SIGVerse - A Simulation Platform for Human-Robot Interaction

*Jeffrey Too Chuan TAN (National Institute of Informatics),

Tetsunari INAMURA (National Institute of Informatics/The Graduate Univ. for Adv. Studies)

1. Introduction

As robotics technology advances, robots are getting more involvements in human life. The interaction between human and robot has emerged into an interdisciplinary research theme across the scope of engineering into cognitive psychology, neuroscience, biology, social science, and many others.

Robotics research never comes cheap, and hence simulation comes into the picture. Two major variants of simulation pioneered the development of robotics simulation: classical robot simulation that focuses on physical behaviors (e.g. OpenHRP [1], Webots [2], The Player Project (Stage/Gazebo) [3]), and multi-agent simulation (agent-based model [4]) that concerns on the collective effect of a big group of autonomous agents. But in the context of human-robot interaction (HRI), what should be the choice?

2. The HRI Problem

This work involves a development of a robotics simulation platform called SIGVerse [5]. In order to address the motivation and novelty of the development, this paper aims to illustrate the features specially designed to address the needs in human-robot interaction development. In the article by Goodrich and Schultz [6], five main factors that define a HRI problem are presented. This paper will response to these five factors to illustrate the SIGVerse capabilities in facilitating HRI simulation development.

1. **Autonomy:** General development platform to model and simulate a wide range of *robot design*
2. **Information Exchange:** *Communication* between agents and human-robot is a main focus in SIGVerse
3. **Teams:** Not just *multi-agent* but *multi-user* is targeted to simulate a whole social interaction
4. **Adaptation, Learning and Training:** Support application based customized *human-agent interface*
5. **Task-Shaping:** *Human-robot task* planning and evaluation

3. Robot Design

In order to offer a general development platform that support various robot design, SIGVerse offers most of the fundamental elements in robotics modeling and simulation.

3.1 Physics and Dynamics Behaviors

In SIGVerse simulation, realistic physics and dynamics calculations are incorporated based on Open Dynamics Engine (ODE) [7]. With this feature, physical and dynamics properties of objects are taken into the calculation to simulate realistic physical interactions such as dynamics motions, object collision, and object grasping and manipulation. This is fundamentally important for human-robot interaction simulation as well, to simulate the physical interaction between object and agent. Below are some examples of physics and dynamics simulations achieved in SIGVerse.

3.1.1 Fundamental Physics and Dynamics

In Fig. 1, the object is released with a height distance from the ground in a simulation. Due to gravitational force, the object starts to fall down and rebound due to the force interaction between the solid body and the ground. An external force in forward direction is applied on the object that causes the object to roll forward.

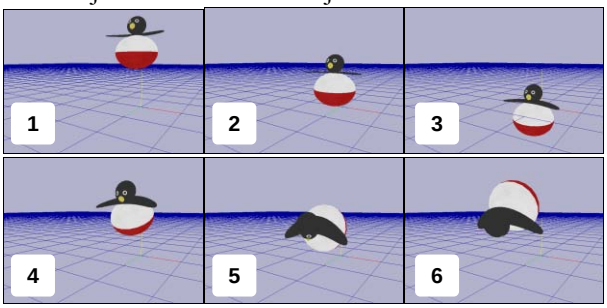

Fig.1 Physical and dynamics behaviors due to gravitational and external forces

3.1.2 Collision Detection

Figure 2 illustrates a simulation of collision detection between agents. The human agent is in stationary position and the robot agent is moving forward. The robot agent turns backward upon collision detection with the solid body of the human agent.

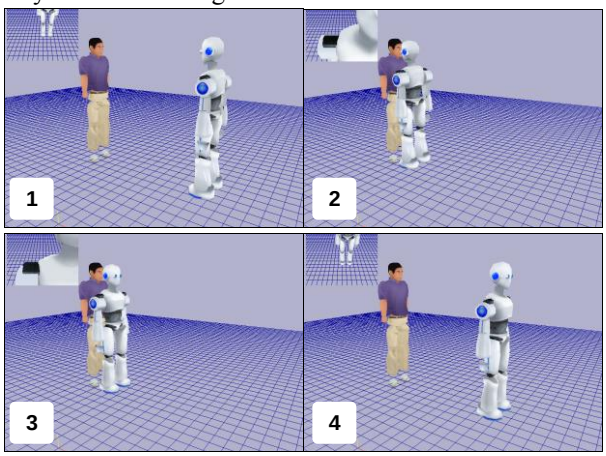

Fig.2 Collision detection between agents

3.1.3 Object Grasping and Manipulation

With the available of physics and dynamics properties, physical grasping and manipulation of solid object can be

realized in SIGVerse simulation. Fig. 3 shows a simulation of a robot agent grasping a bear doll and placing it on a table.

