Educating Future Computer Science Teachers to use the DQN Machine Learning Algorithm with ROS

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***Abstract*—This research paper discusses the importance of training future computer science teachers in machine learning techniques using the robotic operating system (ROS)-based autonomous navigation robots. During the study, the flexibility of a mobile robot using the SLAM (simultaneous localization and mapping) method in mapping and navigation in the ROS system based on the Deep Q-Network (DQN) machine learning algorithm is considered. Research work is being conducted with students of educational programs for training future informatics teachers at Eurasian National University named after L.N. Gumilev and working informatics teachers. The considered works provide a foundation for future computer science teachers to learn and use the flexibility of mobile robots in the ROS operating system for robots based on computer vision methods.**

***Keywords*— Education, Autonomous Navigation, Optimization DQN (Deep Q-Network), Robotics, SLAM.**

I. Introduction

It is known that the skilful integration of artificial intelligence (AI) and robotics has been widely implemented in all industries, as the probability of robot error is much less than human error, accordingly, the need for robots is increasing daily.

Robotics is one of the most demanding areas of modern engineering education, covering various disciplines such as mathematical modelling, computer science, machine learning, mechanical design, electrical engineering, psychology, and many other disciplines [1]. In this process, large algorithms and datasets are used to transform the potential of robotics into human judgment.

Some of the most effective project-based learning methods used by higher education institutions include robotics, drones, and computer technologies for modelling and simulation. In 2007, the first open-source robot operating system (ROS) was developed at Stanford University, called the Open-Source Robotics Foundation, to build robots and drones. Later, in 2008, a startup company called Willow Garage provided significant resources to expand the initial concepts at the Robotics Research Institute. Today, ROS is used for robotics research at many universities, government laboratories, and elsewhere worldwide.

The ROS system is handy for conducting experiments in robotics in the absence of laboratory rooms and robots and using mobile robots in simulation. However, in this regard, we noticed very few studies and experiments on the use of modular robots in the operating system for robots, and they are not even considered in the educational programs of higher education institutions.

The purpose of the presented article is to study the training of future computer science teachers to use the DQN machine learning algorithm during the development of an autonomous navigation robot project based on ROS using the SLAM method by integrating artificial intelligence and robotics.

II. Methodology

Theoretical and empirical research was conducted to determine the prerequisites for future computer science teachers to use machine learning methods in programming autonomous robots. In this regard, the works of methodologists and scientists about the concept of mobile robotics and its directions in education were studied.

It is known that the field of artificial intelligence and robotics is not innovative, it has been taught in the field of education in recent years. Using machine learning allows robots to interact more effectively with their environment and make decisions based on sensor data. It is essential to train future computer science teachers to implement these methods in the learning process successfully.

While completing a course in robotics and computer neural network technologies, creating your project will increase your creative thinking and practical skills [2]. In higher educational institutions, two trends in the teaching of robotics are considered: industrial robots, subjects for robotic arms and manipulators, and based on mobile robots [3]. ROS allows students to develop advanced robotics skills and take a modular approach to robotics research. In addition, ROS enables the creation of complex projects by combining simple robot solutions in a framework for creating robot applications. The ROS operating system opens the way to experiment with mobile robots in various formats and create projects focusing on high-level concepts such as machine learning and deep learning.

Robotics is a popular subject with increasing applicability and demand, requiring knowledge in mechanics, electronics, statistics, art, and software. To avoid "re-designing the bicycle" regarding software, roboticists can use ROS, which supports standard robotics capabilities such as interprocess communication and navigation [4].

ROS integrates multi-platform systems and mobile robot navigation, perception, control, motion planning, simulation, and more. We can see in the picture below that it is

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implemented using many solutions and packages (Figure 1). This allows seamless messaging between different system components.

