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The Application of CoppeliaSim EDU in Robot Course Teaching

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Abstract: CoppeliaSim EDU, as a powerful tool for robot teaching, is changing the traditional teaching mode. This software provides a comprehensive robot simulation environment where users can explore different scenarios, models, and programming interfaces to gain a deeper understanding of robot technology. Its advantage lies in reducing the cost and potential security risks of physical robots, making robot education more widespread and secure. In actual teaching, teachers can use CoppeliaSim EDU for course design, guide students to carry out robot programming and simulation experiments, and improve teaching effectiveness. Through case analysis, it can be found that using CoppeliaSim EDU can better stimulate students' interest in learning, improve their practical ability and innovative thinking. In the future, with the continuous development of robotics technology, the application prospects of CoppeliaSim EDU will be even broader, bringing more possibilities for robot education.

Keywords: Robot Teaching; Virtual Simulation Teaching; Robot Simulation Experiment.

1. Introduction

In the modern world, robotics is a rapidly advancing field, leading to a growing focus on robot education. However, traditional robot teaching methods face challenges posed by the high cost of physical robots and potential safety risks [1, 2]. To address these issues, various robot simulation software has emerged, with CoppeliaSim EDU as a leading solution [3-5]. This study aims to investigate the application of CoppeliaSim EDU in robotic teaching.

CoppeliaSim EDU is a comprehensive robot simulation software that offers a range of features and functionalities. It provides an immersive environment for learning about robotics, allowing users to explore different scenarios, models, and programming interfaces [6]. The software's capabilities make it an excellent tool for enhancing robotic education, offering a cost-effective, safe, and engaging platform for students to learn and experiment with robotics concepts [7].

The application of CoppeliaSim EDU in robotic teaching has the potential to revolutionize the way students learn about robotics. By using the software, students can gain a deeper understanding of the fundamental principles of robotics, including kinematics, dynamics, control systems, and more. They can also improve their programming and problem-solving skills through hands-on experimentation with the virtual robots [8].

Moreover, CoppeliaSim EDU allows students to work in a risk-free environment, avoiding the dangers associated with physical robots. This enables students to take more risks and explore more creative solutions without the fear of damage or personal injury [9].

The case studies presented in this study demonstrate the practical application of CoppeliaSim EDU in robotic teaching. They show how the software can be used effectively in different educational settings, including classroom instruction, hands-on labs, and individual projects [10]. The results of these case studies highlight the positive impact that CoppeliaSim EDU has on student learning and engagement in robotics education [11].

Overall, the application of CoppeliaSim EDU in robotic teaching represents a significant advancement in education technology. It provides an innovative and effective platform for learning about robotics, enabling students to gain valuable knowledge and skills in this rapidly advancing field. As robotics continues to play an increasingly important role in various industries and applications, the use of simulation software like CoppeliaSim EDU will become increasingly essential in preparing the next generation of roboticists.

2. Introduction to CoppeliaSim EDU

CoppeliaSim EDU, previously known as V-REP, is a robot simulation software with a distributed control architecture and an integrated development environment. It is based on a physics engine and provides dynamic robot simulation [12]. CoppeliaSim EDU has high versatility and is suitable for multi-robot applications. Controllers can be written in languages such as C/C++, Python, Java, Lua, MATLAB, and more.

CoppeliaSim EDU offers users a rich library of robot models and comprehensive physical engines, allowing them to control robots through these tools. It is widely used in various fields including algorithm development, factory automation simulation, rapid prototyping and verification, robot-related education, remote monitoring, safety redundancy checks, and digital twins.

CoppeliaSim EDU features a user-friendly interface that facilitates operation and learning. It also provides a range of functionalities and tools to enable efficient robot design and simulation.

Moreover, CoppeliaSim EDU supports multiple programming languages and development environments, allowing users to choose the most suitable programming language and development environment for their robot design and simulation needs.

