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Carla-based Substation Simulation System Design

Can Wang*, Zhibin Li

Department of Automation Engineering, Shanghai University of Electric Power, Shanghai 200090, China

*noo269@foxmail.com

Abstract

The Carla-based substation simulation system is a platform for testing various algorithms of power inspection robots in substation scenes based on Carla and ROS. The system is mainly used for testing localization algorithms, path planning algorithms, and meter recognition algorithms. Through this system, the practicality and effectiveness of the algorithms can be tested using different sensors provided by the system without a hardware platform, which significantly saves hardware testing costs.

Keywords

Substaion Simulation Scene; Power Inspection Robot; Carla; Ros Bridge.

1. Introduction

As artificial intelligence, 5G communication and other technologies become more and more mature, the shortcomings of power inspection robots that existed in the past, such as communication delays and lack of arithmetic power, will be substantially improved. At the same time, as the scale of the electric power system becomes larger and larger, the daily inspection task is large, and there are many inspection points (1). To ensure efficient inspection and timely arrival at the inspection points, the electric power inspection robot should be able to drive independently on the daily inspection route, effectively and reasonably respond to the obstacles encountered in the inspection process for avoidance and detour, and accurately grasp and judge the inspection points that need to be focused on daily monitoring (2).

In the power inspection robot inspection requirements continue to become higher under the preconditions, the verification of the effectiveness of the autonomous navigation algorithm is more important. If we only rely on the inspection robot in the actual substation environment to test its autonomous navigation algorithm, then the experimental process to consider more additional factors, and the experiment in the substation itself there are security risks. The verification of autonomous navigation algorithm based on virtual simulation system highlights more advantages(3). On the one hand, the verification of autonomous navigation algorithm based on virtual simulation system, various parameters are controllable and can set and change various parameters of the actual scene(4). On the other hand, when the object under test fails or needs to be verified, the virtual simulation system is able to restart the last experiment with various parameters and data reproduction more quickly.

2. System Analysis

2.1. Analysis of Substation Characteristics and Robot Inspection Tasks

In order to fully reflect the scene characteristics of the real substation, the substation environment is first analyzed to clarify the working environment of the electric power inspection robot. According to the way the substation building is arranged, the characteristics of the substation inspectable path are summarized, mainly as follows:

(1) The layout of substation equipment is clear, and the robot can exercise the area and equipment placement area clearly, which is easy to drive the inspection robot and set the inspection inspection point;
(2) Electromagnetic interference will affect the poor signal of the inspection robot, leading to the derailment of the magnetic track navigation robot, wheeled inspection robot easily lead to run off, lost, derailment, fall, rollover and can not automatically return;
(3) Because the substation in the spring and autumn maintenance work more, sometimes there is a large work needs to install fences, affecting the implementation of the inspection robot fixed tasks, when the need for inspection robot can not bypass vehicles, fences and other obstacles;
(4) The inspection process is long, the inspection point is more than 2000-5000.

The main equipment in substations are main transformers, high-voltage reactors, current transformers, voltage transformers, shunt capacitors, shunt reactors, circuit breakers, disconnect switches, resistors, busbars, and various terminal boxes and cable terminals(5). According to the characteristics of each equipment and the use of the way, the equipment needs to inspect the reasons for the general operation of the fault, hidden problems tracking, etc., inspection requires the use of sensors such as visible light cameras, infrared thermal imager.

2.2. Carla System

Carla is an open source autonomous driving simulator. It is designed to address autonomous driving aspects such as learning driving strategies, training of perception algorithms, etc.

Carla is a client-server architecture(6). The server is responsible for the simulation part of the simulation, including sensor rendering, physical calculations, updating the world state and its characters, etc. The client is used to control the logic of the characters in the scene and to set the environmental conditions of the world. The Carla API is used as an intermediate layer between the server and the client, and is constantly expanded with new features.

In the substation simulation scene required in this paper, we first need a "world" of the substation scene, which is an abstraction layer representing the simulation scene, including "roles", weather conditions, etc. Here, through the substation characteristics analyzed in the previous section, we find the models of each equipment separately and arrange them according to the distribution of substation equipment in the actual scene. At the same time to distinguish the driveable area and the non-driveable area, to facilitate the later inspection of the power inspection robot driving. At the same time, a model of the robot chassis needs to be constructed, and the motion characteristics of the robot chassis are calibrated according to the parameters of the solid robot chassis. And give the robot the sensors it should carry, including LIDAR, odometer, gyroscope, visible light camera, RGBD camera and range sensor, etc.

