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Virtual Telesar - Designing and implementation of a modular based immersive virtual telexistence platform

MHD YAMEN SARAIJI, CHARITH LASANTHA FERNANDO, MASAHIRO FURUKAWA, KOUTA MINAMIZAWA and SUSUMU TACHI

***Abstract*— In this paper, we focus on designing a customizable modular based virtual platform for modeling, simulating and testing telexistence applications, where the physical parameters are preserved in the virtual environment; for motor control of physical characteristics of robot as well as sensory feedback of vision, auditory, haptic. We proposed "Virtual Telesar" which allows telexistence engineers to model a prototype system before manufacturing it and to experience how the final model will look-like, perform manipulations etc… in real world without building it. The platform consists of three features: first, the user can define a robot using predefined modular components. Second, the user can customize and tune up parameters. Third, the user can have immersive experiences of operating the robot with visual, auditory and haptic sensation. In this paper, we describe a design concept of Virtual Telesar platform and report modeling result based on a physical robot and result of immersive experience with it.**

I. Introduction

Telexistence allows a person to have a real-time sensation of being somewhere else than his or her current location and to interact with the remote environment which might be real, virtual, or a combination of both [1]. In reality, telexistence uses the operators' natural movements to control a robot, and in return operator feels the natural sensation as if he was in the remote environment. There has been number of works related to telexistence in real environments including TELESAR [1] involved in creating an exoskeleton type master-slave Telexistence cockpit, a 6 DOF telexistence head system TELESAR III [3] and an avatar system TELESAR V [4]. Also telexistence in combination of real and virtual environment exists including a master-slave system called TELESAR II [5] which enables a remote participant to not only interact with the robot, but also see the operator through a projected image based on retro reflective projection technology [6]. Also ability to view the operators projected image in a multi angle view was introduced in TELESAR IV [7].

Most of the humanoid robots including telexistence slave robots had been tested and experienced only after physically building it. In case of unexpected user experience occurred, or a new modification was required, the researcher or the engineer will have to wait until the physical fabrication is done. Although some of the previous robots had its own CG simulator environments, they lack the physical properties like editing and tuning features and the immersive experience of the robot as if it exists.

M.Y. Saraiji, C.L.Fernando, M. Furukawa,K. Minamizawa and S. Tachi is with Graduate School of Media Design, Keio University, Japan. Address: 4-4-1, Hiyoshi, Kohoku-ku, Yokohama, JAPAN. 223-0061; Telephone: +81-45-564-2449; email: {yamen , charith, m.furukawa, kouta, tachi}@tachilab.org

Fig. 1 First person view of Virtual Telesar

Other robots like Rollin' Justin, a humanoid robot [8] had its simulation environment which is used for prototyping and testing. The robot, however, aims for performing automated complex tasks without providing user feedback or experiencing the robot.

So rather than rebuilding or modifying the real robot when required to test new features, its more efficient to use low cost, faster methods which can mimic the real process. Such tools were commonly known as simulators, but the graphics simulation alone is not enough to reproduce realistic and immersive user experience because it lacks of feedback systems including first person vision, auditory and haptic sensation when touching remote objects within the simulator environment.

Thus we propose "Virtual Telesar" a virtual environment for building, testing and fine-tuning telexistence robot systems in a virtual environment and to experience the immersive experience as if the physical robot exists. In this paper we describe about the modular based design, customizability, how to fine-tune the components and an example implementation of "TELESAR V" telexistence system using the proposed method (Fig.1). Our proposed method focuses on the following points:

1. User can define a robot entity using basic building blocks including, robot model, input sensors, output actuators, etc…
2. User can tune component specific parameters
3. The method can integrate with physical sensory input

and motor output represented as a set of components with virtual environment.

4. The method enables the user to provide immersive experience similar to physical robots, via stereovision, audio and haptic feedback.

II. PREVIOUS WORKS

There has been many related works on modular based design related to robotics. Farritor and Dubowsky [2] had proposed a modular design approach for field robots systems using prefabricated modules to give low-cost system for specific tasks. This approach would help in simplifying building process into discrete set of options.