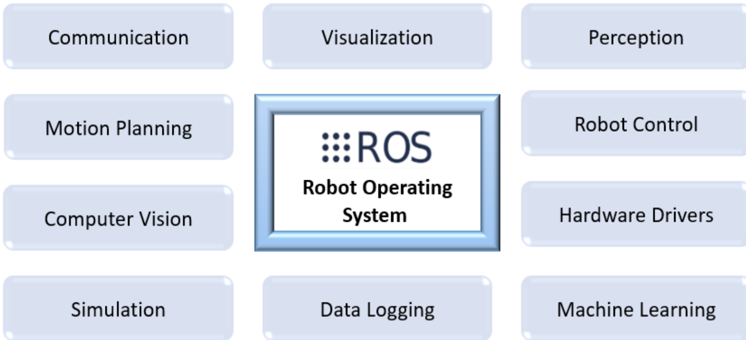

Fig. 1: The ROS Feature Umbrella

Wilkerson, S. A., and others in their research chose ROS as a catalyst for project-based learning and demonstrated that ROS enabled students to develop robotic capabilities that would not otherwise have been possible over time [5].

In 2017, Kazan Federal University launched a new master's program, "Intelli-gent Robotics", based on the analysis of educational programs of the world's leading universities in the field of robotics with the help of "Robotic Operating Systems - ROS". According to the results of the research work of T. Tsoi and others on this program, it was shown that students' motivation to learn robotics with ROS has increased significantly [6].

In Kazakhstan, the robotics education program has just begun to develop rapidly. K.I. KazNTU, named after Satpaev, Nazarbayev University, KazNU named after Al-Farabi, implements a unique trajectory of training students in robotics in their educational programs [7]. In the Faculty of Information Technologies of Eurasian National University, named after L.N. Gumilev, within the framework of the Department of Informatics, particular subjects related to the areas of robotics and artificial intelligence systems are included in the training of future bachelor and Master of Informatics. In particular, the subject "Robotics" is included in the educational program "6B01511-Informatics", and the subject "Social and autonomous robotics" is included in the educational program "7M01511-Informatics".

III. Results and Discussion

In today's world, computer science and robotics are becoming increasingly essential and in-demand fields. However, teaching these fields requires new methodological approaches, especially in programming autonomous robots through machine learning.

There are two main "sides" of ROS: the ROS operating system and rospkg. ROS-pkg is a set of user-provided packages that implement various robotics functions: SLAM, planning, perception, modelling, etc. [8]. ROS provides a ready-made infrastructure for controlling mobile robots, including navigation, perception, and environmental interaction. For these critical mobile robots, autonomous navigation based on machine learning is the key to highly efficient technological progress, as they can understand environments that humans would not usually have access to, such as war zones or nuclear power plants.

Over the past five years, ROS middleware has become a de facto standard in the robotics research community and has also increased its use in education [9]. We use ROS to create projects to introduce students to practical problems in robotics to increase students' motivation to apply machine learning techniques to mobile robotics. At the same time, we expand their knowledge about control methods, vision algorithms, machine learning and electronic integration of the components necessary for our project.

During the experiment, the project of mapping, localisation and navigation of an unknown environment of a mobile robot using the SLAM method of real-time localisation and mapping is considered. The mapping process is performed using the open-source GMapping algorithm. The mobile robot model based on the ROS platform is created using the gazebo package simulator, DQN's Reinforcement learning (RL) algorithm, and simulated in Rviz. RL is a form of machine learning in which an agent interacts with its environment to learn what practical actions to take. RL has been successfully used in robotics to solve various problems, including pathfinding, which ensures that a robot finds a safe and efficient path while performing a task. This allows the robot to adapt to environmental changes and make real-time decisions based on the current situation.

About 180 robots have been developed based on ROS, including custom robots released publicly by developers, and this is an impressive list considering that the same system supports such a variety of robots. The most famous are Wil-low, Garage and Turtlebot3 Burger robots [10]. The Turtlebot3 Burger mobile robot used in the experiment aims to develop a control system based on the DQN RL machine learning algorithm. In particular, it seeks to simulate the learning process for trajectory planning, including obstacle avoidance and collision avoidance.

