Using optical sensors for industrial robot-human interactions in a Gazebo environment.

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Abstract

This paper presents an overview of a robot operating system based architecture for human-industrial robot interactions using peripheral optical sensors for real-time object detection and collision avoidance with an industrial robot in the virtual world of the Gazebo simulator. Machine vision plays a huge role in production automation, and develop a system based on Kuka KR3 industrial robot for detecting and tracking a human and other objects in a working area using optical sensors. The ability to work in low light and crowded conditions, as well as the ability to reconstruct a method of execution of a task, while maintaining control of a robot. This work considers several optical sensors and a comparative analysis.
Keywords: Gazebo, safety, Kuka, HRI, Computer Vision

1. Introduction

Nowadays, while industrial manipulators are effectively used in most modern factories together with human workers[1], many of them are not equipped with touch and collision sensors. Unintended human presence in the work area of a manipulator and incorrect calculations eventually lead to a collision[2]. As a result, standards and regulations are violated.
There are many variants of interaction and collision with robots[3][4][5]. In[6][7] the authors developed an algorithm to classify hazards during human-robot interaction. Cameras were used to ensure safety and calculate distances between a person and a robot. Human interactions with an industrial robot were performed using gestures and commands as follows[8]: the camera detects the hand and recognizes the command[9]. The described method improves the level of human-robot interaction without using a remote control. The authors of the article[10] proposed several methods for face and hand recognition. In the article[11] reviewed the structure of the code, types of scanners and cameras, proposed the calculation and method of human detection.
This article presents an optical sensor which is used for human-industrial robot interaction in a Gazebo environment. In experiment and simulations were used off-the-shelf object recognition methods.

2. System setup

Experiments were conducted using Robot Operating System (ROS), Gazebo, RViZ, MoveIt on Ubuntu Linux 20.04 operating system. Ubuntu is currently considered as a popular distribution based on Debian architecture. ROS is a system used to create robotic applications where the main goal is to provide a powerful robotic application that can be used in other robots. This system has a set of software tools, packages and libraries that make software development for robots easier[12]. With Gazebo we can simulate not only the robot but also simulate a room, sensors and various 3D objects[13]. MoveIt is a set of tools for manipulation tasks, such as picking, moving, placing or simple motion planning using inverse kinematics with the help of ready-made libraries that include a fast inverse kinematics solver. And with RVIZ we can visualize in real time all components of the robot system such as coordinate systems, moving parts, sensor readings, and camera images.

3. Research methods

Research and experiments involving real robots and humans are not the cheapest and safest methods. Mistakes and failures are possible during experiments. As a result, humans can harm themselves or industrial robots can fail due to breakage and damage. Also, during failed experiments, recovery is very expensive and long, which is why using virtual robot and human models in a Gazebo environment is more advantageous[14].

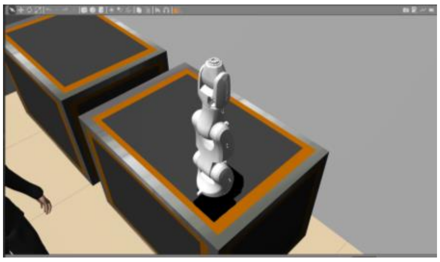

Fig. 1. Kuka KR3 R540 in the Gazebo environment

3.1. Robot control parameters

The described simulations are performed on Gazebo using virtual models. In Gazebo environment we can use 3D model of robots and other objects. Also, due to the capabilities of Gazebo environment, we can create a physical verisimilitude, which is not different from experiments in the real world. During testing, we can use different kinds of models of robots and other objects, and in our experiment, we used a virtual model of Kuka KR3 R540 industrial robot[15] Fig. 1. To control the industrial robot in the Gazebo environment, we use the gazebo ros control plugin with the additional advanced architecture needed to create and provide effective user hardware interfaces between Gazebo and ROS Control.

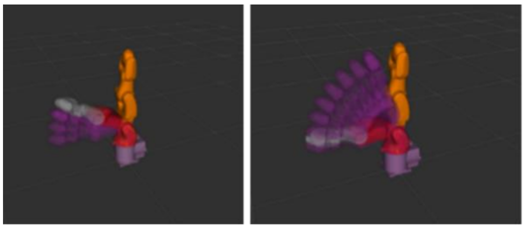

Fig. 2. Example of observation of a manipulator's trajectory

A robot controller is used to make this manipulator model work in reality and perform tasks correctly, which is an important part of this stage, also used as trajectory controller Fig. 2 (a trajectory controller is used for position tracking). To ensure safety and prevent collisions with objects, was developed a system based on the *actionlib* message package, where the communication between the industrial robot and the stereo camera is established. Using such a system provides more accurate calculation of distances and also giving the robot an understanding of its location relative to other objects.

As a result, we know the positions of waypoints and speeds, which gives us a message stream consist of all the information about the final state of the robot. There are also functions needed to convert the desired joint position to a given target. The desired joint position can be obtained from the inverse kinematics and then converted to the ROS goal msg form.

3.2. Optical sensors

A virtual model of the RGB-D-Microsoft Kinect optical sensor is used for experiments. The sensor is an infrared detector (infrared projector with a monochrome CMOS-sensor), which receives an image in three dimensions regardless of lighting conditions, and is also equipped with an RGB camera. The presented virtual model of the optical sensor has the same characteristics as in reality. We get an image from the virtual world of 640 x 480 and depth information, which can be obtained at a maximum frequency of 30 Hz Fig. 3, Fig. 4. The optical sensor is mounted on top of the industrial robot and pointed directly at it.