Related work regarding component based robot design is Webots [10], a robot simulation environment that uses components to describe the model and the modules.

Additionally, Microsoft Robotics Studio focuses providing mobile and automated robots [11]. Gazebo [12] is provided as open source. ABB Robot studio [13] specified for industrial purpose also allows us to tune performance and confirm the result in real-time. These examples support for modular design, performance tuning in real-time.

However, it is difficult to use these tools for telexistence applications because it lacks the immersive experience. Furthermore the representation of most of these parameter tuning is dedicated only for the simulator parameters. These tuning might be useful for CG experts, but not for telexistence researches as they are more focusing on the robot dynamics and overall immersive experience.

III. IMPLEMENTATION OF VIRTUAL TELESAR

A. Design Concept

In our proposed environment, the user should be able to define his robot, scene and environment in any CAD software. Then create basic primitives or import existing meshes for the intended robot and provide textures for those defined meshes. Then physical parameters like weight, collision model mesh, friction and elasticity parameters, adding joints can be done inside the CAD software using a custom build component toolbox for the Virtual Telesar. Component toolbox should include the following:

Physical – defining its physical parameters consists of specifying the primitive or a custom mesh model (collision layer) and physical material parameters (specifying friction, elasticity) and other related parameters such as velocity parameters, acceleration parameters etc….

Kinematics – defining Degrees of freedom for the robot is done via using joints or motors which links the segments of the robot. When defining the joints, the designer will have similar representation with the real robot definition, like defining the rotation axis or the motor shaft axis, and defining joints hardware limits, also the ability to define joints' stiffness and damping parameters (P_{gain}, D_{gain}).

Vision – the ability to define visionary parameters is essential, for example adding a stereoscopic camera and manipulating it's parameters (Field of view, Frame Resolution, Stereoscopic distance between cameras,..). By manipulating these parameters in real time will provide better understanding of the desired robot.

Audio - by attaching stereo audio listener on the robot, and specifying related parameters like its direction, audio gain...

Haptics – specifying the shape of the sensor, its placement, and sensor transfer function. By testing it and experiencing it, then re-tuning and engineering it to get the required performance.

When defining new component, the designer (for example the component manufacturer) takes into consideration specifying component's attributes and parameters which are going to be exposed in the simulation and design environment. Also other considerations like component communication interface should take place within the design step. Such considerations are essential because it will define the behavior of the component when communicating in the channel. For example, sensors like tactile sensors take into consideration communication frequency which will affect the bandwidth of the channel, and thus it will affect the size of data communication.

The ability to modify components' parameters in the simulation environment will give the user the ability to experience alternative configurations of it quickly and zero cost in terms of time and money. Such configurations can be body length or size, or his vision like his field of view, thus he can experience how such configurations will be reflected on the operator.

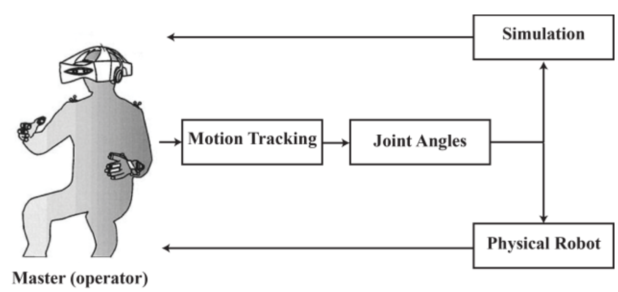

Fig. 2 Communication between Telesar and operator

Regarding the communication with simulator, the simulator as listed previously plays the rule of the controlled avatar, so the communication with it should be abstract and isolated from the simulation environment by defining data-providing layer. Fig.2 shows an overview of the communication between operator and remote avatar which can be either real or virtual one.