Ubuntu 16.04 operating system and ROS Kinetic Kame (from 2016) installed using VM VirtualBox virtual machine are used for the experiment. ROS Kinetic Kame is the tenth release of the distribution, which targets the Ubuntu 16.04 (Xenial) release but supports other Linux systems and Mac OS X, Android, and Windows to varying degrees. As a programming language, Python was chosen to create this model due to its extensive documentation and Keras library support.

In the experiment, an architecture like the one in the figure below is proposed, which integrates multi-platform systems such as ROS, allowing seamless messaging between different system components (Figure 2).

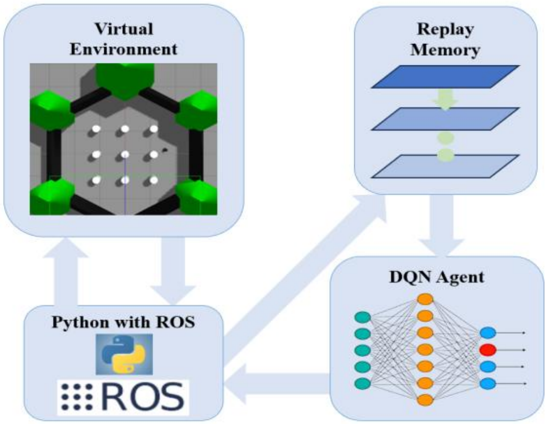

Fig. 2: Study case architecture

During the experiment, a series of experiments were conducted using Turtle-bot3 Burger in a Gazebo simulation environment to evaluate the effectiveness of the DQN RL machine learning algorithm. The objective of this work is to use machine learning in a mobile robot in a simulated environment to solve the problem of avoiding moving and stationary obstacles using an open-source multi-platform system. During the implementation of the experiment, all the necessary components described above were installed: ROS using the roscore command, and TurtleBot3 using the Rviz model. You can then view TurtleBot3 in a free environment using Gazebo to simulate TurtleBot3 (Figure 3).

A. Measures

The questionnaire contains measures for all variables used in the research model (Fig 1). Items representing nine constructs, namely, attitude, injunctive norms, impact of Covid-19, perceived behavioral control, health consciousness, intention to not waste food, past planning, household management skills and food waste were included in the questionnaire. The original items were adopted from earlier related literature. We used a 5-point Likert scale for the measurement of each of the constructs. Additionally, demographic variables such as gender, age, education, etc., were also included in the questionnaire.

We found 160 valid usable samples among collected surveys. Amongst the collected sample, 53% were male while 47% were females. About 5% of the sample was collected from respondents of age below 25 years. About 63% of the sample was in the age range of 25-30 while remaining was in the age range of 31-35. Roughly, 23% and 13% of the respondents had completed high school and college level education while 53% and 11% were university and master's degree graduates, respectively. Many of the subjects (61%), i.e., were married. Approximately 60% of respondents reported an income of less than 500 USD/month while the remaining 40% earned over that amount. Just fewer than 75% of the respondents were from urban areas, while 20% and 5% were from suburban and countryside areas, respectively.