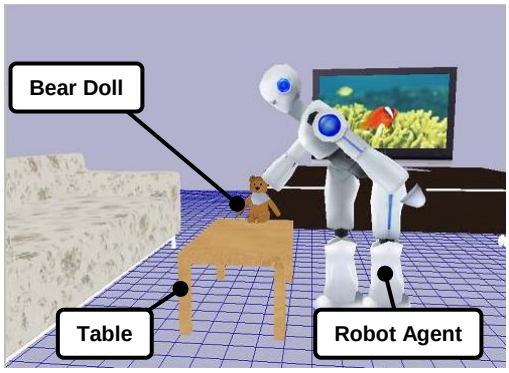

Fig.3 Object grasping and manipulation

3.2 Perception with Physical Constrains

Particularly in human-robot interaction simulation, agent‘s perceptions (visual, audio and tactile sensing) should be significantly subjected to actual physical constrains to be realistic. For instance, in a simulation of voice communication between two agents, the volume of the voice should be reduced as it travels over distance. In SIGVerse, physical constrains are taken into consideration to simulate agent‘s perceptions. The example below shows the implementation of this concept in a multi-agent interaction simulation.

In a multi-agent hunter-target simulation as shown in Fig. 4, the hunter agents are communicating among each other with visual and audio perceptions to coordinate their movement to surround the moving target agent. In this simulation, the visual and audio perceptions of the hunter agents are limited by the distance and obstacle (wall) between them. The sound is attenuated inversely with the square of distance and the vision is occluded by obstacle.

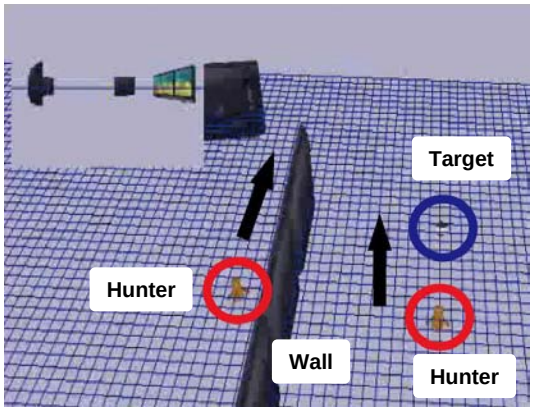

Fig.4 Multi-agent hunter-target simulation

3.3 Robot Modeling

3.3.1 Humanoid

Another important feature of SIGVerse in contribution to robotics simulation is the realistic robot modeling by using VRML and X3D as 3D definition format with PROTO Note in H-Anim specification for humanoid, similar to OpenHRP [1]. The robot modeling is not represented by a single solid body but a chain of link structures connected by joints (Fig. 5). With this method of modeling, simulation on the physics and dynamics behaviors of robot agent especially humanoid can be realized.

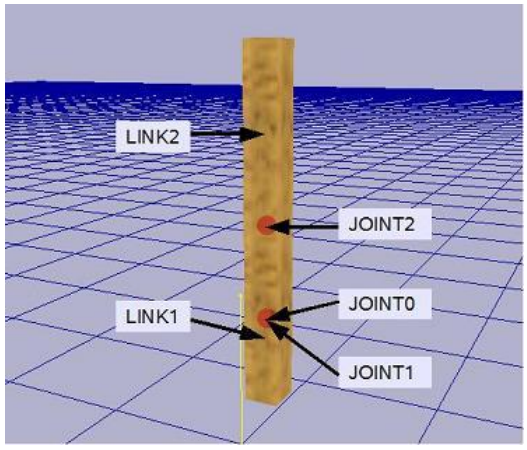

Fig.5 Link structures with joints in robot modeling (especially humanoid)

3.3.2 Mobile Robot

Apart from humanoid robot, popular mobile robot structure, for instance, differential drive wheel robot can be modeled using humanoid link and joint. Figure 6 shows a differential drive wheel robot modeling using humanoid link and joint in SIGVerse. The advantage of this modeling is to take the benefit of the dynamics of humanoid link and joint to accomplish wheel dynamics simulation.

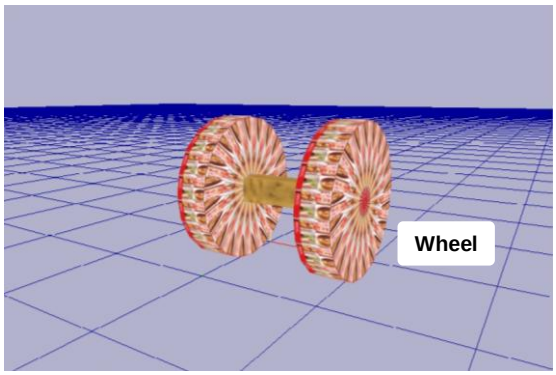

Fig.6 Differential drive wheel robot modeling using humanoid joints

4. Communication

4.1 Verbal and Non-Verbal Communication

Different from conventional robotics simulation, communication between agents (including human in real world) play a key role in human-robot interaction simulation. SIGVerse is specially developed for this purpose. Fig. 7 shows a basic communication simulation by messaging between agents. The robot agent will raises its hand when receiving ―Hello‖ message from the human agent.