B. Implementation

For developing the simulator we used a custom game engine with Nvidia PhysX simulation. Above this engine we implemented the required libraries that provide the required components for the simulation. The simulator accepts an xml file describing the scene and for each object in the scene, a description components file is provided. Those files can be either manually created or automatically generated from the design tool, which is in our case: Autodesk Maya. We designed the required tools (Fig.3) in Maya which allows the designer to add, modify and export the components.

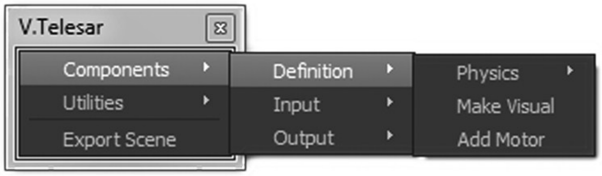

Fig. 3 Virtual Telesar Components Toolbox for Autodesk Maya

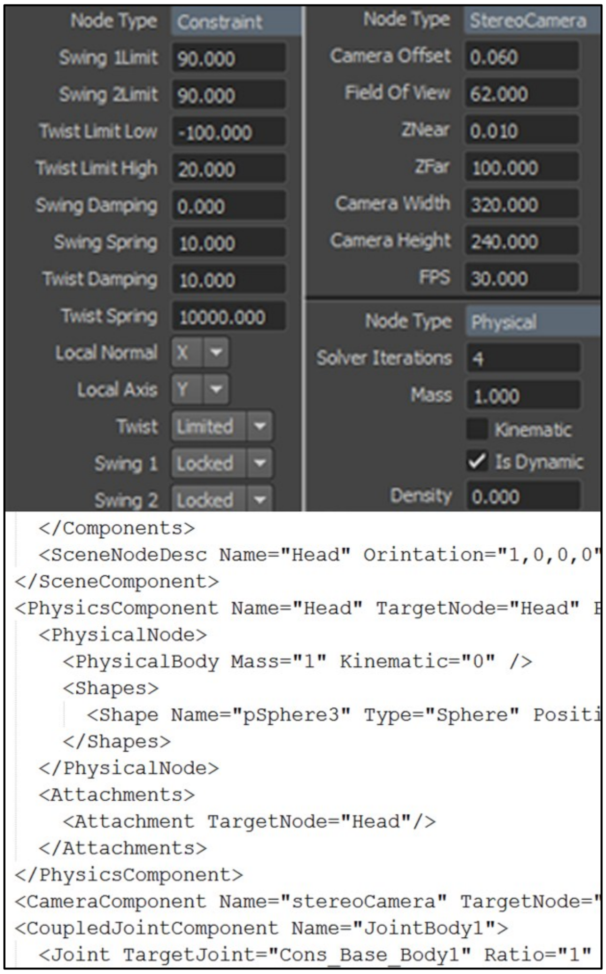

Fig. 4 Components' panels (top)
the generated simulator's xml file (bottom)

Designing process starts by using definition components, these components will serve for local configurations of the model. Defining the model begin by the visual representation, which includes object mesh and visual material. For the physical model, the designer can specify objects' properties, and an estimated representation for the underlying collision models.

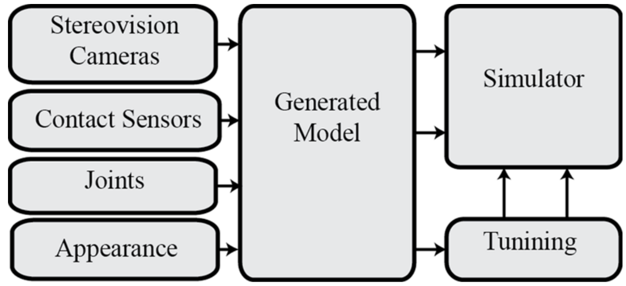

Fig. 5 Design flowchart

After modeling the physical representation and visual representation, control units should be attached to the joints in order to handle the input and feed it into the connected joint(s), if more than one joint where attached to the same control unit, they would become coupled together, coupled joints represents hardware coupling of set of rotational joints, these joints had a coupling ratio, which means the same input value will be weighted and fed into each coupled joint.