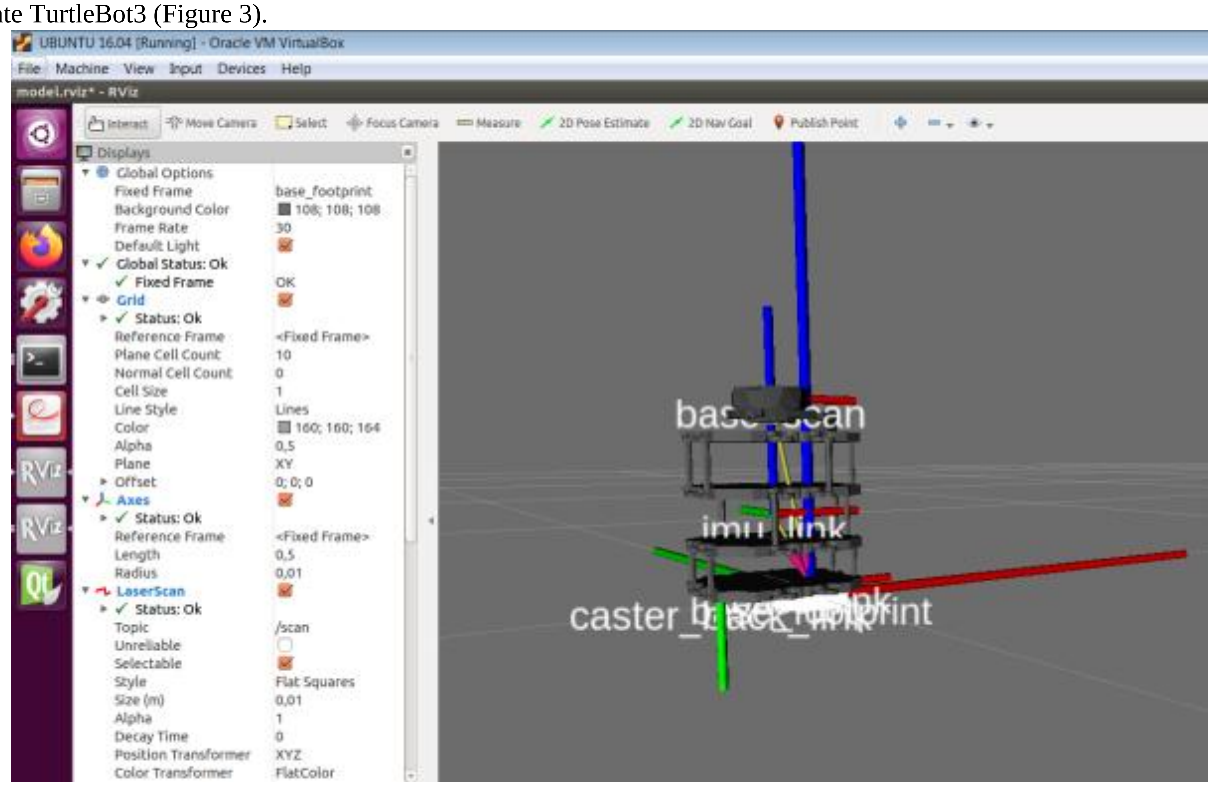

Fig.1 Path Analysis of the Hypothesized Relationships

During the experiment, comparisons were made by launching TurtleBot3 in the first environment (world.launch) and 'roslaunch turtlebot3_gazebo turtle-bot3_home.launch' in the second environment (home.launch) by typing the command 'roslaunch turtlebot3_gazebo turtlebot3_world.launch'. These environments use SLAM and navigation algorithms to design a localisation and mapping robot simultaneously or to update a map of an unknown environment while tracking its position in that environment in real time. To install the SLAM mod-ule, use the command 'sudo apt-get ros-kinetic-openslam-gmapping' in a new terminal window. SLAM modelling with TurtleBot3 in two environments is shown in the images below. In the images, you can see how the Turtlebot3 Burger robot can autonomously move from one place to another and map the environment (Figures 4-5).

