Modelling a crawler-type UGV for urban search and rescue in Gazebo environment

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Abstract

A long-standing goal of robotics is to substitute humans in unreachable or dangerous environments, and one of such environments is urban search and rescue (USAR) domain. For USAR tasks we have selected a novel Russian crawler-type robot Engineer, and this paper presents our first steps toward modelling the robot in ROS/Gazebo environment. We convert provided by robot developers CAD models into workable ROS-based 3D simulation and incorporate physical parameters of the mechanisms into the model, focusing on track simulation. Robot motion and relative interplay of its visible mechanical parts is visualized in RViz software. The proposed model is integrated into a ready-to-use ROS navigation stack and the model's behavior is thoroughly investigated while navigating through static obstacles populated scene in Gazebo environment. In this paper, we introduce an approximation of track-surface interaction of Engineer robot with modeled environment, and discuss the applicability of ROS-based "Gazebo-tracks" package for robust robot locomotion.

Keywords: USAR, ROS/Gazebo, crawler robot modelling, track simulation, system integration.

1. Introduction

Crawler-type unmanned ground vehicles (UGVs) are targeting for urban and rescue operations, especially in situations where a USAR mission deals with dangerous environments and high risk of rescuers' injury or life loss (e.g. buildings with high collapse probability, ruins after technogenic and natural disasters, etc.)[1,2]. In spite of obvious progress in crawler-type mobile robotics, our literature review demonstrated a lack of significant progress on track simulation and visualization. Although there are a number of papers, which dealt with track-type robots, considering crawler belt motion simulation[2] and mathematical modelling[3], track-surface interaction[4] or a simplified approach of contact point estimation in artificial[5,6] and natural environments[7] etc.

In our research, we employ Russian crawler robot Engineer as a USAR-oriented platform[8]. Original Engineer robot system does not contain any operator oriented robotics software. Customers can use only a client-server system to control the robot in a simple teleoperation mode, and our main purpose is to create a robot control software based on robot operating system (ROS) framework. A next essential task is to build a 3D simulation of the robot model in Gazebo simulator, using

CAD models from Engineer robot designers. ROS and Gazebo integration allows simulating Engineer robot in 3D environment, implementing navigation algorithms and providing comfortable and fast synchronization between the 3D model and the robot. To test workability of the robot's 3D model, it is exported into a ready-to-use navigation stack that was previously described by the authors[8], supporting point-to-point navigation in ROS/Gazebo/RViz simulation.

The rest of this paper is structured as follows. Section 2 describes system setup. Section 3 presents Engineer robot modelling with a focus on robot main body's tracks simulation. Section 4 summarizes our conclusions and hints on our future work.

2. Robot system setup

A crawler-type mobile robot Engineer (Fig. 1) is designed and manufactured by Russian company "Servosila" for operating in difficult terrain conditions (e.g. pipeline and tunnel inspection, underneath a suspected vehicle, etc). The robot is equipped with radiation-hardened electronics and a sensors pack, which includes 3D/2D laser scanner, an optical zoom camera, and a pair of stereo vision cameras, IMU, and GPS/GLONASS receiver. The robot is also tooled with a headlight for operations in low illumination conditions and a manipulator for grasping, pushing or pulling potentially dangerous objects or opening different doors with its gripper in teleoperated mode.

Fig. 1. "Servosila" Engineer crawler-type UGV. Courtesy of "Servosila" company.

3. Robot modelling

3.1. *Modelling in ROS*

We performed Engineer robot modelling and simulation in Gazebo 2.2.3 simulator integrated with ROS Indigo. Engineer robot 3D model consists of seven parts: a main crawler-based body, two front flippers, a clamp (which connects upper part to crawler-based body), two links of 3DoF hand-type manipulator with a gripper and a head (Fig. 2). To visualize Engineer robot model in Gazebo we used CAD models from "Servosila" company, and created: (1) step-files, applying physical parameters of robot model parts for 3D model data exchange between CAD software; (2) dae-files for ROS applications, in which all robot parts were transformed into separate files with relevant parameters. Thus, initially we modeled a main crawler-based body with tracks, then robot's upper part with the 3DoF hand-type manipulator, grippers and a head on its end-effector[8]. Using CAD models, we assembled the animated model (Fig. 2), where we connected all robot parts with ROS joints and set angle limits according to the robot specifications. In future, we are planning to use an adaptive PID controller to optimize the robot manipulator control and to damp oscillations that appear when operating the manipulator at a high speed.

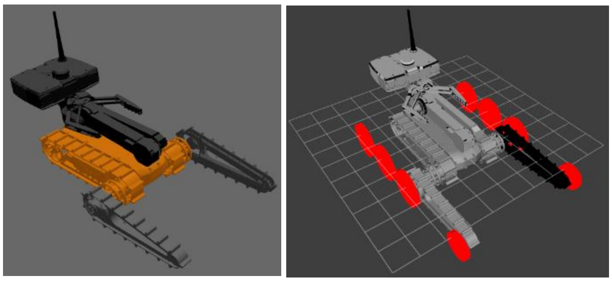

Figure 2. Simulation of Engineer robot in ROS/Gazebo (left) and in ROS\RViz (right). Imaginary pseudo wheels are marked in red.

