A SIMULATED ENVIRONMENT FOR ELDERLY CARE ROBOT

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Abstract: The population of elderly people is increasing steadily in developed countries. Among many other technological methodologies, robotic solutions are being considered for their monitoring and health care services. It is always desired to validate all aspects of robotic behavior prior to their use in an elderly care setup. This validation and testing is not easily possible in real life scenario as tests are needed to be performed repeatedly under same environmental conditions and controlling different parameters of a real environment is a difficult requirement to achieve. Developing and using 3D simulations is the most beneficial solution in such scenarios, where different parameters can be adjusted and different experiments with identical environmental conditions can be conducted. In this paper development of a simulated environment for an autonomous mobile robot, ARTOS, has been presented. The simulated environment imitates a real apartment and consists of different rooms with a variety of furniture. To make the situation more realistic, an animated human character is also developed to validate the robotic behavior. As an application scenario, searching of the human character by the robot in the simulated environment is presented, where the simulated human walks through different rooms and the robot tries to find him.

1 INTRODUCTION

With the increase of elderly population in developed countries, it is becoming necessary to use modern technologies to maintain their standard of living and to provide them with better health care services. The technological advancement can make it possible to detect an accident to the elderly person at home or even report the accident immediately to the caregivers. Besides several monitoring devices being installed at home, robots are also being used to monitor the aged person. The added benefits of using robots, besides others, are that they can

- help the elderly person in performing different tasks at home
- be a companion to the elderly person
- act as an interaction partner
- be tele-operated in case of an emergency situation.

Elderly care robots have to work in a very delicate environment and they have to deal not only with the uncertainty of the environment but also with the uncertainty in regards to the elderly person. It is, therefore, fundamentally desired to extensively validate the working of these robots. Testing and validation of the robotic behavior is not possible in the real environment since any malfunction can harm the elderly person. Moreover, it is almost impossible to conduct the test cases repeatedly with same environmental conditions to re-generate and improve the results. Therefore, it becomes necessary to develop a simulated en-

Figure 1: Autonomous Robot for Transport and Service (ARTOS).

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vironment that is as close to the real scenarios as possible and should provide all the necessary parameters that can influence the working of the robot.

Autonomous Robot for Transport and Service (ARTOS), see fig. 1, is being developed to provide help to the elderly person in transporting different objects within a home environment and to render tele-operation service between care-givers and the elderly person. It can move autonomously to different rooms, avoiding collisions and planning paths between closely placed furniture and door ways.

In this paper, the development of a simulated apartment-like environment to observe the behavior of ARTOS in the humanly environment is being presented. The simulation and visualization is based on SimVis3D (Braun et al., 2007) (Wettach et al., 2010) and the simulation of a human character complying to H-Anim [1] standards as discussed in (Schmitz et al., 2010).

This paper has been organized in the following way. First a summary of related work is presented in section 2. The development of the simulation is discussed in section 3 with subsections describing different aspects of simulation. A brief account of experiment is presented in section 4. Finally, section 5 presents the conclusion and the future work.

2 RELATED WORK

Developing a close-to-reality simulation for robotic environments requires a simulation framework that features a range of sensor systems and robotic platform. It must be capable of handling user defined structures and have possibilities of extension.

A variety of simulation frameworks are available for developing a 3D simulated environment for robots, but most of them are limited in their functionality and provide little room for extension. Gazebo (Koenig and Howard, 2004) is a 3D simulator for multiple robots. It contains several models of real robots with a variety of sensors like, camera, laser scanner etc. Robots and sensors are defined as plugins and the scene is described in XML format.

SimRobot (Laue et al., 2005) uses predefined generic bodies to construct a robot and allows a set of sensors and actuators that can be used. It uses ODE to simulate dynamics. Based on SimRobot, (Laue and Stahl, 2010) have modeled and simulated an assisted living environment to evaluate maneuvering of an electric wheelchair.

EYESIM (Koestler and Braeunl, 2004) is a 3D simulation tool for EyeBots. It provides different sensors like camera or bumper, but does not support dynamics. UASRSim (Wang et al., 2003) is a simulation tool based on the *Unreal Tournament* game engine. The 3D scenes can be modeled using *Unreal Editor* and dynamics are calculated by *Karma* engine.

Usually robotic simulations do not include simulation of a human character. But in case of a household robot, human interaction cannot be avoided at all. Therefore, in case the robot has to work among the human being, it is necessary to evaluate the behavior of the robot in the simulation.