3. Advantages of CoppeliaSim EDU in Robotics Education

In the realm of robotics education, CoppeliaSim EDU stands out as a transformative tool, offering numerous

advantages that enhance the learning experience. The following are the main benefits of implementing CoppeliaSim EDU in robotics courses.

3.1. Cost-effectiveness and Safety

Physical robots can be expensive, especially for educational institutions. CoppeliaSim EDU provides a cost-effective alternative, allowing students to simulate robotic systems without the need for actual hardware. This significantly reduces the financial burden on educational institutions.

Physical robots pose potential safety risks, especially when operated by students or novice users. CoppeliaSim EDU eliminates these risks by providing a virtual environment, ensuring that no harm comes to students or the robots themselves.

CoppeliaSim EDU is platform-independent, allowing students to access it from any computer with minimal hardware requirements. This ensures that students can easily access the software and focus on their learning without any technological hurdles.

3.2. Immersive Learning Experience

The software provides an immersive and interactive learning environment, engaging students and enhancing their understanding of robotics concepts. Through simulations, students can visualize and experiment with different scenarios, enhancing their problem-solving and critical thinking skills.

CoppeliaSim EDU can be seamlessly integrated with other educational tools and platforms, enhancing the overall learning experience. It allows for easy integration with course management systems, providing teachers with a unified platform for teaching and assessing student performance.

CoppeliaSim EDU offers advanced simulation features, including real-time simulation, precise motion planning, and complex dynamics modeling. These features provide students with a comprehensive understanding of robotics concepts and enable them to explore complex scenarios that would be difficult or unsafe to replicate in the physical world.

3.3. Adaptability and Customizability

CoppeliaSim EDU is highly adaptable and can be used across different educational levels, from introductory courses to advanced robotics programs. It caters to both undergraduate and postgraduate students, offering a flexible platform for teaching and learning.

The software provides users with the flexibility to customize simulations according to their specific needs. Teachers can create their own scenarios, models, and challenges to tailor the learning experience for their students.

4. The Practical Application of CoppeliaSim EDU in Robot Course Teaching

4.1. Basic Theory Teaching

In basic theory teaching, CoppeliaSim EDU can serve as an auxiliary tool to help students better understand the basic principles of robotics technology. Through the visualization effects in the simulator, students can intuitively understand the core concepts of robot kinematics, dynamics, perception systems, etc. Teachers can use the simulation environment of CoppeliaSim EDU to demonstrate the basic composition and working principle of robots to students, allowing them to establish a solid theoretical system before actual operation.

4.2. Programming Teaching

In programming teaching, CoppeliaSim EDU provides students with a safe and economical practical platform. Students can write, debug, and test robot programs in simulators without worrying about hardware damage or security issues. By being compatible with actual robot programming languages, students can apply the knowledge they have learned to practical scenarios, improving their programming skills and problem-solving abilities. In addition, CoppeliaSim EDU also provides rich programming examples and tutorials to help students quickly get started and learn.

4.3. Experimental and Practical Teaching

Experiments and practical teaching are important components of robotics courses. The simulation environment of CoppeliaSim EDU provides students with various opportunities for experimentation and practice. Teachers can design various experimental scenarios for students to design, assemble, and debug robots themselves, and observe their performance in simulated environments. Students can try different algorithms and control strategies in the simulator, observe their impact on robot behavior, and analyze and optimize them. This practical teaching method can help students better understand the practical application of robot technology, improve their practical ability and innovative thinking.

4.4. Innovative and Exploratory Teaching

CoppeliaSim EDU encourages students to innovate and explore. Due to the openness of the simulator, students can try various creativity and experiments in the simulated environment, constantly challenge themselves, and go beyond the traditional robot teaching mode. Teachers can guide students to participate in project-based learning, challenging tasks, and competitive activities, stimulating their creativity and teamwork spirit. By combining with practical projects, students can apply the knowledge they have learned to practical scenarios and improve their ability to solve practical problems.