2.3 Ros Bridge

Another Carla package that needs to be analyzed in detail in this substation simulation is the Ros Bridge, a functional package that is used between the ROS system and other systems and acts as a "bridge" to allow two-way communication between the Carla and ROS parts. Messages from Carla can be translated into topics in ROS, and messages from ROS nodes can be translated into commands that can be applied in Carla.

After analysis Ros bridge has several advantages:

(1) It provides data from many sensors such as LIDAR, semantic LIDAR, depth camera, RGB camera, dvs, GNSS, radar and inertial measurement unit;
(2) It provides target data such as visual markers and object collision;
(3) It controls the AD agent in Carla by throttle, brake and direction;
(4) It controls Carla simulation pause, set simulation parameters, synchronization mode, etc.

The carla_ros_bridge function pack is one of the most important function packs for running Ros Bridge and is available once the environment is deployed in the ROS system. Other CARLA packages in ROS are Carla Spawn Objects package for generating inspection robot carts, Carla Manual Control package for manual control of inspection robot carts, Carla Ackermann Control package for control of carts on Ackermann chassis, and CARLA Waypoint Publisher package for marking inspection robot carts. Carla Ackermann Control package: to control the trolley of Ackermann chassis; CARLA Waypoint Publisher package: to mark the inspection point where the inspection robot trolley needs to stop; Carla ROS Scenario Runner package: to wake up the whole substation simulation scene in ROS; Carla Twist to Control package: to convert the twist message in ROS to a motion control command in CARLA. Carla Twist to Control package: converts twist messages in ROS into motion control commands in CARLA; RVIZ Carla Plugin package: uses the visualization tool Rviz in ROS to observe the sensor data of the inspection robot trolley in the substation scene, etc.

3. Build the System

3.1 Build the Substation Simulation Scene

First, establish the necessary traffic elements within the virtual simulation scene, based on the 3D production software Autodesk 3Dmax, establish the 3D model of the electric power inspection robot, roads, buildings (mainly for the primary and secondary equipment of the substation) and other elements. Then Photoshop was used to create mapping and model rendering to enhance the visual effect experience. Moreover, before finally importing the 3D model into Carla, the model needs to be fully optimized and refined to reduce the file size while improving its quality to enhance the smoothness of the whole simulation system.

According to the actual substation in various equipment, charging room, office building and other environmental conditions, the simulation scene is built. The overall overview of the substation scene can be seen from the figure, and the white line segment in the figure is the inspection route of the inspection robot.

Figure 1. Substation simulation scene overall

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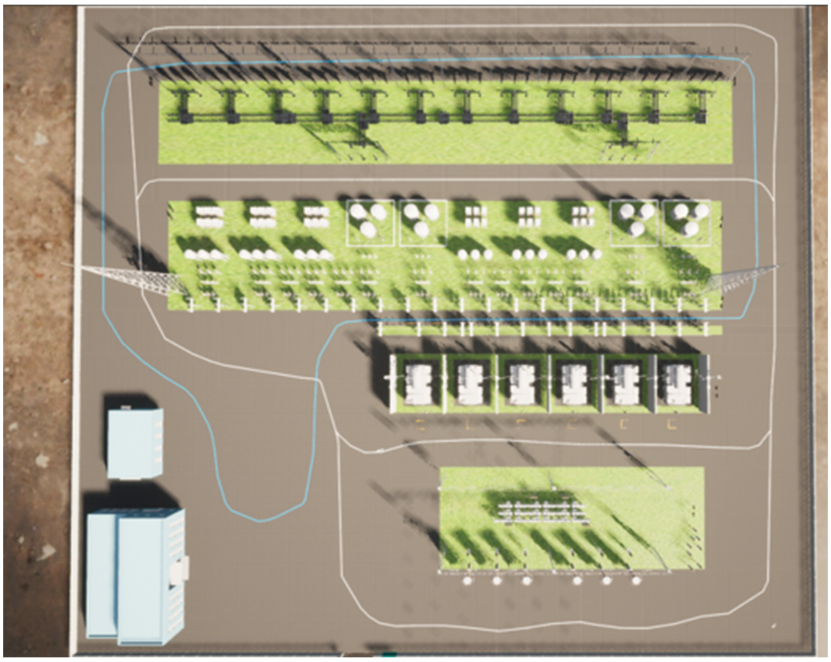

Figure 2. Top view of substation simulation scene

The figure 3 and the figure 4 show some of the equipment, including lightning arresters and transformers, respectively. The need for visible light camera transformer appearance, flange, lead joints, oil pillow oil level, oil thermometer, winding temperature, etc.; circuit breaker appearance has no breakage phenomenon, the appearance of the discharge traces of the body and well-linked capacitor infrared temperature measurement is normal.

