Modeling of Human Actions in a Collaborative Robotic Space Using AR601M Humanoid Robot: Pilot Experiments in the Gazebo Simulator

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Abstract

To guarantee a safe human-robot collaboration, a collaborative system development requires a significant amount of real world experiments. Yet, it is critical to avoid injury risks for participants of such experiments. The risks could be reduced by introducing a virtual experiments' stage to detect mistakes in a robot behavior prior to the real world experiments. This paper presents a virtual model of a humanoid robot AR601M in the Gazebo simulator. Unlike the standard human models in the Gazebo, this model allows to simulate the gross and fine motor skills of a human and could be used when performing various human actions in collaborative robotic cells.

Keywords: Humanoid robot, Anthropomorphic robot, Gazebo simulator, Collaborative robotics

1. Introduction

Recently, human-robot interaction during collaboration in a shared workspace[1] and efficiency of distributing tasks between actors of different origin[2] attract great attention of researchers. Collaborative robots are often considered safer for humans than industrial robots[3]. However, unexpected failures, poorly thought-out security systems, and the human factor still maintain the risk of injury when a robot and a person work together. Expanding the possible cases of human interaction with a robot[4], building process maps and conducting experiments can increase the level of safety of the collaboration between a robot and a human.

Experiments with real people in the first stages of testing can be traumatic, and the use of anthropomorphic-type robots as human models can be unreasonably expensive. Therefore, the use of simulators and simulation models of a person for collaborative interaction modeling becomes an urgent task. One of the popular simulators used in robotics is Gazebo. However, when trying to apply ready-made animated human models available for the Gazebo[5][6] environment, we encountered several problems that do not allow them to be fully used in pilot experiments.

The first problem concerns the animation of the so-called actors in the Gazebo environment. Available by default Gazebo actor animations are limited to 9 types of actions. Creating custom actor animations requires to work with the COLLADA format files which is often inconvenient and time-consuming.

Another significant problem is that actors cannot interact with the environment. Because of this, it is impossible to simulate collisions of actors with physical objects. In addition, actors cannot be detected by most sensors.

Instead of Gazebo actors, we propose to use the AR601M anthropomorphic robot virtual model as human models. This robot can interact with the world. It has gross and fine motor skills, which is necessary for most pilot experiments.

The purpose of our research is to combine the related works into one model of AR601M robot, modeling human actions for this model, and perform pilot experiments.

2. Related Works

Some motor functions of the AR601M virtual robot model were partially implemented earlier. Khusainov et al. modeled AR601M locomotion with Walking Primitives approach in Simulink environment[7][8]. Walking primitives is a popular approach for biped robots that automatically generates joint trajectories[9]. The authors used simplified models of AR601M with 6 DoFs and 12 DoFs per legs. This approach showed good results in simulation, but it cannot be applied to the real AR601M robot because it doesn't support fast biped locomotion due to the leg's motor torque limitations.
Khusainov et al in the next work with AR601M robot model researched two walking stability algorithms in Simulink - virtual height inverted pendulum model (VHIPM) and preview control methods[10]. The preliminary VHIPM method has been modeled for AR601M robot and got onto his influences of robot height and step length[11]. As a result of the work, the preview control method turned out to be more reliable, than VHIPM method. The preview control method has feedback, it allows to avoid error accumulation for better robot locomotion. The authors decided to continue their work for both algorithms. They wanted to add calculations for peak walking speed simulations to VHIPM method and consider full body dynamics for high-speed walking to the preview control method.
Khusainov et al using knowledge of the above mentioned works addressed the issue of optimization gait pattern for a bipedal robot, which maximizes its locomotion speed under a joint angular velocity, actuator power limits and acceleration[12]. The authors compared kinematic[13] and dynamic approaches. They determined kinematic approach are applicable only if we use the upper body motion to balance the robot dynamics during walking. As opposed to kinematic approach, dynamic approach allows to use different acceleration and velocity limits depending on the payload applied to the actuated joint. This allowed them to reach physical limits for the swing leg.
Magid and Sagitov reviewed various approaches of fall detection and management procedures for different size humanoid robots and evaluated the possibility of implementations them for the AR601M robot[14].
Beside works with AR601M robot leg movements there is progress in hand control. Khusnutdinov et al. implemented household objects take and place tasks in Gazebo Simulator[15]. Authors configured mimic joints of right-hand fingers, focusing on the real AR601M robot possibility. In another work Khusnutdinov et al. presented grasping algorithm utilizes the simplicity of an antipodal grasp and satisfies force closure condition[16].

