration, testing and evaluation of system modules. Therefore, a strong cooperation between the MMI and all other project partners of the CENTAURO project is important to achieve a seamless development of all partial modules, already capable of integrating into the Virtual Testbed and consequently also into the real CENTAURO robot when it is ready.
The four major tasks of modeling and simulation are:

1. Virtual Testbed Concept
2. Simulation of CENTAURO robot and environment
3. Predictive robot-environment model
4. Switching between direct control and prediction mode

To understand the final "Switching between direct control and prediction mode" component, and thus the prediction capabilities of a virtual CENTAURO in prediction mode, we will highlight the key control mode of CENTAURO operation in the following sections. The key control mode of CENTAURO will be introduced, focusing on the current task of developing a concept for the Virtual Testbed (see Sec. 1.2). The basic ideas of Virtual Testbeds (see Sec. 2) and applications (see Sec. 3) will be shown, before the concept for the Virtual Testbed for CENTAURO will be described (see Sec. 5) and additionally highlighted regarding a deployment sketch (see Sec. 6.1) as well as specific implementation ideas (see Sec. 6.2).

1.2 Centauro Mode

In Fig. 3 four different CENTAURO operation mode are shown, whereas the fourth mode is an additional possibility and not a central task in the CENTAURO project.

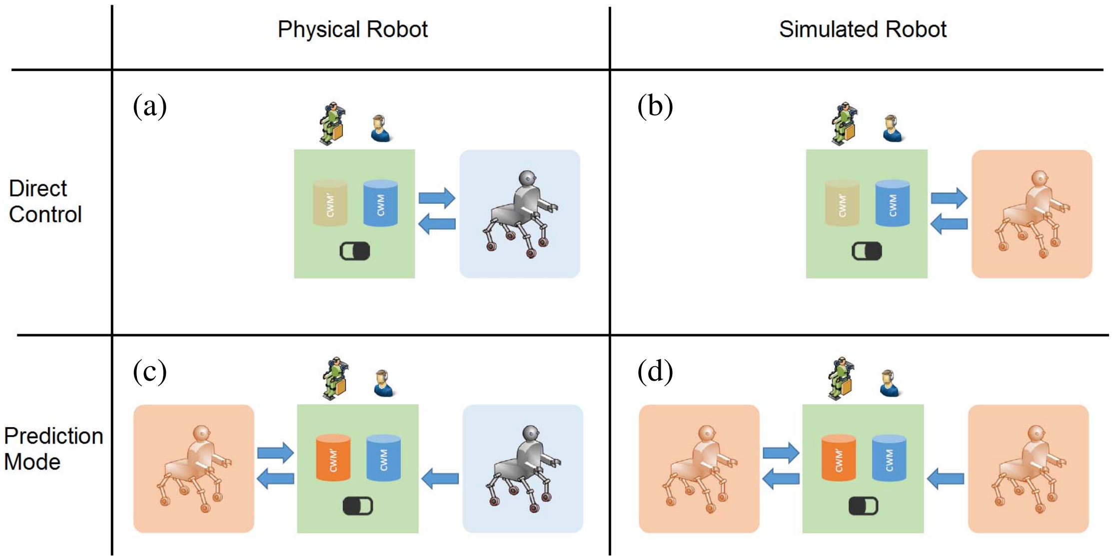

Figure 3: The four CENTAURO operation mode (top left to bottom right)
(a) Direct Control
(b) Virtual Testbed
(c) Prediction Mode – final operation
(d) Virtual Prediction.

The physical robot is illustrated in light blue, while simulated CENTAURO models are shown in light orange color. For early testing and integration, the whole robot with its environment can be substituted by the VTB, by simulating each relevant system module (Fig. 3 (b) and (d)) and feeding the data processing algorithms with simulated sensor data. The central world model (CWM) is part of the master communication relay at the operator site (indicated by green color in same figure). The simulation model from the VTB (CWM) will also be used for prediction (Fig. 3 (c) and (d)). System components, such as the exoskeleton, communicate either with the physical robot or with the simulated robot, depending on operator choice. An additional third-person view of a support operator will use the virtual testbed in all mode to maneuver a virtual CENTAURO, advise the operator and highlight important aspects, gathered from the simulation, into the first-person view.
Besides the different CENTAURO modes the final configurations, using the VTB, can be categorized in:

- VTB View:
  - Close to reality 3D view of the simulated environment in offline mode, for example for training purposes of the first person operator,
  - Augmented reality view in online mode displaying advices given by support operator
- VTB Console:

  - Support operator console to support the main operator by adding information to the virtual view
  - Configuring the data processing algorithms and the sensors
  - Commanding the robot to execute tasks autonomously

- VTB Prediction:
  - Predictive robot model for modular replacement of real and virtual robot for planning, look-ahead simulations, etc.

To understand the idea behind Virtual Testbeds and the opportunities and possibilities they bring along we will focus on the Direct Control of a Simulated Robot (see Fig. 3 (b)) in the next chapter.

2 Related Work

As described in the CENTAURO project plan [1], the CENTAURO VTB will based on the 3D simulation system VEROSIM which has already been used in a variety of similar projects developing mobile robots, actuators or sensors for mobile robots as well as sensor data processing algorithms. In order to demonstrate the basic ideas of the VTB approach, some examples will be shown is Sec. 3. Using this approach, a first VTB with a first robot design working in an exemplary environment can be realized within a few weeks.