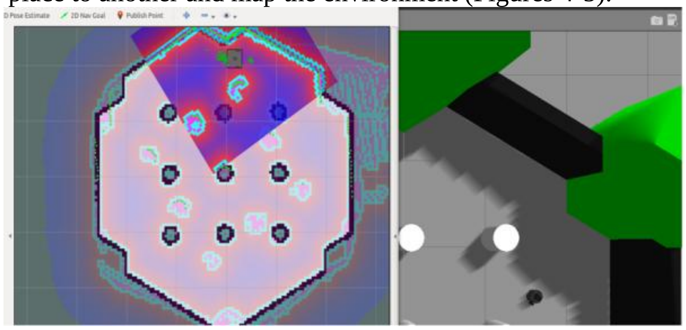

Fig. 4: Running SLAM on Gazebo (Left: Gazebo, Right: Rviz, world.launch)

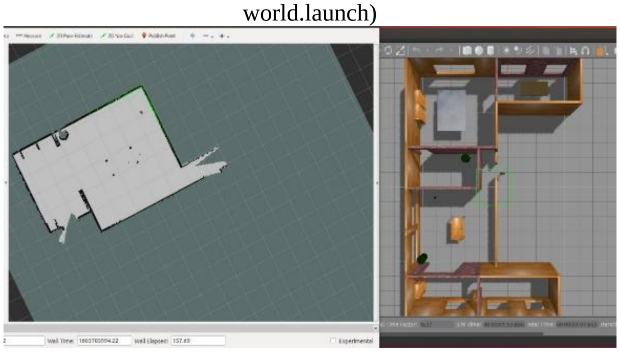

Fig. 5: Running SLAM on Gazebo (Left: Gazebo, Right: Rviz, home.launch)

According to the experimental results, in each scenario, the Turtlebot3 Burger robot was placed in the same initial position and received information about obstacles and walls through the Lidar sensor. In the first scenario, both mediums were simple and went without a hitch. The DQN algorithm was run for a total of 600 episodes. Then, the reward level increased to 1200 points, which shows that the DQN algorithm can learn from experience, resulting in the robot moving to-wards the target by itself, avoiding collisions (Figure 6).

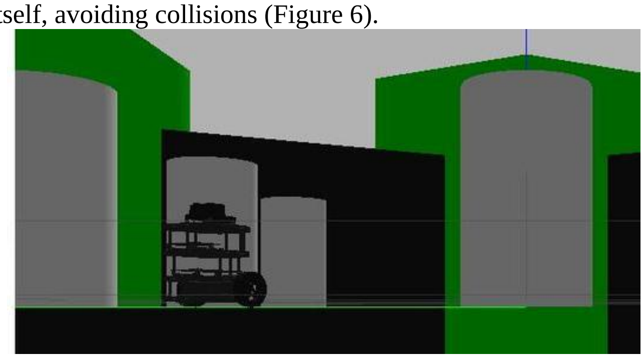

Fig. 6: Turtlebot3 Burger autonomously navigate toward the goal while avoiding collisions.

To compare the effectiveness of the machine learning algorithm of the considered Turtlebot3 Burger mobile robot DQN RL, analytical work was carried out with students. The results are shown in Table 1.

TABLE I

EVOLUTION OF THE REWARD FOR DIFFERENT VALIDATION SCENARIOS USING THE DQN ALGORITHM

	Evolution of the reward for the first validation scenario using the DQN algorithm.	Evolution of the reward for the second validation scenario using the DQN algorithm.
Reward	Maximum 1200	Maximum +2600
Episodes	Maximum 600	Maximum 800
Gazebo real-time factor, %	93%	98%

IV. Conclusions

The main results of the reviewed study show that the DQN machine learning algorithm can be successfully used for pathfinding on robotic platforms. The algorithm was trained on string sequence datasets and tested in different environments, achieving high accuracy scores in both cases. In addition, the algorithm demonstrated the ability to adapt to changing environmental conditions and generalise data across other robot platforms.

Students of the educational programs consider the research mentioned above works "6B01511-Informatics", "7M01511-Informatics", and "7M01525-STEM education" of the Eurasian National University named after L.N. Gumilyov, and at the same time there is an opportunity to use them for working informatics teachers.

The importance of training future computer science teachers in machine learning techniques using mobile robots in ROS is shown. This approach not only enriches the educational program, but also prepares a new generation of specialists for the complexity of today's high-tech world.

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