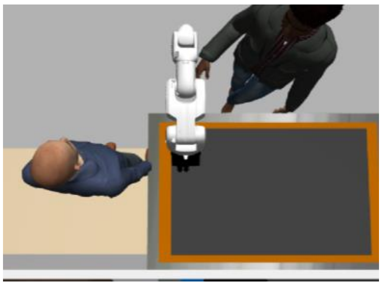

Fig. 3. Image coming from a stereo camera

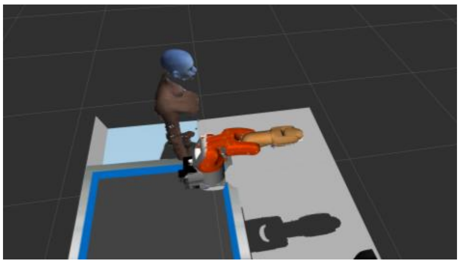

Fig. 4. Point cloud from RVIZ

3.3. Object recognition methods

A system based on the YOLO v3 and MEDIAPIPE algorithms was created to recognize objects from image streams coming from the optical sensor. Used algorithms, unlike others, provide fast and more accurate object detection. The developed Python script integrates the object detection algorithm based on YOLO v3 Fig. 5 and Mediapipe into ROS via a node. The node subscribes to the */depth_camera/image_raw* video stream thread, which receives data from an optical sensor mounted above the industrial robot. The received video stream frames are processed and the downstream module performs industrial robot and human detection.

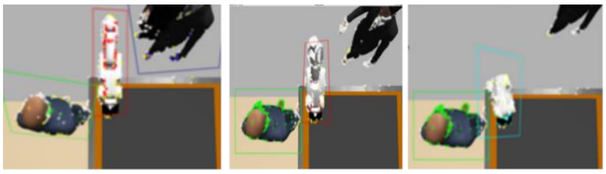

Fig. 5. Detecting objects by stereo camera

3.4. Collision detection methods

After image processing and the detection of objects coming from the image stream, these objects are highlighted and the distances between the object and the industrial robot are calculated. In experiment describes the calculation of the distance between objects[16]. Based on similar works, we developed an algorithm calculating the distance between an industrial robot and objects in the working area of the industrial robot Fig. 6.

Fig. 6. Detecting a collision between an industrial manipulator and a person

To avoid collisions with objects while controlling an industrial robot, we use two methods. Both methods include autonomous trajectory planning and real-time obstacle detection. The first method is global collision-free trajectory planning of an industrial robot in case the object is static or the route of the moving object in time is known. In the second method, the route of the object is unknown and it is necessary to measure the distance between the object and the industrial robot using a real-time vision system.

3.5. Risk assessment of human-robot interaction

The flowchart shows an algorithm that provides safe interaction without touching an object during a task. The algorithm looks as follows. The industrial robot starts to perform the task if there are no obstacles in the working area Fig. 7. In case that object is detected in the working area, the speed is set to minimum values. Next calculating the distance between the robot and the object function started working. If the distance decreases, the task process is temporarily stopped to find a new route, waiting for the release of the optimal route.

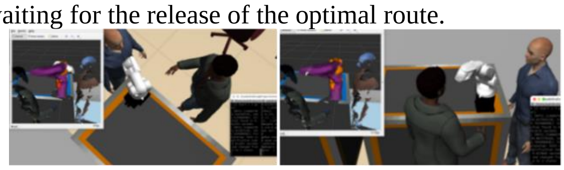

Fig. 7. Calculating the trajectory of the manipulator

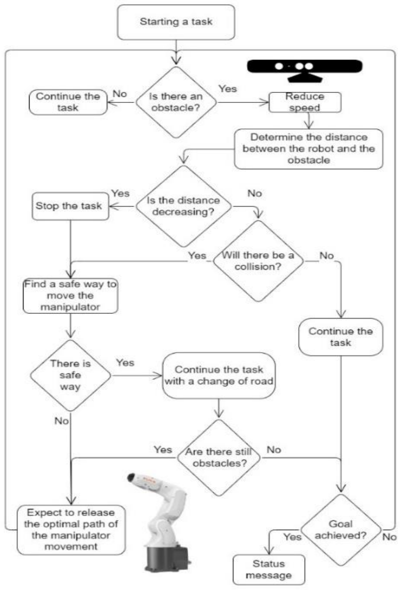

Fig. 8. Block diagram of the collision avoidance method

If the distance does not decrease and does not interfere with the movement of the industrial robot, the execution of the task continues with the set minimum values. In the process of task execution, a report will be issued indicating the status of task execution Fig. 8.

3.6. Results

We conducted a series of experiments simulating human intervention in the process of an industrial robot. In the working area of the robot different positions and animated actions of a virtual human models from an open-source library for the Gazebo[17] were used. This allowed us to test the algorithms of human-industrial robot interaction for safety. All experiments were conducted in the virtual world of Gazebo.

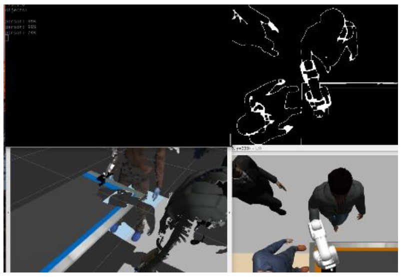

Fig. 9. Human detection using an image stream

Was developed a system which ensures that a human is located safely next to the industrial robot at the moment of performing its tasks Fig. 9.

4. Conclusion

The developed system is quite successful in its tasks, still it needs improvements, because the frequency of image updates is not fast enough to ensure a high efficiency.

Acknowledgements

This paper has been supported by the Kazan Federal University Strategic Academic Leadership Program ("PRIORITY-2030").

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Authors Introduction

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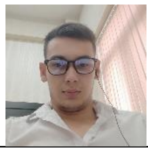

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