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Humanoid Robot Movement Simulation in ROS

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Abstract:

This article examines the task of humanoid robot movement forward and backward simulating in ROS RViz core. The main research lies in the creation and testing of programs to ensure a stable and smooth movement of the robot along a given trajectory. Based on the capabilities of ROS, a system of hand-washing was implemented as a way of balance and stabilization. The results of the simulation demonstrate the effectiveness of the fragmented program and its production exactly follow the markers installed in the virtual middle. The study reinforces the importance of ROS for the modeling and testing of collaborative robots in the context of Industry 5.0, where interactions between people and robots are of key importance.

Key words: Industry 5.0, Collaborative Robots, Humanoid Robot, ROS, RViz.

Introduction

The relevance and necessity of research in the field of humanoid robot movement simulation in ROS is becoming more and more obvious in the context of the development of Industry 5.0 [1]-[14]. This new era of industry emphasizes the integration of people and machines in the production process, where collaborative work plays a key role [15]-[19]. Humanoid robots, due to their ability to perform tasks that require human skills and flexibility, are ideal candidates to work alongside humans in Industry 5.0. ROS provides a powerful platform for modeling, testing and implementing algorithms for the movement and interaction of humanoid robots [20]-[22]. Simulation in ROS allows developers to create realistic virtual environments where different scenarios of interaction between robots and people can be tested. This not only reduces the cost of physical prototypes, but also speeds up the development process by being able to quickly make changes and test their effectiveness. Here you can also use various methods and approaches [23]-[34].

Collaborative robots must be safe, reliable and effective in cooperation with people, which requires complex algorithms for planning and controlling movement [35]-[41]. Modeling in ROS allows you to develop and optimize such algorithms, ensuring their compliance with real-time requirements. In addition, the use of ROS promotes standardization of developments and facilitates the exchange of knowledge and technology between different research groups and companies.

Thus, research in the field of humanoid robot movement simulating in ROS is an important step to realize the concept of Industry 5.0, where collaborative robots help create more flexible, efficient and human-centric production processes.

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Related works

With the advent of Industry 4.0, and especially Industry 5.0 technologies, robotics is becoming increasingly in demand. Humanoid robots movement simulatiщn is currently an extremely important task. Let us consider several recent works devoted to this topic.

Back in 2012, scientists [42] noticed that humanoid robots are biomodels of the human body. The mechanical structure of humanoid robots consists of several joints and segments. Multiple degrees of freedom cause a redundancy problem. An unanswered question remains regarding the strategies that the central nervous system uses to predict human posture and gestures during various movements.

Paper [43] asserts that well-validated computer simulation can provide a virtual proving ground that in many cases is instrumental in understanding safely, faster, at lower costs, and more thoroughly how the robots of the future should be designed and controlled for safe operation and improved performance.

Authors in [44] present an approach to use standardized work description for automated procedure generation of mobile assistant robots. A simulation tool is developed that implements the procedure model and is therefore capable of calculating different objective parameters like production time or ergonomics during a production cycle as a function of the human–robot task allocation.

Chignoli, M., & et al. [45] present a new humanoid robot design, an actuator-aware kino-dynamic motion planner, and a landing controller as part of a practical system design for highly dynamic motion control of the humanoid robot. For the landing control, they effectively integrate model-predictive control and whole-body impulse control by connecting them in a dynamically consistent way to accomplish both the long-time horizon optimal control and high-bandwidth full-body dynamics-based feedback.

The study [46] introduces a method to study the potential of haptics for five construction tasks: drywall installation, painting, bolting, welding, and pouring concrete by using the SAI robotic simulation environment and human-safe compliant robots.

Reseracher in [47] consider gait planning for the humanoid robot. The linear inverted pendulum (LIPM) model is proposed to simplify the study and to obtain better gait planning of humanoid robot NAO. Simulations are executed on the simulated NAO robot for the conventional PID controller and the proposed controller.

The research [48] tackled the integration of motor control and long-horizon decision-making in the context of simulated humanoid football, which requires agile motor control and multiagent coordination.

Kashyap, A. K., and co-authors [49] note, that the humanoid robot is widely used because of its ability to imitate human actions. The selection of navigational techniques is of prime importance because the quality of the opted technique directly affects the success of output. They make their own suggestion to solve this problem. Simulation and experimental results on humanoid NAOs demonstrate target attainment with collision-free optimal paths.

So, we see that the problem of modeling the movement of a humanoid robot is non-trivial and multifaceted. Later in this article we will look at our point of view to the process of modeling the forward and backward movement of a humanoid robot.

Setting up the OS ROS environment

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At the first stage, it is necessary to directly install all the necessary software to successfully perform the gait simulation of a humanoid robot.

Essentially, ROS is a collection of various well-known libraries, such as:

1. OpenCV - a library containing algorithms for computer vision and image processing;
2. PCL - a library for working with 3D point clouds;
3. Ogre is an open source object-oriented graphics engine;
4. Orocos - library for controlling robots (for example, calculating kinematics).

ROS also includes drivers for various manipulators and sensors (including MS Kinect). The fundamental advantage is the client-server architecture of ROS - the developers have implemented a mechanism for sending messages between various objects, the ability to build distributed systems, providing the so-called. “bridges” to the C++ and Python languages.

Today, ROS is installed stably and works only on Ubuntu version 10 and higher; using Natty as an example, all the intricacies of this process will be discussed. So, step one is setting up the repositories. It is necessary to unlock the “restricted,” “universe,” and “multiverse” components; to do this, you need to uncomment the lines of the standard security packages in the repositories file.