Greggio et al. simulate a humanoid robot in (Greggio et al., 2007) using UASRSim simulation. Similarly, (Hodgins, 1994), focuses on simulating the running of human beings. Thalmann discusses the autonomy of a simulated character in (Thalmann, 2004). But these simulations are independent and do not portray the needs of a household environment.

Although most of the simulation frameworks support a realistic 3D simulation of robots with standard sensors and support for system dynamics, there is still a need of a more flexible, allowing usage of custom objects, and extensible framework like SimVis3D. Besides supporting a variety of robots and environments, the framework in hand is able to realize different movements of autonomous human characters, discussed in section 3.4.

3 DEVELOPED ENVIRONMENT

The goal of ARTOS is to search, monitor and inquire health of an elderly person and in case of any emergency situation alert the care-givers and establish a communication channel between the resident and the care-givers. For this purpose, autonomous navigation, obstacle avoidance, path planning and tele-operation have been implemented for ARTOS and have been tested in a real environment developed at IESE, Fraunhofer (Mehdi et al., 2009). However, testing the methodologies for searching and monitoring the human being is not an easy task in the real environment. A slight change in the environmental conditions may result in a complete different robotic behavior. Therefore, to thoroughly validate a particular behavior of the robot it is very important to conduct the experiments in exact identical situations. In such scenario it seems judicious to develop a simulated environment that is as close to the real environment as possible and also, besides providing static environment information, provides the dynamics of a real environment.

In order to illustrate the environment developed

[1] http://www.h-anim.org

```
<part file="artos/vis_obj/iese_.wrl" name="LAB" attached_to="ROOT" pose_offset="0 0 0 0 0 0" />

<part file="hanim/yt_002b.wrl" name="Model" attached_to="LAB" pose_offset="4 2 0 90 0 180" />

<part file="artos/vis_obj/artos.iv" name="ARTOS" attached_to="LAB" pose_offset="0 0 0 0 0 0" />
<element name="artos_pose" type="3d Pose Tzyx" position="5 5 0" orientation="0 0 -90"
  angle_type="rad" attached_to="ARTOS"/>
...
```

Figure 3: A snippet of XML description for the scene shown in fig. 4

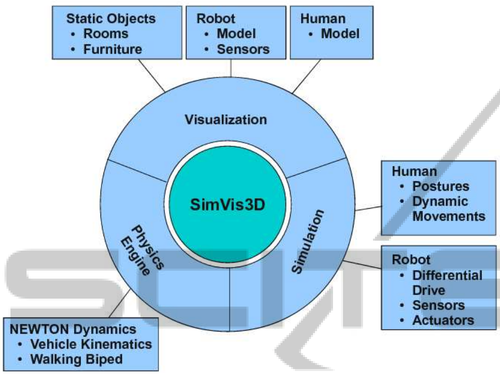


Figure 2: Overview of SimVis3D.

(a) (b)

Figure 4: Different views from camera in the environment showing (a) simulated human character and (b) simulated robot.

and demonstrate the flexibility and the capabilities of SimVis3D, the following subsections will discuss the SimVis3D framework (section 3.1), the development of simulated apartment (section 3.2) and the simulated robot (section 3.3). The simulated human being that is used to facilitate understand the behavior of the robot in the simulation is discussed in section 3.4.

3.1 SimVis3D

SimVis3D is an open source framework based on the widely used 3D rendering library *Coin3D*[2] that rely on *OpenGL* for accelerated rendering. It is compatible to *Open Inventor* and is capable of generating complex simulation and visualization for robots and their environments. It was designed to allow users to create custom scenes by using basic building blocks in a meaningful situation. It can be used to visualize and simulate a variety of environmental situations.

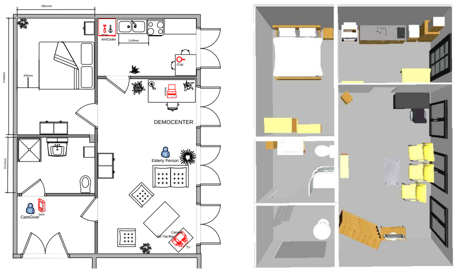
Figure 2 depicts the main components of SimVis3D framework. The visualization module is responsible for visualizing the environments, robots and human characters. It also shows the robot's view of the world. The simulation module simulates and generates the data for actuators and sensors. Currently, it is capable of simulating different kinds of actuators (stepper motors, servo motors etc.), distance sensors (laser scanners, ultrasound and PMD[3] cameras), tactile sensors, vision sensors and acoustics (see (Schmitz et al., 2010) for the last aspect). The physics engine module based on the NEWTON dynamics engine has been used for vehicle kinematics and biped walking.