3. Robot AR601M and its Gazebo model

The AR601M robot shown in Fig. 1 is a bipedal walking robot of humanoid type. The robot is being developed by a Russian company Android Technics. Its height of 144 cm and weight of 65 kg. Robot has 41 active DoF. AR601M has the ability to grab objects and hold them. The load capacity of each grip reaches 1 kg. The robot is made with an anthropomorphic structure that provides kinematic characteristics that are approximate and inherent of a person.

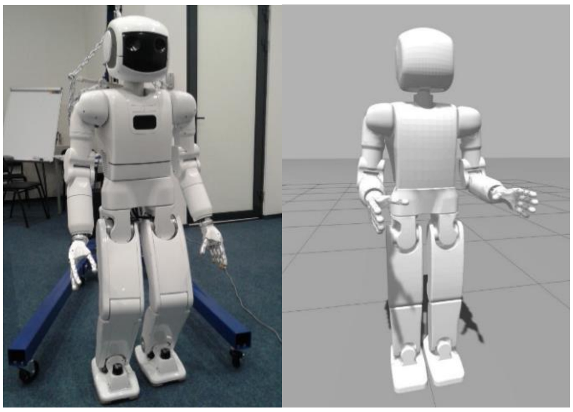

Fig.1 Real AR601M(left)[17] and its Gazebo model(right)

Model of AR601M in Gazebo should coincide with the real robot. We have two options for the robot model: model with Kinect is shown in Fig. 2 and without is shown in Fig. 1. Our model uses revolute joint controllers for the robot's body control and mimic joint controllers for the robot's fingers control. All controllers have the same limits, like on a real AR601M robot. With these controllers, the robot can walk, turn its head, move its arms, squeeze and unclench its fingers.

Additionally, for our pilot experiments, we modeled the following human actions:

1. Walking from a given point to a given point.
2. Movement of each hand along a given arbitrary trajectory (set of points).
3. Gripping a wrench.

4. Experiments

Using the results of the works presented in the literature review, we combined the fine and gross motor skills of the robot in one simulation model. In this section, we present the experiments with this model and the results of these experiments.

The first experiment shown in Fig. 2 simulates typical human actions in collaborative workspace such as walking, object take and place tasks. During the experiment AR601M robot needed to turn around, walk over to the table, pick up the wrench from a special holder, carry and place it to the conveyor used by the UR3 and UR5 robots.

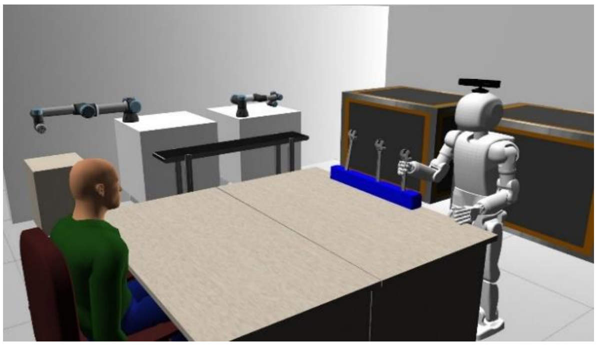

Fig.2 Frame of the first experiment, where the AR601M robot with Kinect grasped the wrench

The second experiment shown in Fig.3 presents a situation where the human and manipulator have co-working space - here is the table. Our AR601M robot stands at the table and simulates human actions close to the manipulator. Robot AR601M move apart small cube by hand, turns torso and moves its arms in front of UR5. The resulting model of AR601M in Gazebo coped with experiments. The robot performed human actions such as walking, turning to the side, hand movements and grasping objects in a collaborative workspace.

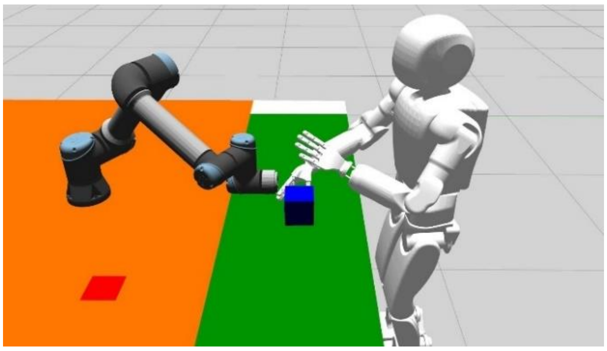

Fig.3 Frame of the second experiment, where the AR601M robot moves the work cube

5. Conclusion

Simulation modeling is an important stage in the design of the processes of collaborative interaction between a robot and a person. This research presented a model of AR601M robot that can be used in pilot experiments as a human in Gazebo Simulator. This model can interact with the environment unlike standard Gazebo “actors”, simulate the gross and fine motor skills of a human.

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