Then you need to add a repository for software installation and updates. The command to add a repository is given below:

```
sudo sh -c 'echo "deb http://packages.ros.org/ros/ubuntu natty main" > /etc/apt/sources.list.d/ros-latest.list'
```

The next step is to install a digital signature, to do this you need to run the following command:

```
wget http://packages.ros.org/ros.key -O - | sudo apt-key add –
```

Then let us update ROS:

```
sudo apt-get update
```

After the update, you need to install the ROS package itself. There are four installation packages, differing in the amount of modules provided. It is necessary to use the most complete.

```
sudo apt-get install ros-electric-desktop-full
```

From this point on, ROS is ready to go. To make sure the installation was successful, you need to open two terminals and write “roscore” in one. This will launch the main process, which is where ROS actually starts working.

Everything is almost ready for interactive planning. You need to start the scheduler using the console command:

```
roslaunch footstep_planner footstep_planner_complete.launch
```

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The run command causes the sample map to load, then starts the scheduler, and launches RViz to interact with it. After some time (depending on stops, speed heuristics and environmental assessment), the planner will visualize movement planning in RViz. If a failure occurs, an error will be printed to the terminal.

Implementation of robot walking in forward and backward directions of a humanoid robot in ROS

At the stage of the walking module development, the next task was set: to implement a module that would be responsible for walking directly in the forward and backward direction. In the specified section of the program code, which is presented below, an algorithm is described that sets the model of a humanoid robot in motion in the forward direction. This code is responsible for alternating movement of the left and right legs. First, a movement is performed with the left leg to a height of "y", followed by a movement of length "x", after which the leg returns to the surface. The same procedure occurs with the right leg. The leg with which the movement begins does not matter. The movement can start from any of them.

```
void
    Footstep::calculateForwardStep(Leg leg, double global_theta,
    double* shift_x, double* shift_y)
    const
    {
    double foot_separation_half = ivFootSeparation/2;
    double x = disc_2_cont(ivX, ivCellSize);
    double y = disc_2_cont(ivY, ivCellSize);
    double theta = angle_disc_2_cont(ivTheta, ivNumAngleBins);
    double theta_cos = cos(global_theta);
    double theta_sin = sin(global_theta);
    if (leg == RIGHT)
    {
    *shift_x = theta_cos * x - theta_sin * (y+foot_separation_half);
    *shift_y = theta_sin * x + theta_cos * (y+foot_separation_half);
```

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```
global_theta += theta;

*shift_x += -sin(global_theta) * foot_separation_half;

*shift_y +=  cos(global_theta) * foot_separation_half;

}

else

{

*shift_x = theta_cos * x + theta_sin * (y+foot_separation_half);

*shift_y = theta_sin * x - theta_cos * (y+foot_separation_half);

global_theta -= theta;

*shift_x +=  sin(global_theta) * foot_separation_half;

*shift_y += -cos(global_theta) * foot_separation_half;

} }
```

To check the correctness of the developed humanoid robot software module for walking forward and backward, we will carry out simulations in RViz; the results of the trajectory of the robot's movement along the given "markers" are shown in Figure 1.

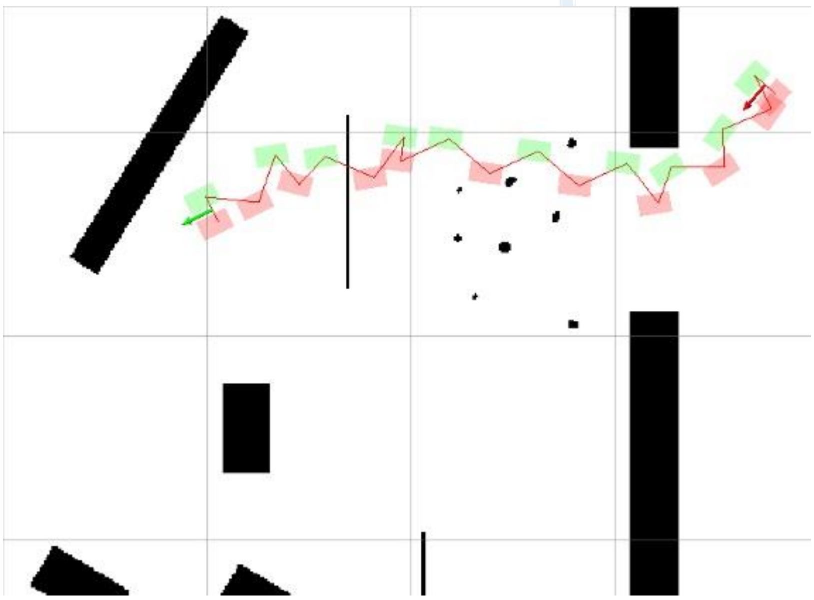

Figure 1: Trajectory of the robot's movement along given "markers"

Conclusion

Based on the simulation results in RViz, several positive conclusions can be drawn regarding the correctness of the developed software module for walking forward and backward of a humanoid robot. First, the robot successfully moves along the given trajectory, which is confirmed by the precise passage through the established markers. This testifies to the correctness of the calculations and effective synchronization of the servomotors, ensuring smooth movement. Second, the robot demonstrates stability during movement, which is important to prevent falls or loss of balance. This is achieved through proper implementation of balance and stabilization algorithms, which is critical for humanoid robots. In addition, the software module successfully processes commands for reverse movement, which indicates the versatility and reliability of the code. The third positive aspect is the accuracy of robot positioning when reaching the end points of the trajectory. This indicates the correct operation of sensors and feedback algorithms, which allows the robot to accurately follow the given commands. Overall, the simulation results in RViz confirm that the developed forward and backward walking software module meets the requirements and can be used for further experiments and improvements.

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