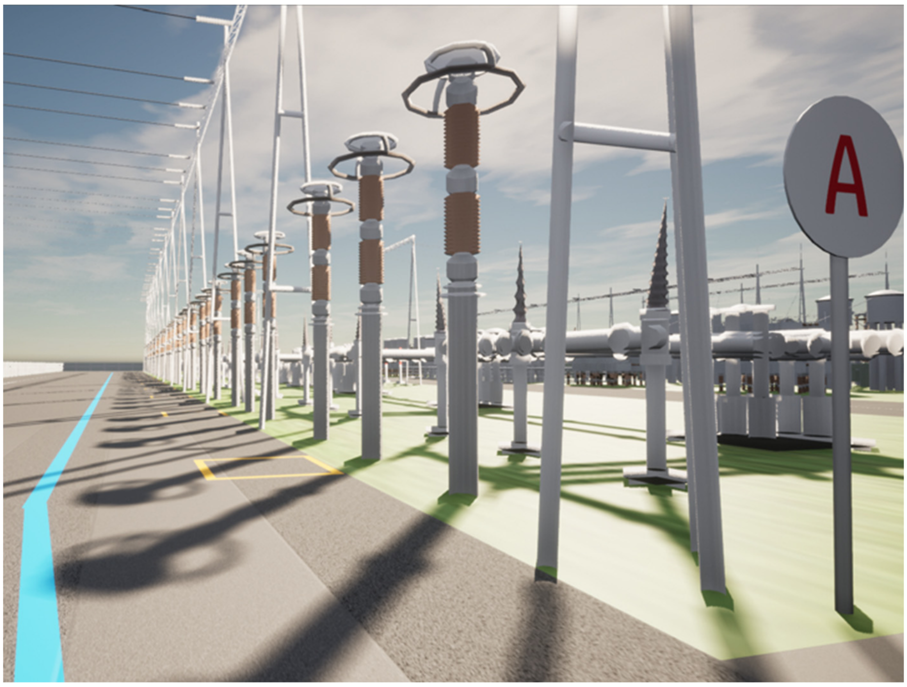

Figure 3. Lightning arrester

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Figure 4. Transformer

3.2 Build the Power Inspection Robot Model

The power inspection robot chassis model comes from the actual real car model Traxxas RC buggy, the scale is 1 to 5, the vehicle length, width and height are about 65, 47 and 31cm respectively, this paper will establish the virtual simulation vehicle model in 3Dmax according to the model car size 1 to 1.

The virtual robot chassis model is first designed within the Autodesk 3Dmax software and rendered everywhere after the format is determined to be error-free, and finally imported into Carla. The modeling process of the robot chassis includes: exporting the axes, volume, and dimensional information to the chassis model, importing it in Carla, and finally checking the validity of the chassis.

Figure 5. Inspection robots make stops at inspection points

During the operation of the power inspection robot trolley, the running frame rate, map selection, vehicle selection, simulation time, speed situation, compass situation, acceleration information, gyroscope information, current position coordinates and the motion control information of the vehicle chassis including throttle, brake, direction, etc. can be displayed in real time. The yellow box is the optional inspection stops, which can be set as waypoints in Carla until the real coordinates of these points.