5. Teaching Case Analysis

Below, this paper analyzes the teaching example of robot kinematics. In order to help students better understand and master the basic concepts of robot kinematics, this study used the CoppeliaSim EDU platform to construct a typical RRRP type SCARA robot model, and implemented kinematic simulation of the robot using Python programming. This teaching method closely combines theory and practice, aiming to improve students' practical abilities and innovative thinking.

5.1. Teaching Objectives

The goal of this teaching case is to:

1) Enable students to master the basic structure and working principle of robotic arms.
2) Enable students to master the method of establishing robot kinematic models in CoppeliaSim EDU.
3) Enable students to use Python programming to implement kinematic simulation of SCARA robots.
4) Cultivate students' practical abilities and innovative thinking.

5.2. Teaching Content

The teaching content of this teaching case mainly includes:

1) I Introduction to serial joint robots:
Provide a detailed introduction to the application, characteristics, and advantages of joint robots in the industrial field, and explain why SCARA joint robots were chosen as the teaching model.

2) SCARA robot structure:
Thoroughly analyze the various components of SCARA robots, such as linkages, joints, actuators, etc., and demonstrate their 3D models in CoppeliaSim EDU. The 3D model is shown in Figure 1.

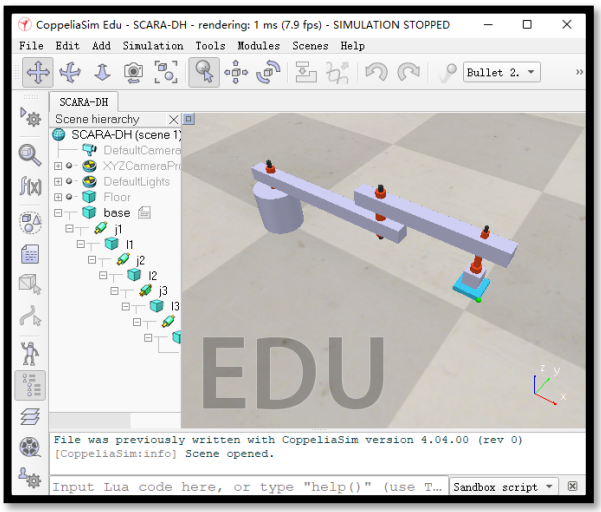

Figure 1. SCARA robot 3D model

3) Fundamentals of Kinematic Modeling:
Elaborate on the basic concepts of kinematics, establishment and transformation of coordinate systems, laying a solid foundation for subsequent kinematic modeling.

4) Robot kinematic modeling:
Using the modified D-H parameter method, explain in detail how to establish a kinematic model for the SCARA robot. In CoppeliaSim, design the following Python code to generate mdh parameters for kinematic calculations.

```
def MDH(alpha,a,th,d):
 c=np.cos
 s=np.sin
 return np.array( [[c(th), -s(th), 0, a],
          [s(th)*c(alpha), c(th)*c(alpha),
          -s(alpha), -d*s(alpha)],
          [s(th)*s(alpha), c(th)*s(alpha),
          c(alpha), d*c(alpha)],[0, 0, 0, 1]])
```

5) Python programming and simulation:
In the CoppeliaSim EDU environment, guide students to write kinematic simulation programs for SCARA robots, and perform trajectory planning and simulation. Design the following Python code for kinematic simulation and draw the final motion trajectory, as shown in Figure 2.

```
    global j, jdir, jmax, jmin
    a=[0.0,0,0,0]
     for i in range(4):
            a[i]=sim.getJointPosition(j[i])
            na=a[i]+jdir[i]
            if na>jmax[i] or na<jmin[i]:
                jdir[i]*=-1
            na=a[i]+jdir[i]
            sim.setJointTargetPosition(j[i],na)
    tip=sim.getObject("/tip")
    M1=MDH(0,0,a[0],0.075)
    M2=MDH(0,0.3,a[1],0.05)
    M3=MDH(0,0.2,0,a[2])
    M4=MDH(0,0,a[3],-0.05)
    p5=sim.getObjectPosition(tip,sim.handle_parent)
    p05=M1@M2@M3@M4@np.array(p5)
    Sim.addDrawingObjectItem(linered,p05)
```