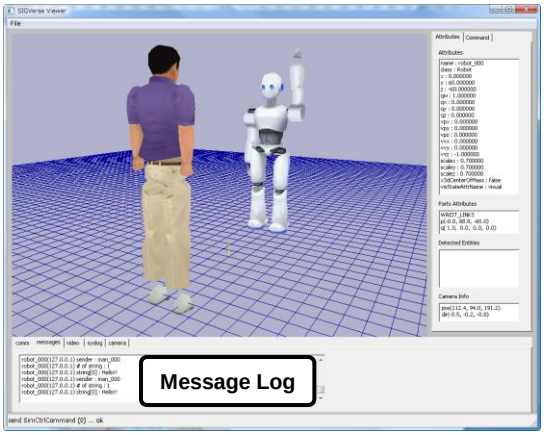

Fig.7 Communication by messaging between agents

As mentioned in the previous section, audio and visual perceptions are available in SIGVerse to simulate more sophisticated communications via voice or gesture behaviors. Non-verbal communication can be simulated in SIGVerse via visual perception and gesture behaviors recognition. Fig. 8 illustrates a joint attention simulation via visual perception to recognize human agent's eye-gazing and finger-pointing when danger situation arises (a book is dropping from the cabinet).

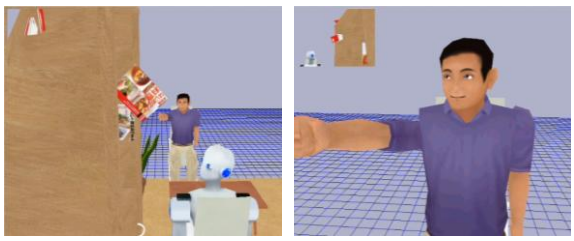

Fig.8 Joint attention simulation via visual perception and gesture behaviors recognition

4.2 Level of Perception Data

Fig. 9 illustrates a simulation on agent's visual perception for object detection. On the top left corner, it shows a view window as the visual perception output of the robot agent. With this visual perception, the robot agent is able to detect two objects (apple and bear). In SIGVerse, two different levels of perception data are available. In the simulation in Fig. 9, the robot agent is given high abstract level of perception data as in 3D viewpoint as visual input and objects' metadata (name, id, position and other attributes described in the objects' shape data). However, to further facilitates research in image processing and object recognition, raw visual data in pixel map is available as robot agent's visual perception for object recognition development. Similarly, audio perception works in the same fashion, where comprehended messages or raw audio data are available as audio perception of the agent.

5. Multi-Agent and Multi-User

Communication simulation in SIGVerse is not limited to a pair of agent but it is designed to enable multi-agent and multi-user in real world. Refer to the software configuration of SIGVerse in Fig. 10, SIGVerse system is executed in a server-client architecture, where central server runs the simulation on dynamics and communication with perception simulation as a service provider, and connected with agent controller in user applications. Multiple clients are able to connect on the same simulation running on the central server. Hence, multi-agent can be realized in a simulation while multi-user can participate in the simulation from various client applications. With this architecture, SIGVerse is able to run multi-agent and multi-user simulation to achieve social interaction in a big scale.