SimVis3D uses the *scene graph* data structure to store and render the graphics in three-dimensional scene. The *scene graph* data structure is populated from an XML file containing scene description. Figure 3 gives a glimpse of the XML file to define a scene and objects in this scene. The *part* adds arbitrary 3D objects stored as *Open Inventor* models in external files and in *.wrl* files written in VRML [4]. These subgraphs are inserted at the anchor nodes defined by the *attached_to* attribute. The *element* is used to define parameters, including pose offset, position etc., for that particular object defined in *attached_to*. The scene developed using the XML scene description file is depicted in fig. 4 showing different views of the camera. This camera can be placed anywhere in the scene to observe any particular aspect of the robotic behavior.

3.2 3D Model of Apartment

A real apartment has been established at IESE, Fraunhofer to conduct experiments with the real robot. Its area is $60m^2$ and is equipped with furniture necessary for the apartment. Corresponding to this real apartment, a 3D model has been developed using

[2]http://www.coin3d.org
[3]Photonic Mixer Device
[4]Virtual Reality Modeling Language



(a) (b)

Figure 5: (a) Assisted living lab at IESE Fraunhofer and (b) Visualization of assisted living lab.

Blender [5]. It was ensured that the dimensions of different rooms of the 3D model matches the real environment. Figure 5 shows the layout of the real apartment and the 3D model of the assisted living facility at IESE, Fraunhofer. A variety of furniture have been added to the visualization to make it closer to the reality.

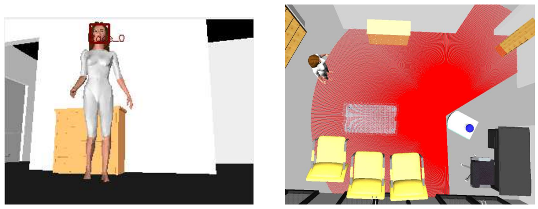
The visualization of these 3D models is carried out using SimVis3D. The XML description file containing the mounting position of different objects and desired parameters is used to place the furniture at appropriate places in the 3D scene. The objects, e.g. furniture, are inserted to the mounting point ”*LAB*” with parameters specifying their location and orientation. Currently these are static objects in the scene and the human or the robot cannot move the furniture from their defined location.

3.3 Simulated Robot

The robot for visualization is composed of chassis, wheels, camera and laser scanner. According to the scene description in fig. 3 it has been introduced as ”*ARTOS*” object in the visualized ”*LAB*” environment. A 3D pose element ”*artos_pose*” is attached to the robot to be able to move and rotate it in its working space.

The control structure for the movement of ARTOS in the simulated environment is based on the MCA2-KL [6] framework. It is noteworthy that it is the same control structure that is being used by the real ARTOS and nothing needs to be changed for simulating sensors and actuators. Like the real robot, the simulated ARTOS is equipped with a simulated pan-tilt camera and a simulated laser range finder. Figure 6a shows the view from the camera of the robot and fig. 6b shows the range of laser scanner.

For an autonomous navigation of the simulated ARTOS, the laser scanner is used to generate a grid-map of the environment. This grid-map maintains the information of the obstacles and is used to generate path for navigation avoiding these obstacles. For detecting human being in the simulation, the pan-tilt camera of the robot is used to detect the face of the human using a Haar Cascade classifier (see fig. 6a).



(a) (b)

Figure 6: A simulated view of environment with simulated robot’s (a) camera, (b) laser scanner.

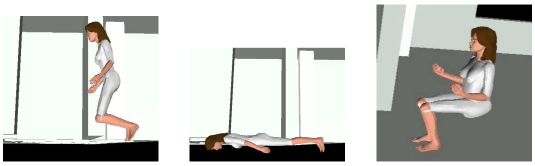
3.4 Simulation of Human

In order to simulate the animated character close to the real human being, different body movements have to be defined. This requires a detailed description of the human being which may offer possible body part movements. To incorporate such level of articulation, the well established human modeling standard H-Anim has been used. This standard defines a specification for defining interchangeable human figures to be used for simulation environments. An avatar [7] conforming to the H-Anim modeling standards has been used to visualize different movements of the human.

Human body movements have been divided into two categories, namely simple movements and complex movements. Simple movements are those which are generated using a 3D modeling tool like Blender. These movements are independent of each other and have a definite time for execution. These movements include, walking, falling on the ground, standing up from the fall, sitting on a chair and standing up from a chair (see fig. 7). Complex movements, on the other hand, are a combination of simple movements, for example walking from one room to the other requires a combination of several simple walk motions. For complex movements it becomes necessary to ensure that the body of the character is in a position from where it can perform the next simple movement. Various other movements, both simple and complex, can easily be defined and incorporated in the same manner.

