Accelerating the development of autonomous machines using Vostok

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***Abstract*—Simulators play a key role in robotics research as tools for testing the efficiency, safety, and robustness of new algorithms. Despite the increasing number of commercial and open-source robotic simulation tools, there is still a need for an easy-to-use integrated solution suitable for developers, researchers and students. *Vostok* allows the interaction with robots, vision systems and sensors within a dynamic operating environment to accelerate the development and deployment of autonomous machines.**

***Index Terms*—Robotics, Machine Vision, Simulation**

I. Vostok 3D Studio

In the last few years, we are experiencing an exponential proliferation of research and applications concerning robotics and machine vision. Robots are required to autonomously operate based on information derived from sensors or vision systems. Due to the variability in this data, it is mandatory to test the safety, efficiency, and robustness of any new algorithm by means of realistic and reliable simulations. A growing number of simulation tools are available for developers and researchers that allow to design and control robots in virtual environments [1]. *ROS* [2] is an open-source operating system which provides libraries and tools to create robot applications. One of the most interesting characteristics of *ROS* is the presence of a broad community of researchers contributing to its expansion. *Matlab & Simulink* can be jointly used, together with the *Robotic Toolbox* [3] provided by P. Corke, to design simulations with robot manipulators. That toolbox provides functions to generate trajectories and analyse results from the simulations and real robots. *Gazebo* [4] or the latest *Nvidia Isaac SDK* [5] are 3D simulators developed to accurately reproduce the dynamic environment a robot may encounter. Robots can be assembled allowing the user to model a wide range of robotic platforms. Some of these software provide powerful development tools and accurate simulations without an integrated environment, while others are rather complex and difficult to use by unskilled users. Trying to address all these issues in a unique solution, we introduce a free powerful simulation software, called *Vostok* [6], that allows interacting with robots, vision systems and sensors within a dynamic operating environment. Fig. 1 shows an example of a work cell designed using Vostok.

Apart from the easy modification of sensor parameters, the main advantage in simulation is the opportunity of carrying out experiments under reproducible conditions, especially for dynamic scene setups. Vostok aims to help manufacturers, developers, researchers and students by providing a guided and user-friendly interface through which to design, program and test autonomous machines. In particular, there are three main reasons that inspired the development of this project.

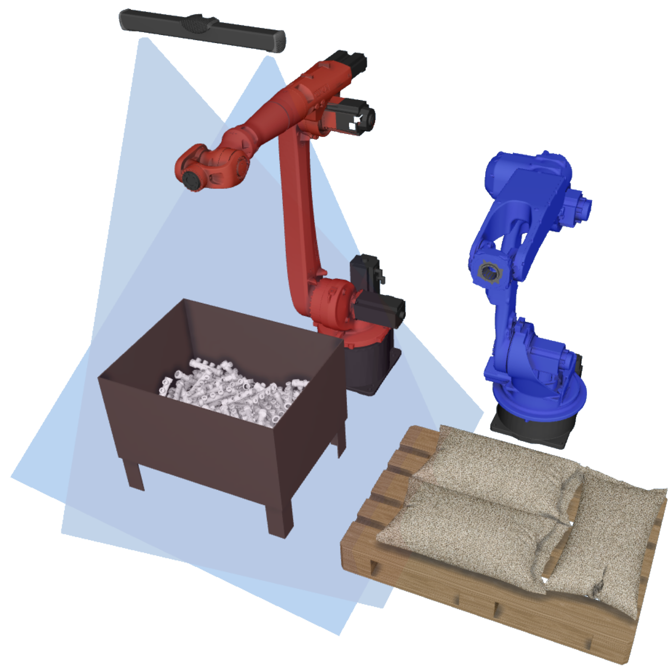

Fig. 1. A Vostok work cell example featuring two 6-axis robots, a structured light scanner and two items generators (box with randomly placed samples and a structured pallet).

- Provide a totally free solution that encourages individuals who want to experiment with robotics but fail due to high hardware and software costs. For this reason, the simulator should be easy to use, flexible and modular.
- Allow companies testing their projects within a simulated safe environment and, consequently, to cut down long installation time. This enables developers to deploy the automation process faster and more confidently. With this aim, a key feature should be the code portability from a simulated to a real platform, along with a library of

ready-to-use commercial known devices (robots, 3D scanners, 2D cameras). Another interesting feature concerns the possibility to connect the simulator with proprietary systems via TCP/IP protocols.