Even though the robot side does not contain sensing the depth in a scene, visual enhancement, and to create better visualization of the surrounding environment, the platform automatically generates real-time ambient occlusion for the scene and High Dynamic Range rendering. Also cameras support Depth of Field.

Fig.4 shows an example of the panels (Constraint –or the motor-, Stereo Camera, Physical Node) and the generated xml file. The general design method can be represented in the Fig.5. It shows how the simulator accepts the generated model, and the ability to tune it based on the model.

C. Virtual Telesar implementation for TELESAR V

We have modeled a virtual representation of TELESARV, which allows a person to experience telexistence in a virtual environment. Fig.6 shows Master/Slave operation, and a description of TELESAR V system. The physical robot supports stereo cameras, and force, temperature and tactile sensors on 3 fingers per hand.

A real-time simulation has been carried out with the existing TELESAR V system. The results was observed a general simulator tool in 3rd person view as well as an immersive 1st person experience wearing the original HMD used for TELESAR V system.

In this experiment a two WXGA (1280x720) stereoscopic screens were rendered in real-time providing the user to see the virtual environment in first person 3D view. We experience a real time video and clear vision also was able to render at 30 FPS.

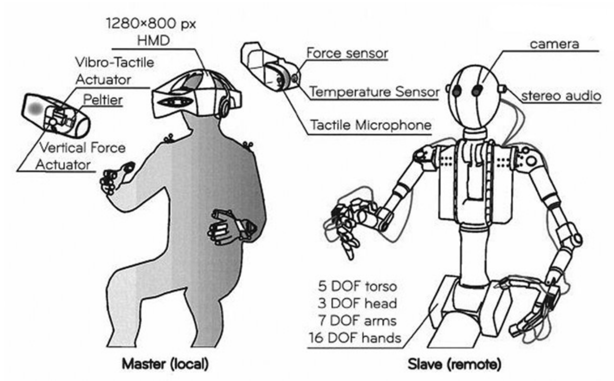

Fig. 6 Features of TELESAR V Master-Slave System

Furthermore the collision model stability was sufficient to have a very smooth movement of the virtual Telesar. Also we conducted manipulation tasks in CG environments. Fig.7 shows both: third view camera for the robot while it was holding two cups and the representative physical environment for the robot (physical visualization has been done using PhysX Remote Debugger).

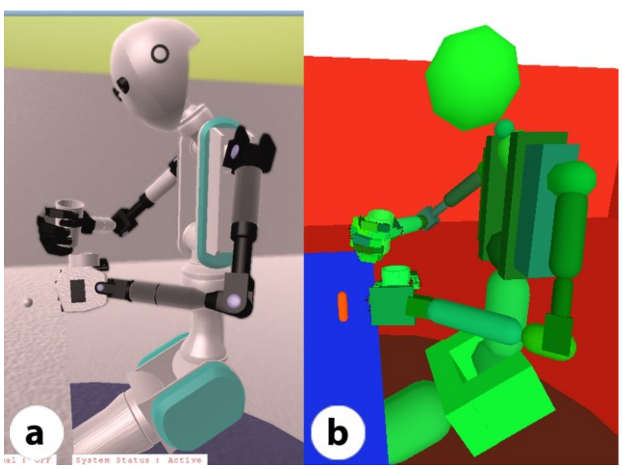

Fig. 7 Telesar in action, physical simulation for cup holding

IV. Conclusion

We proposed a customizable modular based virtual platform for modeling, simulating and testing telexistence applications, where the physical parameters of vision, auditory and haptic are preserved in virtual environment. The effectiveness of the system is tested by implementing a virtual telexistence platform based on existing TELESAR V system. Virtual Telesar platform will help telexistence engineers to model a prototype system before manufacturing it and the ability to experience how the final model will look-like, perform manipulations etc… in real world without building. In the future, we aim to provide more support for developers and researches by giving the features of generating manifest data or blueprints and send to fabrication houses.

Acknowledgement

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