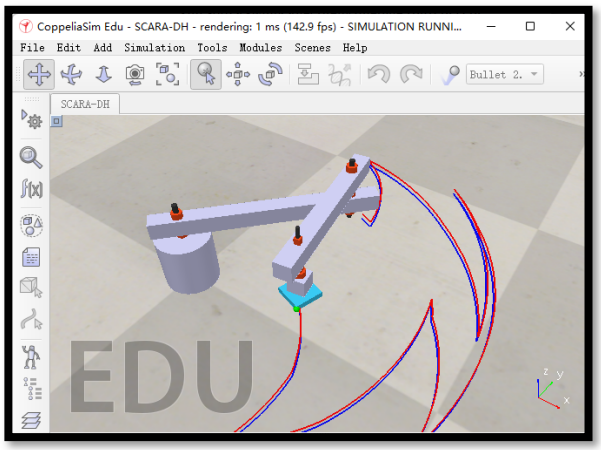

Figure 2. Kinematic simulation

This code calculates the end position through forward kinematics based on the joint angles and visualizes the motion trajectory.

6) Experiment and Verification:
Organize students to conduct experiments to verify the correctness of the established kinematic model, and conduct in-depth analysis and discussion of the experimental results.

7) Extended application:
Introduce practical cases and introduce the application of SCARA robots in production, guiding students to think about how to apply the knowledge they have learned to practical problems.

5.3. Teaching Method

This teaching case adopts the following teaching methods:

1) Theoretical teaching and real-time demonstration:
Combining CoppeliaSim's real-time model demonstration to ensure that students can deeply understand the basic knowledge of robot kinematics. By teaching and real-time demonstration of models in CoppeliaSim, students are taught the basic knowledge of robot kinematics, ensuring that they can understand and master relevant concepts.

2) Practical operation:
Using the CoppeliaSim EDU platform, allow students to personally design SCARA robot models and write kinematic algorithms, thereby deepening their understanding of theoretical knowledge [13]. Combining CoppeliaSim EDU, let students design SCARA robot models, design operational algorithms, experience their motion characteristics, and deepen their understanding of theoretical knowledge.

3) Classroom interaction and group learning:
Encourage students to ask questions and express opinions, timely understand their learning situation,

and provide guidance. Organize group collaboration to jointly design robots in CoppeliaSim EDU. Utilize classroom interactive activities to encourage students to ask questions and express their opinions, timely understand their learning situation and provide guidance, organize student group cooperation, and use CoppeliaSim EDU for robot design.

4) Evaluation and feedback:
Design an evaluation method based on CoppeliaSim EDU to analyze students' knowledge mastery and practical abilities from the results of simulation runs. Adjust teaching strategies and methods based on feedback. Evaluation and feedback: Design an evaluation method based on CoppeliaSim EDU, analyze students' knowledge mastery and practical ability from the simulation results of CoppeliaSim EDU, and adjust teaching strategies and methods based on feedback.

6. Conclusion

Overall, CoppeliaSim EDU has brought revolutionary changes to robot education by reducing costs, improving safety, and providing abundant teaching resources, making robot education more widespread and effective. This software provides an immersive learning environment, allowing students to explore different scenarios, models, and programming interfaces, and gain a deeper understanding of robotics technology. Through practical application case analysis, we can see that CoppeliaSim EDU has significant advantages in robot teaching, which can stimulate students' interest in learning, improve their practical ability and innovative thinking. With the continuous development of robotics technology, the application prospects of CoppeliaSim EDU will be even broader, bringing more possibilities for future robotics education.

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