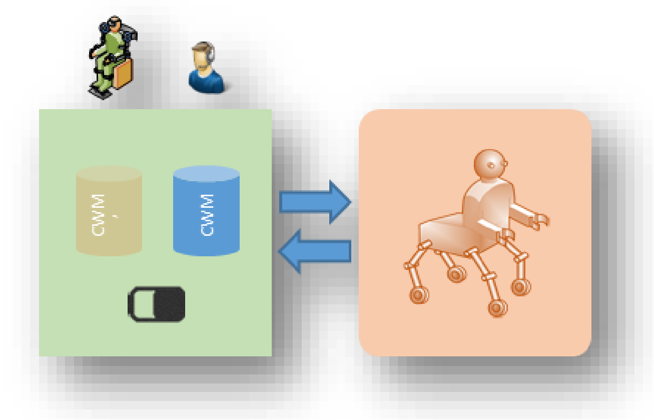

Figure 4: Simulation in VTB.

This early VTB will comprise first setups of the View and Console configurations and is the basis for further developments. Once a VTB (see Fig. 4) has been configured for the CENTAURO project, the simulation models as well as the simulation results can be distributed to the partners. In addition, software components like the robot control algorithms can be directly included in the form of submodules or software-in-the-loop concepts. Algorithms will be developed to process the sensor data resulting in a model of the environment which is the basis of the subsequent simulation in VTBs. To collect this data and to provide a single point of information for the VTB based components which rely on this data, a Central World Model (CWM) database will be developed which will be based on the well-known ”Central World Model” concept. The CWM will also be the point to introduce previous knowledge about the environment e. g. for the simulated CENTAURO robot. It enables all VTB components of the

CENTAURO software infrastructure to request the current state of the environment as a whole but also keeping track of changes.

3 Examples of Virtual Testbeds

The CENTAURO approach makes high demands on the underlying 3D simulation technology to realize the operator interfaces. During “normal operation”, 3D simulation technology is used to support the operator to optimally execute his tasks (display hints, display sensor data, identify grasp targets, etc.). In addition to this, 3D simulation technology will provide a virtual environment to allow the operator to pre-simulate operator actions or the execution of autonomously executed tasks and to test, verify and optimize the results. This virtual environment will act at the same time as a versatile operator training environment for different scenarios. The basis is a comprehensive 3D model including geometry, physical parameters of the robot and its environment, sensors, actuators as well as robot control algorithms.

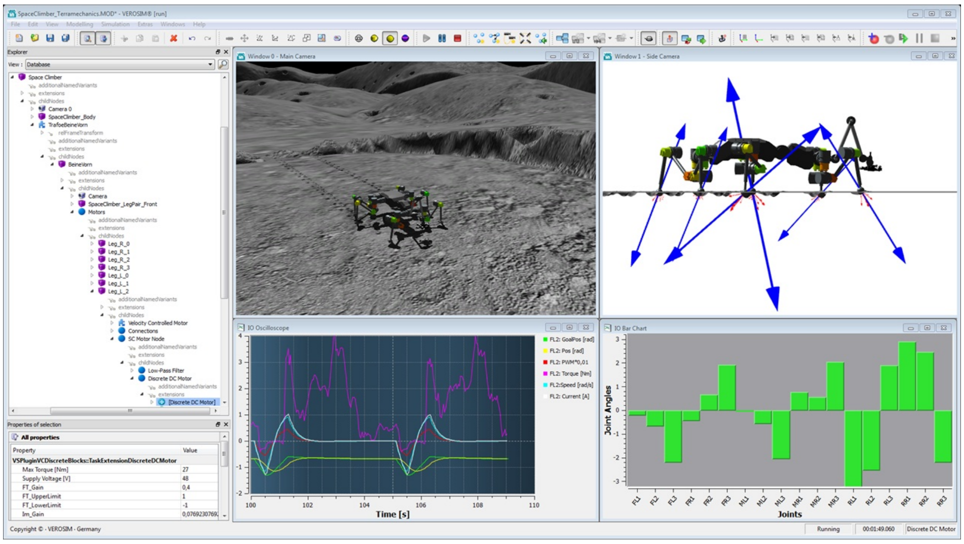

Figure 5: The Virtual Crater Testbed [10], one example for various Virtual Testbeds realized so far, integrates all aspects necessary for the development of mobile legged robots like dynamics, actuators, sensors, terra-mechanics, hardware interfaces, etc. (robot model (c) DFKI Bremen).

The methods for this are – at first glance – well known. Digital prototypes and simulation technologies are widely used in the development of new technical systems and, of course, in (mobile) robotics too. A large variety of software systems and frameworks have been developed and are widely used within this area. With respect to the development of the CENTAURO robot, the tools listed above mainly focus on single aspects, concrete application areas or the analysis of the robot itself. The 3D simulation framework used for CENTAURO will provide the necessary capabilities for appealing visualization, close-to-reality simulation of rigid bodies, sensors and actuators, and integration of robot control algorithms. It has to be able to run in desktop as well as real-time environments. That is why the CENTAURO partners intent to use the Virtual Testbed approach [[5], [8], [6]], one of the key concepts in the field of eRobotics [7]. Virtual Testbeds provide an integrated simulation framework comprising not only system, environment and simulation models as well as simulation methods, but also perception and control algorithms, the inner and outer dependencies of the digital prototype, as well as interfaces to real systems and means for appealing visualization and intuitive interaction. In addition to this, selected parts of Virtual Testbeds can be run under real-time restrictions which is necessary to drive the exoskeleton in offline-mode. In Figure 5 one can see the comprehensive possibilities of a VTB, from 3D simulation to force analysis of a mobile legged robot for space operation.

