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Study of touch interaction in Virtual Reality using Delta robot

ABSTRACT

The dissertation deals with the problem of effective use of Virtual Reality (VR) methods and tools to create interactive training simulations oriented at work at a production stand.

As a result of the analysis of existing VR solutions for industrial training, it was noted that the expected level of training performance can only be achieved by providing adequate immersion and touch interaction between the user and the virtual environment components for the need for direct control over the image being presented. Existing VR systems provide useful (from the training point of view) tactile stimuli mainly based on haptic manipulators, which, according to the author, have significant hardware limitations (e.g. large dimensions, small work area, lack of mobility), and thus they are not able to provide the freedom of movement for the user. In addition, commercial solutions integrate immersive and haptic devices to a small extent, while simultaneously providing physical manipulation of digital data representations to enhance the realism of the simulation. It is therefore reasonable to undertake work on a solution that will support user interaction studies, on the basis of which it will be possible to analyze and interpret its commands and actions resulting directly from physical manipulation of objects integrated with virtual environment (VE).

Doctoral thesis presents the concept, design process and testing of the new VR system based on the innovative application of the Delta robot. The main task of the manipulator is to maintain a functionality of haptic devices in the field of simulating the shape of virtual objects during interactive simulations in a similar but an alternative way. Prepared solution integrates robot with a parallel kinematics with low-cost VR devices for projection (Head Mounted Display) and real-object tracking (optical tracking) and also manages physical models representing digital data. The concept of the system implies applying it to a virtual training aimed at acquiring the competence to perform manual procedural tasks as a response to the growing demand for low-cost industrial training systems.

The aim of the work was to develop a new approach to the development of VR systems dedicated to training, which consists in introducing into the virtual environment a new

element - an active touch device that simulates digital objects. The approach required the development of a hardware and software integration method for all components of the VR system, as well as the design of a demonstration stand. In practice, on the basis of the developed method, an algorithm for simulating digital objects by the end effector of a Delta robot was created (a physical object representing digital data was placed on the effector). Communication interface with VR systems was configured as well. The main purpose of the work involved integrating the manipulator with the Virtual Reality systems. It was important to provide the ability to adapt to the developed solution also other robots (e.g. SCARA robot).

Experimental research was concerned with the touch interaction between the user and the end effector of the robot. An interactive VR application has been prepared for the simulation of the developed test scenarios during which the participant of the virtual scene interacted with the simulated object and the manipulator task was to move to a location enabling such interaction. The experiments were aimed to see how the presence of a touch stimulus influences the immersion of the solution. Analysis of the obtained results also contributed to the detection of potential limitations (hardware or software) of the developed system and directions of further research.

The scenario of virtual training from the selected procedural task was also performed on an experimental test stand. The purpose of the test was to demonstrate whether the solution could be applied to work-oriented training at the production stand. Cyclical attempts to perform a procedural task by test groups have helped to determine the effectiveness of simulation as a training application for future operators of a selected workplace. The realism of the simulation and the level of immersion in the developed Virtual Reality application were determined using a survey.

The work consists of a theoretical and practical part. Theoretical part of the dissertation was divided into three chapters. Chapter One is an introduction of the need to develop a new approach to interactive training simulations that incorporate touch interaction study. Chapter two presents the main assumptions of VR, describing the characteristics of VR systems and the VR applications in engineering. Existing approaches and solutions used in development of virtual simulations for interactive industrial training are also described. When analyzing the faults of existing solutions, it was justified to develop a new solution that simultaneously supports touch-based testing. The theoretical part of the dissertation is completed by chapter three, setting the purpose of the work.

The practical part consists of three chapters. Chapter four presents the research methodology. The plan and objectives of the research experiments were determined and the main assumptions of the Virtual Reality system were described. The resources (hardware and software) used to built the experimental test stand were also presented. The developed method of integrating an active touch device with the selected Virtual Reality systems and physical models representing digital data is presented. The method of building a system for studying touch interaction in virtual reality is based on the method. Chapter five describes the conduction of research experiments. The results of the study were posted. On their basis, the possibility of applying the solution in interactive simulations of manual procedural tasks was evaluated. The final chapter summarizes and concludes the work and presents the directions of further research.