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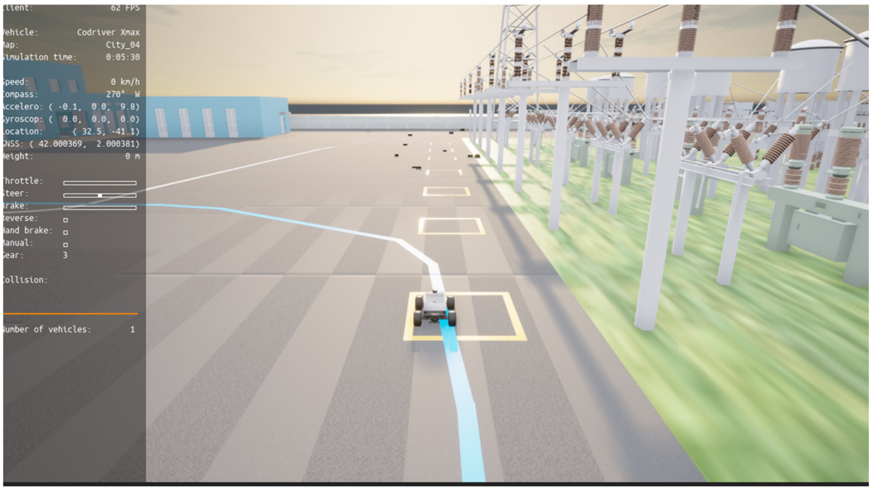

Figure 6. Operational status of the inspection robot

3.3 Build the ROS System

The official MATLAB toolbox Robotic System Toolbox is used for interfacing MATLAB and ROS, and MATLAB scripting is done through java to output control to ROS. Simulink creates a network of ROS nodes in the ROS network and can send and receive messages. When the model is simulated, Simulink connects to the ROS network and Simulink exchanges messages with the ROS network until the simulation is completed. The process includes creating the model, initializing ROS, creating publishers, creating ROS messages, creating subscribers, configuring and running the model, and correcting the model to react to new messages.

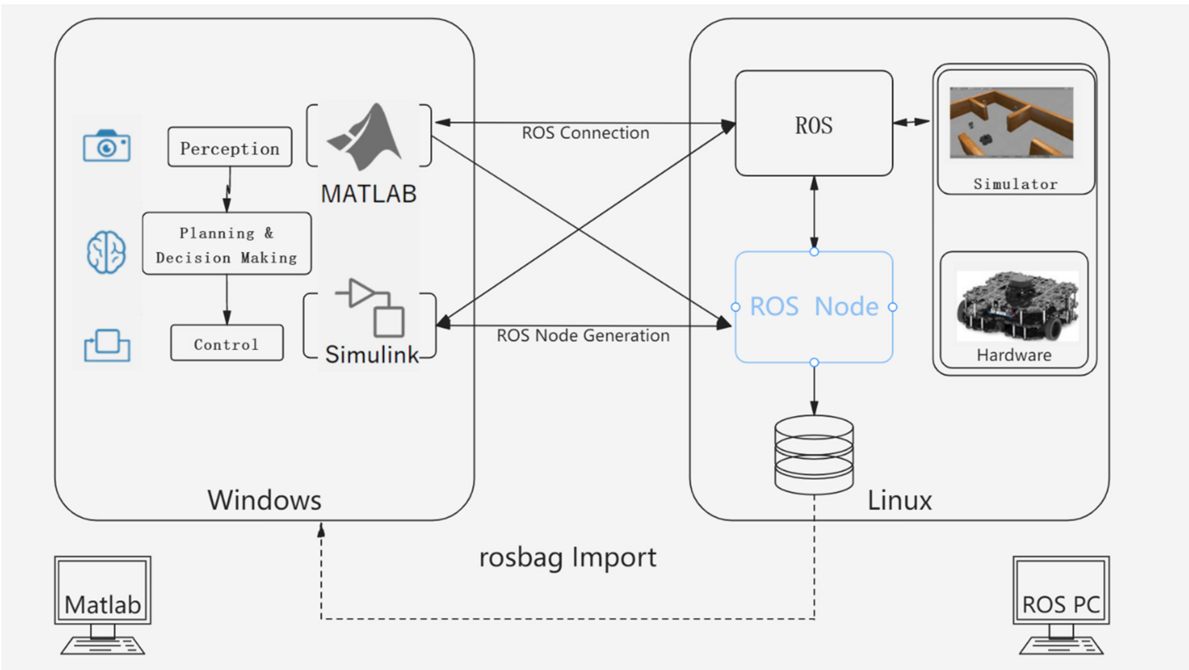

Figure 7. ROS and MATLAB for data exchange

4. Conclusion

The substation simulation system works Carla with the ROS system, proving the significance of the substation simulation scene for verifying the site-specific positioning and navigation algorithm, and applying the booming self-driving technology to the electric power inspection robot, which can provide technical support for the navigation, positioning, target detection and

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identification, and autonomous operation of the inspection robot, and escort the safety of electric power inspection.

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