4 Progress in CENTAURO beyond the State-of-the-Art

The developments in the field of Virtual Testbeds are based on the VEROSIM 3D simulation framework co-developed at RWTH [9] which has proven its performance in a variety of application areas. It will provide a sustainable basis for the project developments right from the beginning but will be extended in a variety of different fields.

Besides the general problem of seamlessly integrating different modules from various project partners there are three major challenges in the CENTAURO project for simulation: 1) the highly dynamic robot and environment simulation regarding rigid body simulation; 2) the 3D visualization and sensoric generation of semantic models of time-varying highly dynamic object in unknown environments; 3) the integration of a Virtual Testbed in the loop of operation and integrating the prediction prospects (look-ahead simulation, supporting the operator,...) into the workflow, running in real-time.

The most obvious challenge we are addressing with regards to the simulation back-end is the real-time rigid-body simulation. To provide a high-fidelity feedback to the main operator using motion capturing and exoskeleton devices, hard real-time restrictions, and short response times require a high-performance rigid-body simulation. To ensure the necessary degree of transparency and ensure system stability, it is well known that update rates of 1000 Hz are necessary. For this, methods will be researched and developed to speed up the necessary computations with special attention to optimize the operator's experience to reach the transparency and stability goals.

CENTAURO will also address 3D visualization and simulation in time-varying environments built from sensor data. In CENTAURO, the simulation model is dynamic in two different ways: 1) the state variables of simulated/visualized objects change over time according to the simulation run/to the physical robot working in the real world; 2) the environment model changes permanently depending on the current field-of-view of the different sensors and the current processing state of the various perception and control algorithms. For this, the CENTAURO project will develop new methods to cope with such time-varying environments as well as with complex and highly detailed environment models which make great demands on the rigid-body and sensor simulation and the visualization algorithms.

The final operation mode needs an integration workflow of all building blocks mentioned above – and many more. For example, the predictive robot simulation must be able to provide look-ahead simulations of the robot's behavior. For this, the necessary control algorithms such as the motion control have to be integrated within the simulation environment, partly under real-time restrictions. Hence, new methods will be researched to seamlessly integrate simulation and robot control algorithms. It is also possible to compare results from other simulators used by project partners (like for example USARSim, GAZEBO, Matlab evaluation, ...) with the VTB to optimize the outcome and/or interface structure.

All in all, this modularity of algorithms, soft- and hardware, control and visualization puts strong demands on the simulation real-time capabilities and the Virtual Testbed modularity and integration prospects.

5 The Virtual Testbed Concept

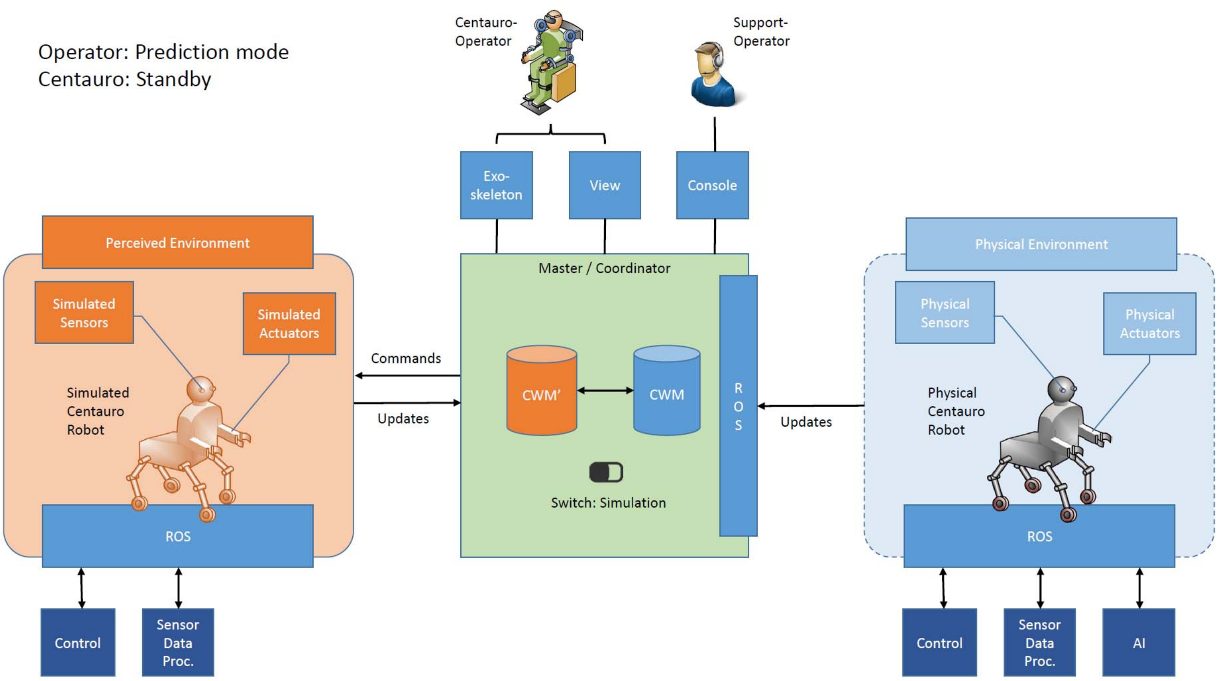

Figure 6: CENTAURO final setup: prediction mode.