3.2. *Track simulation*

The Engineer robot body is equipped with soft tracks, and it is a well-know problem to simulate and animate them. Moreover, to the best of our knowledge, track simulation has no standard robust solution in ROS. Modelling chain track belt-drive mechanism is a difficult task since it contains multiple details, which should be properly built into a model and animated. The difficulties in a track modeling arise because of a heterogeneous structure of a track and its supporting elements, with significantly varying properties along the track length.

One of possible solutions is based on imaginary pseudo wheels next to robot tracks (Fig. 2, right). Such simplified model does not simulate physical phenomena of track-surface contact with typical track slipping and skidding[2]. Further increase of pseudo wheels' number and decrease of their size improves the correspondence to a real crawler physics. This solution for motion animation of tracks and front flippers was implemented[8] and provided a simple wheel control with ROS request and response messages that synchronize wheels' speed. Engineer flipper wheels have different sizes, and in order to match them with chain tracks and synchronize to each other, limits on flipper wheel rotation were assigned and rotation speed control was realized with standard ROS modelling mechanisms. The simplified model was visualized with ROS\RViz software. However, our next goal is to create a realistic track simulation, taking into account physical phenomena of track-surface contact.

Currently, there is only one ROS-based package for tracks modelling - *Gazebo-tracks.* It contains a script that creates a track driven SDF model for Gazebo environment[9]. SDF model uses XML format to describe objects and environments for ROS/Gazebo; it helps defining robots, static and dynamic objects, lighting, terrain, physics, and could be further integrated into robot simulation, control, and visualization. Gazebo-tracks package supports track modelling of a system with two equal radii rollers. Thus, it could not be directly applied for Engineer robot flippers that have rollers of different radii. Gazebo-tracks takes into account a distance between tracks, a roller radius, a distance between rollers, a track chain width and thickness, a number of track chains. An example of a crawler robot prototype (main body) SDF file visualization is demonstrated in Fig. 3.

Initially, we had generated a complete Engineer robot model in Unified Robot Description Format (URDF)[8], which is also an XML format that represents a robot model in ROS/Gazebo. Unfortunately, it turned out that URDF does not support involvement of track joints in a

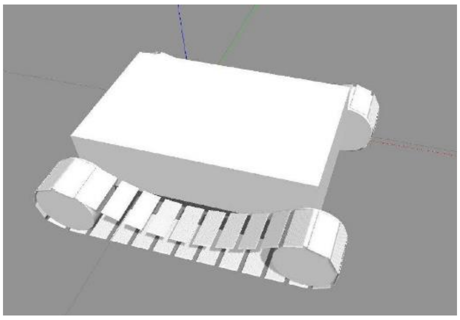

Fig. 3. Generic robot's main body tracks prototype modeling with *Gazebo-tracks package*

loop closure configuration. Thus, only SDF format could be directly applied for track modelling. SDF approach with Gazebo-tracks allowed connecting modeled tracks to the robot body (Fig. 4), although the solution demonstrated a number of critical drawbacks:

- Typically, the modelled tracks are not stable and fall down not so long after the robot starts moving, which is resulted by inertial forces and accumulating shift of the tracks with regard to the rollers;
- As was previously emphasized, Gazebo-tracks package supports only two equal radii rollers and this restricts its application for Engineer flippers modelling;
- Gazebo-tracks package does not have proper ROS API, and thus rollers could not be synchronized via ROS topics and message exchange.

Therefore, we plan to develop a ROS-based approach, which generates tracks of any configuration for different number, location, and radii of track rollers.

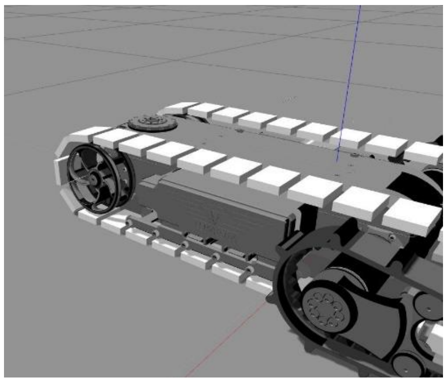

Fig. 4. The result of Engineer robot modelling with *Gazebo-tracks package* for main body tracks (shown in light grey)

4. Conclusions and future plans

Proper modelling of a crawler-type UGVs is an important task within USAR domain. In this paper, we introduced track modelling for a crawler-type UGV Engineer in ROS/Gazebo framework using original CAD data (provided by "Servosila" company) and Gazebo-tracks package. This ROS-based package was integrated into our model in trials to substitute our initial approach of modelling track-surface interaction with hidden pseudo wheels. Unfortunately, Gazebo-tracks package demonstrated a number of critical drawbacks, such as track instability due to inertial forces, strong restrictions on number and radii of track rollers, and a lack of proper ROS API, which prevents its smooth integration into a crawler robot model.

Therefore, as a part of our future work, we plan to create a novel ROS package for modelling tracks of a crawler-type UGV within ROS/Gazebo environment. The requirements for such package include robust robot locomotion, flexibility with a number, location and radii of track rollers, mechanisms for rollers synchronization, ROS API and messaging.

Our Engineer robot model and original software files are available for a download in the public domain of GitHub[10].

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