For autonomous movements in more humanly way, the simulated character walks in the environment from one place to the other. One approach can be to

[5] http://www.blender.org
[6] http://rrlib.cs.uni-kl.de/mca2-kl
[7] Avatars based on H-Anim are available at http://www.h-anim.org/Models/H-Anim1.1/



(a) (b) (c)

Figure 7: Dynamic postures of human character (a) Intermediate posture for falling human, (b) Human fall and (c) Sitting posture.

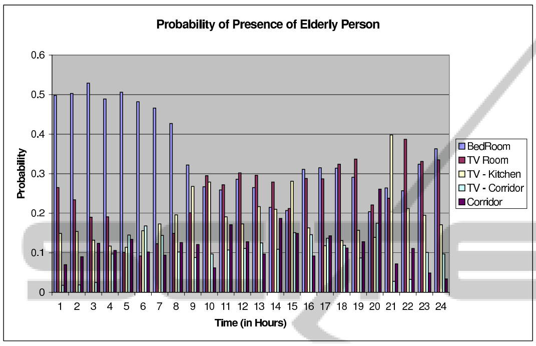


Figure 8: Probability of presence of human being in different rooms at different times.

randomly select a room and move the simulated human in that room. In order to make this movement more realistic, probabilities of presence of a human being in different rooms have been generated. These probabilities represent the presence of a human being at different places in the apartment based on time, see fig. 8. Using these probabilities make it possible to move the simulated character based on some pattern that represents the real human being and thus the movement to different rooms is not completely random, although destinations in a particular room are still random.

Moreover, it is also possible, that the simulated human performs different postures while moving from one place to the other. These postures may include, sitting, standing, falling, getting up etc. A random selection of such movements may result in a chaotic movement pattern where after falling on the ground the character may start walking without getting up. Therefore, different probabilities are assigned to different movements. In this way, selection between different movements ensures that no unrealistic movement may occur and co-occurrences of movements are regulated.

4 EXPERIMENTS AND RESULTS

The idea is to test the visualized and simulated environment for its effectiveness and level of details with

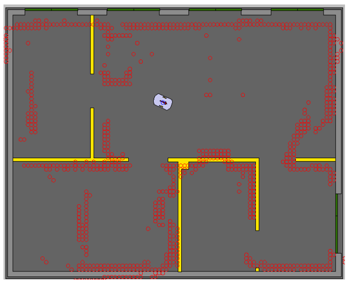


Figure 9: Grid-map of the environment generated using simulated laser scanner.

respect to the real situations that are required for observing different actions performed by the robot. As an application scenario searching the human being by the robot in the environment has been developed, see (Mehdi and Berns, 2010) for details. The task of the robot is to find the human being as early as possible with minimal navigation necessary. To accomplish this task, the robot has to drive autonomously in the simulated environment and detect the human face using the camera. For autonomous navigation, it is necessary that the grid-map is build using the simulated laser scanner, containing information about the obstacles in the scene, and the path is planned avoiding these obstacles. Figure 9 shows the grid-map generated for the visualized environment where red blocks show the detected obstacles.

In order to measure the performance of the robot for searching the human, certain points are marked as reference points in the environment. To make the scenario more interesting, it is not always possible to view the human character from these reference points even if the simulated human is present around the same area. This is consistent with a real life situation where sometimes it is not feasible to identify the human being due to lightening conditions or orientation of the human or the robot. In this case the desired behavior of the robot is that it should move to another place and try to find the human there.

The experimental results show that the robot autonomously navigates to different locations to find the human character in the simulation. In some cases, due to orientation and positioning of the human, the robot was not able to find the human in the environment but in such cases it navigated to the other rooms as was desired.

5 CONCLUSIONS

This paper has presented a close-to-reality simulation of a typical household scenario with a simulated human character and a service robot. The simulation and visualization are based on the SimVis3D framework. Due to flexibility of this framework static furniture objects as well as dynamic human with typical motion patterns could easily be realized. Moreover, different sensor systems and actuators for the robot can easily be employed. As a practical scenario to underline the need of a simulation environment a series of tests have been performed where the robot had to search the human being in different situations.

In order to make the simulated human more realistic, future work will include collision detection and effects of collision to the human and the environment. Besides, additional standard motion patterns of the human character will be developed to increase the level of realism during testing of methodologies being developed for the robot. This will be assessed by consecutive real world experiments under similar conditions. Future developments concerning the robotic platform concentrate on identifying different postures of the human and on detecting and handling unexpected changes in the human behavior. With respect to the SimVis3D framework, the integration of physics engine for static objects is the next task to accomplish.

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