Using a Virtual Testbed offers the integration of hard- and software modules prior to their final release. But this "virtual prototyping" is only one aspect of the Virtual Testbed in CENTAURO. Besides this **early virtual modular integration** (Fig. 4) the Virtual Testbed is also used in the **final prediction operation mode** (Fig. 6). Consequently, the conceptual phase of developing a virtual testbed can be divided into (whereas this overview can be modified and expanded throughout the project duration):

1. Early and continuous integration
   - INPUT – Interfacing Exoskeleton/ Input devices in general
   - MODELING – Integration of CENTAURO Hardware - models,...
   - INTERFACES – Use of general interface ROS
   - INTEGRATION – Integration of CENTAURO Software - algorithms,...
2. Virtual Testbed for Prediction Mode demonstration
   - RBS – Real-time capable rigid body simulation
   - MODE – 1st and 3rd person view
   - VISU – Visualization possibilities - sensor data, highlighting, ...

In the early development phase we will focus especially on the early virtual modular integration. Consequently, a first step with regards to integration and interfaces is to set up a first test scenario with a (close-to-real) CENTAURO robot in an disaster environment using different types of sensors (see Fig. 1). Therefore, good communication to all other project partners is necessary to enable everybody using the promises of a virtual testbed.

In the following, the different steps of deployment and of setting up a Virtual Testbed for CENTAURO will be outlined and associated to the different project partners who already have committed to develop a first virtual CENTAURO scenario.

5.1 Central World Model Concept

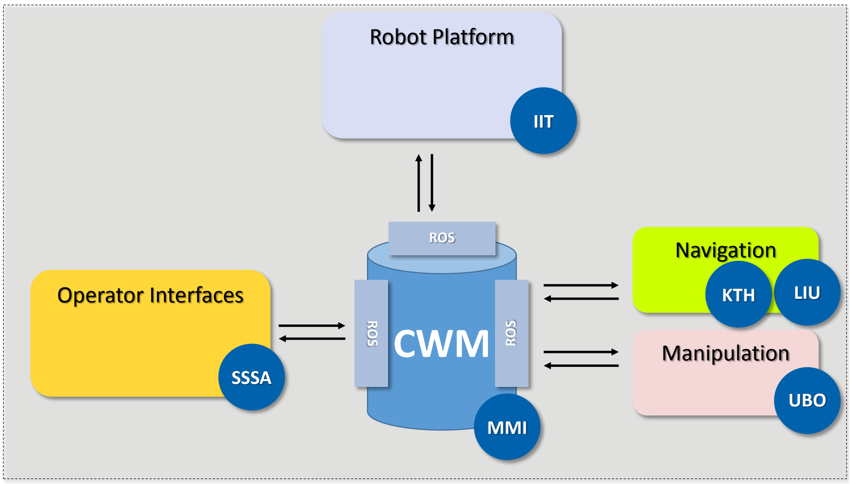

Figure 7: CENTAURO Central World Model Concept (based on Fig. 2).

The key aspect of the Central World Model is already given in [1] on page 46: "Algorithms will be developed to process the sensor data resulting in a model of the environment which is the basis of the subsequent simulation in VTBs. To collect this data and to provide a single point of information for the VTB based components which rely on this data, a central world model (CWM) database will be developed which will be based on the well-known "Central World Model" concept."

The CWM is the conceptual basis for intra- and intermodular communication. It will be a central compartment of the CENTAURO project establishing data storage, processing, and management. In Fig. 7 the different project partners and their key contribution to the project are visualized with their connection to the CWM. The CWM will be realized either as an on board PC carried by the CENTAURO robot communicating with the operator, or externally and stand-alone communicating with the different modules. The choice between these two option mainly depends on the communication and interface structure within the whole CENTAURO project. There are multiple possibilities for each module to use or fill the Central World Model. For example, a Virtual Testbed can be used to generate a dynamic environment and a virtual CENTAURO robot, writing all necessary data into the CWM. Via ROS interfaces external algorithms – for example for sensors – can access this data for testing and data processing purposes. On the other hand, real sensory data can be filled into the CWM updating the Virtual Testbed. This bidirectional use of the Central World Model shows its promises not only in the early development processes (where the "external" modules **get** specific data from the CWM) but also in the final operation mode (where the "external" modules **set / fill** specific data into the CWM which can be harnessed by the VTB).

As we have seen, this modularity of interfacing the CWM is only possible with the generally accepted ROS interface. Based on this standard the CWM, as a central database storage unit can be accessed by the first person operator in direct control and mirrored into a Virtual Testbed for the third person operator (cf. eg. Fig. 6). Details about the synchronization between these two databases (CWM and CWM') is one major challenge and have to be developed during the process of integrating different modules.

6 Implementation Plan

In this chapter we will define and describe specific deployment ideas and implementation procedures.