- Exploit deep learning techniques at industrial level. This is crucial because, in this context, it is not always feasible to start from real examples. The latter are usually not available during the developing phase and it is therefore necessary to simulate them. For this reason, the simulation must be really fast, in particular for three-dimensional scanners. Therefore, we stress the need for a trade-off between simulation accuracy and computation time. Deep learning is playing a growing role in computer vision and robotics applications. One of the main problems regards the availability of data to train those systems. With this aim in mind, Vostok would be a powerful tool to generate test datasets of synthetic images.

Through Vostok is possible to design an entire work cell by adding robots, vision system, sensors and objects. Then the user can program robots, simulate their behaviours, grab photos or trigger scanners to generate point clouds. Fig. 2 shows Vostok workspace during the testing of a simple pick and place robot application.

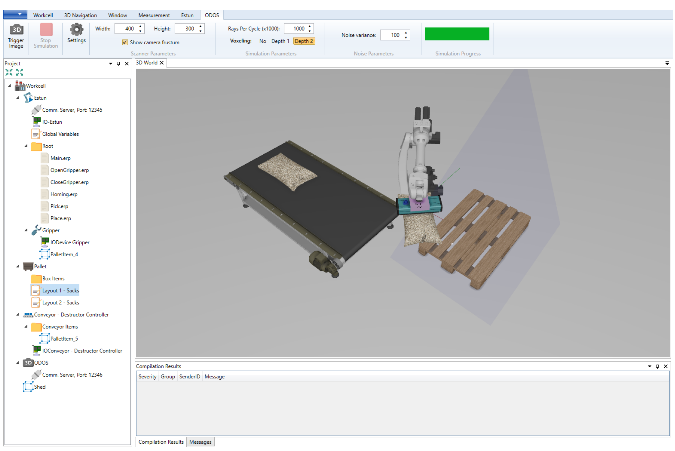

Fig. 2. Overview of Vostok workspace: example of a pick and place robot application using a time-of-flight 3D sensor.

In particular, after loading a robot the user can set robot TCPs, frames, touch-up points and define trajectories. In addition, Vostok allows to check for collisions with the surrounding environment. It is possible to connect grippers to the robot flange to control its IOs and simulate them by means of a virtual PLC creating a digital twin of the real work-cell. Moreover, the user can program the robot using its specific programming language: this allows to cut down installation time since the code can be transferred to the real robot as it is.

Actually, a key point distinguishing Vostok among other commercial simulators is the possibility to simulate three-dimensional sensors. We believe this can be a great added value since the cost of these devices is really high and it is convenient to simulate them to test the efficiency and robustness of new computer vision algorithms. We recently published an article regarding the simulation of three-dimensional scanners based on structured-light and time-of-flight techniques [7]. Actually, in the literature we find very complex models aimed at achieving the maximum realism without worrying about the actual applicability in the industrial field. For this reason, it was necessary to find a trade-off between simulation speed and accuracy by exploiting GPU architectures. The article presents a novel simulation approach based on the ray tracing technique. We compare the results obtained with those provided by real commercial scanners proving that the simulator is able to provide a good level of realism. Quantitative and qualitative results demonstrate the efficiency and reliability in industrial environments. We proved simulator effectiveness especially for evaluating the occlusions within a point cloud. Although reconstruction models can be expanded and improved, simulator performances are sufficient to test any computer vision algorithm without the need for real expensive scanners. In addition, Vostok allows to simulate camera sensors and optics. Actually, most recognition algorithms are still based on images. Even the smallest artefacts may cause an incorrect target recognition and, thus, the implementation of an ideal camera is not sufficient for industrial purposes. Obviously, it is not possible to exactly replicate a real camera: lens physics and light conditions deeply characterize the acquired image, and modelling them is extremely complex. Therefore, we focused our interest to the main lens effects, i.e. optical distortion, defocus aberration, vignetting and we implemented them within Vostok.

Vostok is a powerful simulator for testing the efficiency, safety and robustness of new algorithms in a realistic dynamic environment. It can be a great support tool for courses on robotics and computer vision. For example, students can learn directly by solving several real problems in a simulated environment. Finally, it can be used to generate datasets of synthetic images to address the problem of data lack to train deep learning systems. A beta version of this software has been released and it is freely accessible [6]. Thereby, Vostok will help making robots and sensors easy commodities abstractions for everyone.

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