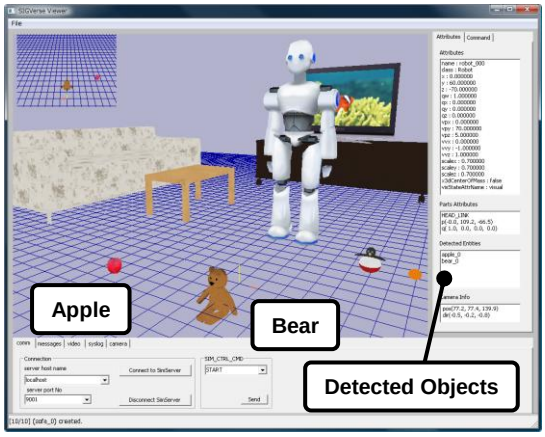

Fig.9 Agent's visual perception for object detection

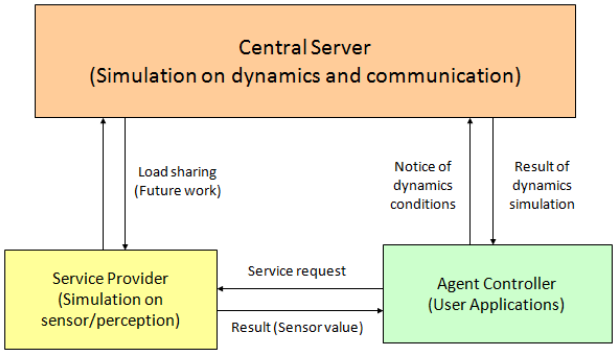

Fig.10 Software configuration of SIGVerse

6. Human-Agent Interface

Apart from communication within the virtual world, SIGVerse also focuses on the interface development to establish communication between agent and human user in real world. Also, this feature supports application based customized interface development with APIs.

In Fig. 11, the simulated agent takes a bow when greeted by human user in real world by text message sending via the GUI. Similar communication can be achieved by audio with the same GUI.

For non-verbal interaction between SIGVerse agent and real world user, Fig. 12 shows a current development to interface the interaction by haptic device. Human user in real world is controlling his/her avatar to perform a collaborative work with the agent in the simulation. Interaction involving whole body movement also can be ma-

terialized by using a motion capture system as shown in Fig. 13.

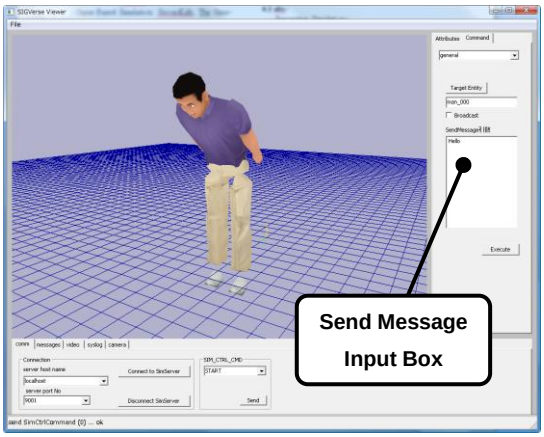

Fig.11 GUI interface between agent and real world user

Fig.12 Haptic device as interface system [Provided by Dr. Tomohiro Shibata at NAIST]

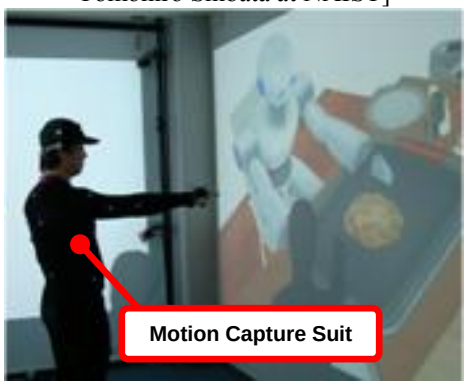

Fig.13 Interaction by motion capture system

7. Human-Robot Task

As described by Goodrich and Schultz, the introduction of HRI induced changes to the original human task. In the human-robot collaboration simulation to perform an ‗okonomiyaki' cooking task [5] in Fig. 14, the SIGVerse application itself is an evaluation function on the collaborative work. This development has facilitated task planning and evaluation on the human-robot interaction.

8. Conclusions and Future Work

This paper aims to illustrate the features specially designed in SIGVerse to address the requirements in human-robot interaction development. Based on the five main factors, the SIGVerse capabilities in facilitating HRI simulation development are discussed:

1. **Robot design:** General development platform that offers physics simulation, realistic perception and robot modeling
2. **Communication:** Verbal and non-verbal communication with level of perception data
3. **Multi-agent and multi-user:** Social interaction that involves all multi-agent and multi-user
4. **Human-agent interface:** Highly customized interface to suit application's needs
5. **Human-robot task:** Application on collaboration that improve task planning and evaluation

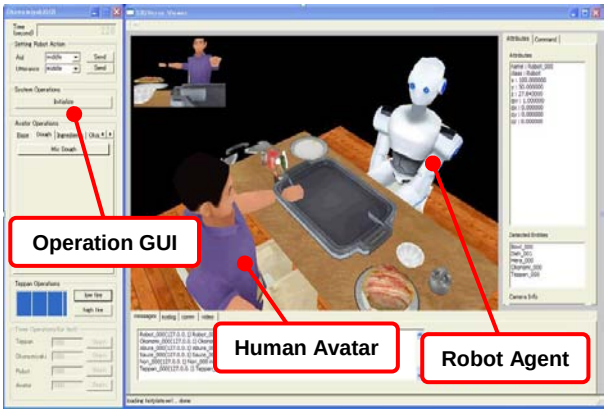

Fig.14 Human-robot collaboration simulation

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