6.1 Deployment Sketch

The procedural deployment is a continuous process and progress. Based on the four major conceptual corner posts – Input, Model, Interfaces, and Integration – we have to permanently integrate, update, and reflect the input from all project partners. Therefore, in the beginning especially control possibilities, the robot model itself, and the interfaces have to be of importance. Consequently, the use of a virtual CENTAURO robot in a Virtual Testbed requires the interfacing schemes of all project partners. This includes for example the control via an exoskeleton, the interface structure of ROS, or some hard parameters of the robot regarding links, joints or motors.
The idea is to use the capabilities of a Virtual Testbed – its ability to test, validate, try, ... different modules in a realistic (but virtual) application oriented situation – as early as possible in the process of the CENTAURO project to support other project partners and to make the final integration as smooth as possible. Therefore, the MMI has started to contact the individual project partners to prepare a suitable and easily accessible first version of a Virtual Testbed. In particular, the MMI already contacted SSSA for exoskeleton details (see Sec. 6.1.2) and prepared a basis for data exchange with IIT (robot modeling) (see Sec. 6.1.1) as well other project partners (ROS interfaces) (see Sec. 6.1.3) which can be seen in more detail in the following section. The specific implementation in detail can afterwards be seen in Sec. 6.

6.1.1 CENTAURO Robot Model – IIT

The IIT as one major contributor to the robot platform itself is the essential source of information for the modeling of the virtual CENTAURO robot. Besides the general specification of the robot, the details of actuators and sensors are important.

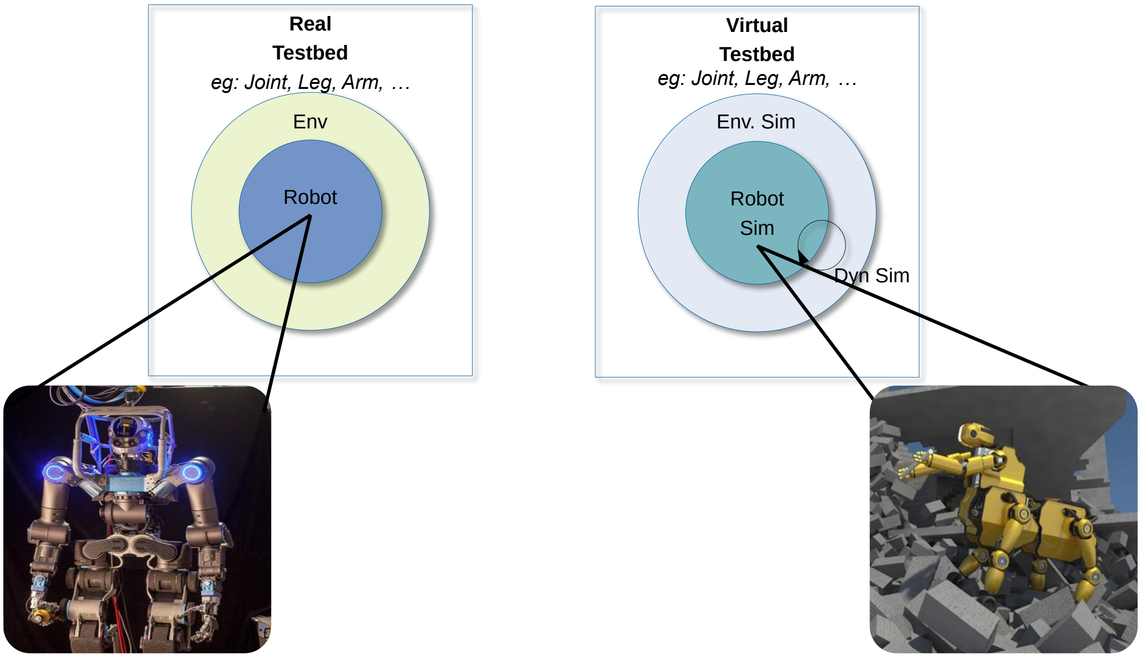

Figure 8: Transfer from Real [http://www.walk-man.eu/] to Virtual Testbed with regards to the CENTAURO [https://www.centauro-project.eu/] robot

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In Fig. 8 one can see the real testbed on the left and the Virtual Testbed on the right. In each of them the environment will interact with the robotic system. In the simulation, this interaction is symbolized with the dynamic simulation loop. The central aspect of an adequate representation of the real robot (which in parts will be make use of the WALK-MAN platform) in the virtual world is one of the major points in the early development stage of the CENTAURO project. Starting with e.g. one joint, leg, or arm, the transformation from real to virtual is planned to be an accompanying process. Using the scheme of Fig. 8 one can infer some central aspects and parameters.

We suggest a step-wise procedure of integration which can schematically be seen in Fig. 9. The **first** step would be the exchange of general (hard) parameters, like the mass, inertia, etc for the individual parts of the robot. This, motor parameters and some CAD data files can be used to generate a first virtual prototype of the CENTAURO robot. Due to the fact that the upper body part will mainly be based on the WALK-MAN from IIT, we suggest to start with some joints, arms and motor parameters already available from the real robot. The **second** step would then be the transfer of internal parameters, like dynamic forces, torques or specific joint vectors from the real system to the virtual robot. This will add more realistic behavior to the virtual CENTAURO model. As a **third**, and last, step the joint vectors, for example, can directly be mapped onto the virtual joints and vice versa. What exactly has to be mapped is based on the communication specification of the real robot. Afterwards the direct transfer between simulation and reality should be seamless.

Consequently, the representation of the CENTAURO system for simulation can be generated gradually and updated according to the development of the real robot to use the Virtual Testbed approach already in the early stages of development.

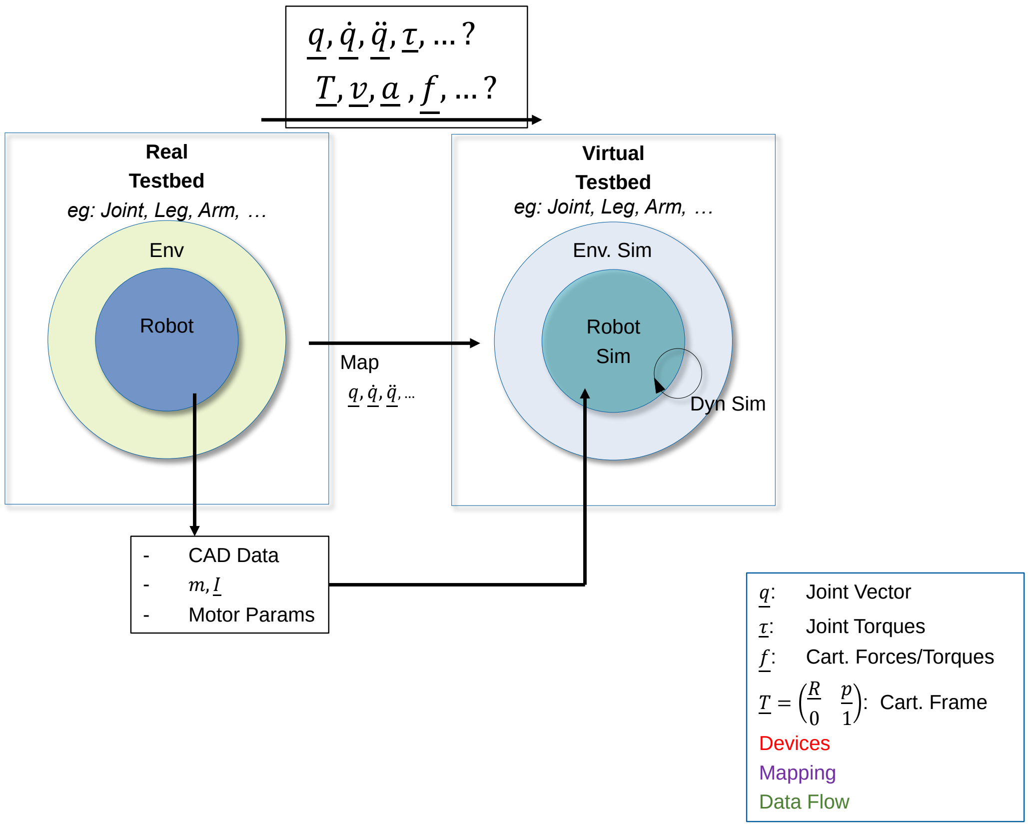

Figure 9: Scheme for modeling the CENTAURO robot.

6.1.2 Control via Exoskeleton – SSSA

The SSSA as work package leader for operator interfaces realizes the CENTAURO control station, namely the exoskeleton. To enable the use of an exoskeleton as input (and output) device in the real and virtual world, an interface for the simulation needs to be developed enabling force feedback in general, the use of an exoskeleton and the communication with the exoskeleton prior to completion.

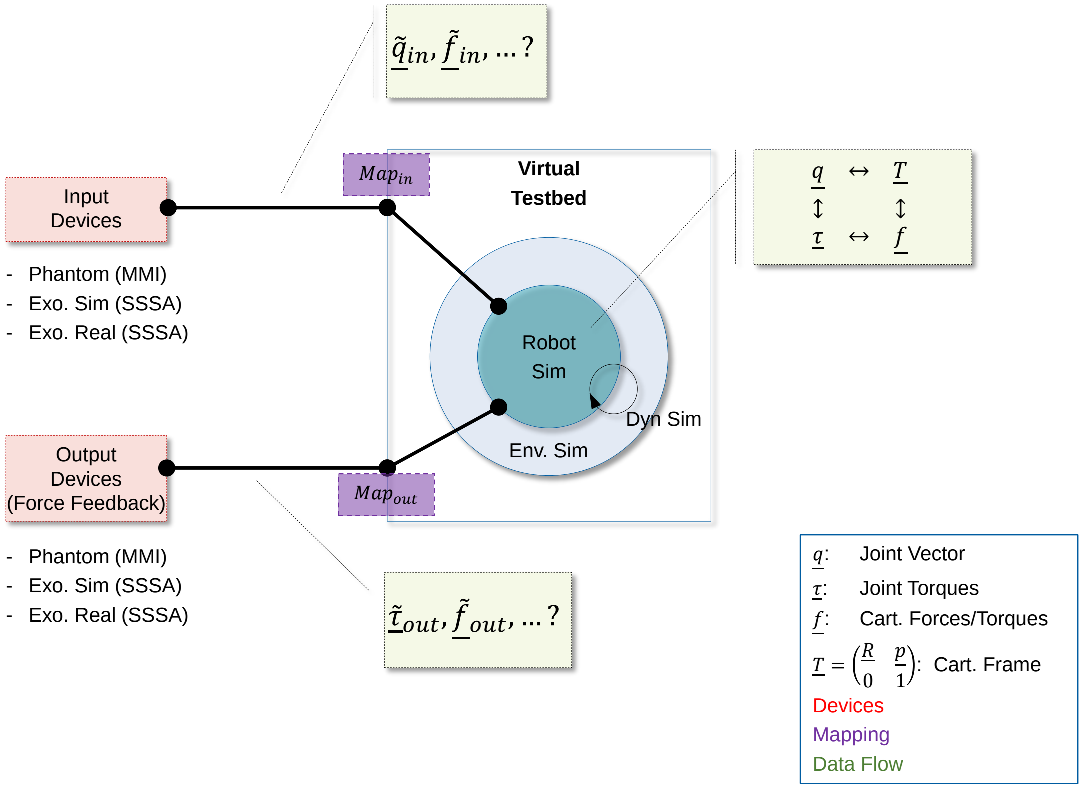

Figure 10: Scheme for exoskeleton interface.

In Fig. 10 one can see the Virtual Testbed itself and three major links involved in the interconnection between the exoskeleton development and the simulation: Input Devices, Data Flow, and Mapping. Within the Virtual Testbed, the environment and the robot interact via a dynamic simulation loop where forces, torques, joint vectors and frames are updated and synchronized in each iteration.

Interfacing this testbed needs the aforementioned three links. At **first**, the exoskeleton is not available yet and will only be available at the end of the CENTAURO project. Therefore, we have two approaches in mind. On the one hand, a Phantom Device [2] will be used to make the virtual testbed capable of force feedback in general. In the other hand, a exoskeleton simulator by SSSA will be used to emulate a virtual exoskeleton interfacing the Virtual Testbed to test and evaluate the communication protocol and structure of such teleoperating systems. A first test case will be to use the Phantom Device as an input device for the simulation and map the output on the exoskeleton simulator. In the **second** link, we will address central questions concerning data transfer: What kind of data are we dealing with? And what kind of communication link will be used? Although most interfaces are using ROS [3] as an interface, the high-frequency force feedback integration needs an additional channel to transfer data in the range of ms. Therefore, UDP and some kind of wired transfer from exoskeleton to control PC and wireless communication with the robot will be the method of choice. The UDP transfer will be specified in detail by SSSA and with progenoX, but a first approach is a 4 socket UDP for sensing (1), actuation (2), and configuration set (3) and get (4). The **third** link addresses the mapping from exoskeleton movement to robot movement. The low-level mapping will be carried out already within the exoskeleton and therefore by SSSA. The high-level mapping is an issue which will be defined by SSSA and IIT.

The next steps regarding the exoskeleton integration need the definition of the coupling from skeleton to simulation (virtual coupling, passivity observer, ...) whereas this coupling module will be provided by SSSA.

6.1.3 Interfaces and Integration – All project partners

As stated in the grant agreement [4], ROS is the central interface regarding any communication between robot and control station and with the simulation .

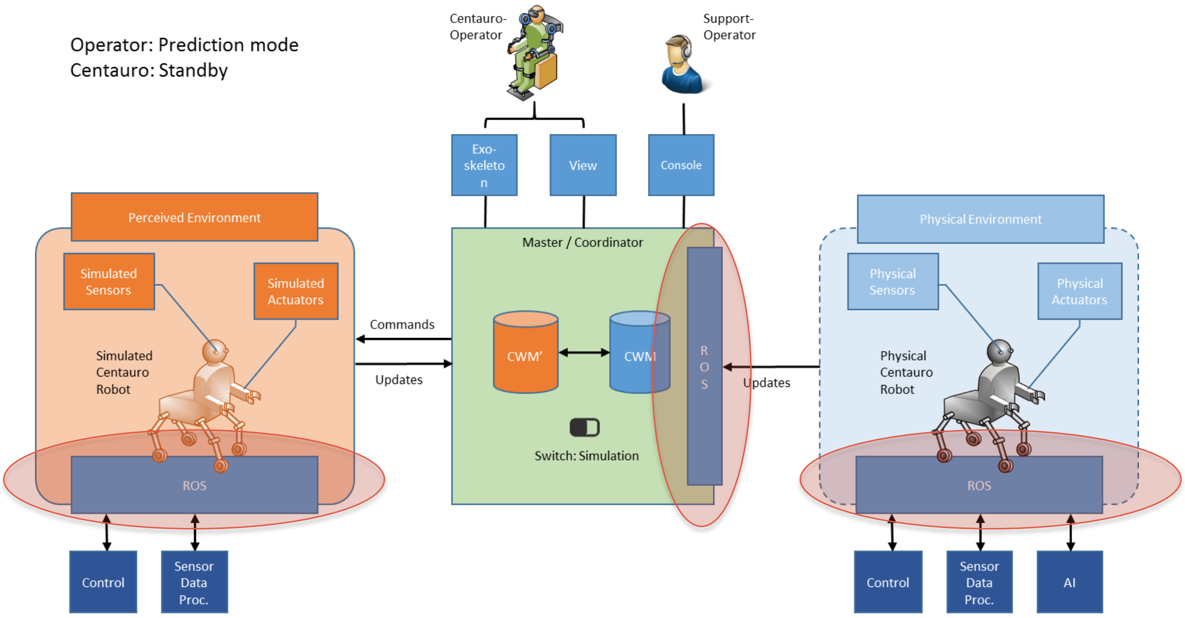

Figure 11: ROS as an universal interface.

In Fig. 11 one can see the final prediction mode of operation, where the real CENTAURO robot is in standby and the virtual CENTAURO robot can be maneuvered within the perceived environment. There are three different communication interfaces which have to be considered:

1. Exoskeleton – see Section 6.1.2
2. Internal CENTAURO – different modules interface with robot
3. External CENTAURO – robot communicates with operator/ CWM

The data communication within the CENTAURO robot system and between the robot system and the Central World Model is based on the Robot Operating System (ROS). Consequently, ROS topics and ROS services need to be interconnectable within the real and with the simulated robot system in terms of control, sensor data, AI, ... as well as a general interface between the CENTAURO robot and the central data storage system, the Central World Model. This concept of several modules, or building blocks, connected to the central system – no matter if real or simulated – needs a strict definition of data communication structure to enable the seamless transition from real to virtual testbeds. Implementing a ROS interface for VEROSIM – and thus for the virtual system in general – a standard has to be defined which kind of data is about to be transferred (a) within the CENTAURO robot system and (b) between the robot and the Central World Model. Prior to the final deployment of ROS nodes, the single modules can – also prior to encapsulation into a module – tried and tested within the Virtual Testbed and then decoupled and transferred into a stand-alone building block.

6.2 Implementation

Implementation of the Virtual Testbed for CENTAURO involves a step-wise development and integration of the individual modules. In the following list, the modules currently under development are outlined. This overview is categorized according to the four major points mentioned in Sec. 5.

- MODELING
  - CENTAURO Robot Model
  - Environment Model(s)
- INPUT/ Teleoperation
  - Integration of Force Feedback
  - Teleoperation with Exoskeleton
- INTERFACES
  - ROS Interface for VEROSIM
  - Test Cases for Interfacing the Real Robot from Simulation Using ROS
- (Preparation for) INTEGRATION / Real-time Optimization
  - Rigid Body Dynamics for Real Time Applications and Simulation-in-the-loop Applications
  - Real-time Hardware Capabilities

First of all, the force feedback integration will be integrated in the given rigid body simulation framework. Beginning with the integration of the Geomagic Touch X (formerly known as Phantom Device) and afterwards using the exoskeleton simulator provided by SSSA to finally use the real exoskeleton. The incorporation of the Phantom Device will provide two different options. On the one hand, the direct control of the tool tip frame, mapped into the simulation to move a rigid body accordingly. On the other hand, a direct mapping of the individual joints of the Phantom Device onto a model of the device. Especially the second option will be the foundation of integrating a exoskeleton because the direct mapping of joints will also be one central aspect in this mapping. Simultaneously, a first CENTAURO robot (see Fig. 1) and defined test scenario environments will be modeled. Here, we will focus on an application-oriented test scenario where the CENTAURO robot is maneuvered in virtual buildings and measures to model test grounds from pre-fabricated building blocks. This testing ground can then be a basis for building a real testing ground for final evaluation experiments. All models – no matter if environment or robot – can be updated during the whole process of development, starting with some specifications of the upper body and some motor parameters of the robot provided by IIT. The different environment models will evolve from being static in the beginning to fully dynamic environments in the end, using an updated sensor framework within the simulation (based on the used real sensors) and the input from KTH, LIU and all other project partners who are involved in the sensoric input of the CENTAURO robot.

The next step is the incorporation of a ROS interface to VEROSIM to make interfacing easier. The capabilities, functionality, and accessibility will be specified in cooperation with all project partners, particularly UBO for hard- and KTH for software respectively.

As a third step, the optimization of the given rigid body dynamics in VEROSIM will be analyzed and optimized with regards to the real-time capabilities necessary for force feedback and CENTAURO robot control. Additionally, the cross-platform utilization – Windows, Linux (Ubuntu 14.04LTS) and QNX – will be focused to meet the requirements for data processing and accessibility. This optimization procedure will take place throughout the whole development process and will be adapted to the possibilities and needs of the project partners.

7 Conclusions

The final CENTAURO setup uses a dynamically updated Virtual Testbed with environment and robot simulation in parallel to the real system (see Fig. 6). The Virtual Testbed can grow, evolve, and thereby support all CENTAURO project partners. The Virtual Testbed Concept will support a continuous, modular integration process utilizing the capabilities of Virtual Testbeds in general, but focusing on the novel approaches and challenges in the CENTAURO project. The Virtual Testbed Concept is the basis for developing the four main operation nodes (input, modeling, interfaces, integration). These will be developed in close communication with the project partners, starting with the following tasks:

- CENTAURO model
- Multiple environment models – simple geometry based (“box city) and application oriented (destroyed village)
- Force feedback integration into RBS – Phantom Device link
- Database storage – Central World Model
- Cross platform development – Ubuntu, QNX

Especially the rigid body simulation could become a bottleneck regarding the 1000 Hz force feedback limit. The complexity and information density has to be evaluated to achieve an accurate and realistic integration of force feedback in a highly dynamic simulation environment.

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