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TECHNOLOGIES FOR BUILDING COMPLEX SENSOR SYSTEMS FOR COLLABORATIVE SERVICE ROBOTS

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Abstract

In this paper, we study the issues of developing an interface, that ensures optimized operator interaction with robotic systems. The interface should have a high degree of intuitiveness and provide the user with access to up-to-date information about the current state of the system through feedback sensors. These sensors record parameters such as torques, forces, and positions, which allows monitoring the relative position of the robot's and operator's work elements. Special attention is paid to the visualization of algorithms designed to identify potential drive overloads and changes in technological parameters. Software and hardware have been developed to provide a dialogue with collaborative robots using laser graphics, taking into account the individual needs of the operator and realizing the recognition of sign language and voice input. This is aimed at freeing the operator's hands from the need to enter instructions using the keyboard or remotes. The results of experimental studies aimed at indicating mutual intentions between the operator and robotic systems are presented.

Keywords: Mobile service collaborating robots; common video-streaming web-cam field; laser and immersive technologies; indication of intentions; synesthesia

1. Introduction

Modern robotic systems, that operate in cooperation with humans (known as collaborative robots or cobots), enable the combination of machine efficiency in handling repetitive tasks and human creativity in resolving ambiguous situations. The traditional safety approach for such complexes involves completely excluding the operator from the robot's workspace during its operation, which often hinders the full automation of processes requiring human intervention. A key objective is building effective collaboration where humans and machines share the same workspace. In this context, controlling parameters such as movement speed and applied force becomes critically important. Safety systems are built using machine vision, force-torque sensors, and specific control algorithms, that reduce the robot's speed and force upon detecting a human. Such solutions pave the way for automating new types of tasks, including assembly, quality control and maintenance. Significant attention is paid to designing user-friendly interaction interfaces.

They must be intuitive and provide the operator with data from sensors (torque, force, position) to assess mutual positioning with the robot. Visualizing the operation of algorithms, that identify actuator overloads and adjust system parameters is also necessary. The adaptive control systems being developed must flexibly adapt to changing conditions and individual user needs. Besides standard programming methods, interfaces based on gestures and voice commands are gaining popularity; their main goal is to free the user from using keyboards or buttons for input. This report describes our experiments on demonstrating the mutual intentions of the robot and the operator using laser projections.

2. Technologies for Collaborative Interaction Under Development

Our research focuses on integrating heterogeneous sensor systems, creating universal software [1–10], and expanding the service zone of robotic complexes through the use of dual manipulators [11–14]. We have developed a method for identifying intentions in the human-robot system based on a compact laser prototype, that projects pointer arrows, text prompts, or pictograms onto surfaces (Fig. 1, 2). This led to the concept of a unified information space based on webcam video streams for cobot-human interaction. If the operator uses wearable sensors (electromyography and/or inertial IMU sensors), it will enable the creation of algorithms, that dynamically coordinate mutual movements. Compared to known methods like Kinect, this approach offers the potential to account for the dynamic characteristics of human motion. A promising direction is cooperation in the "robot-operator" system through the indication of emotions, facial expressions and schematic drawings to demonstrate motivation, based on the principles of synesthesia. This research area is just beginning to be explored in collaborative robotics.

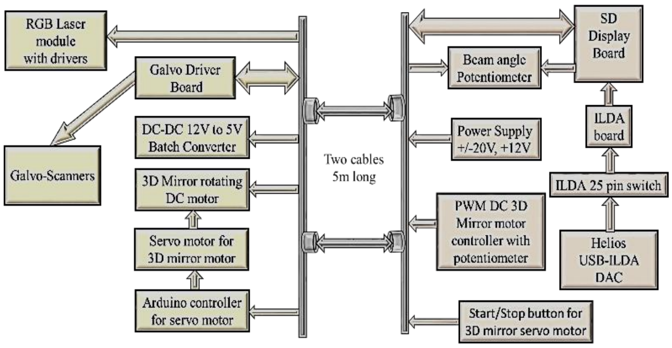

Fig. 1. Functional diagram. On the left is the scanning and emitting module, on the right is the interface and control.

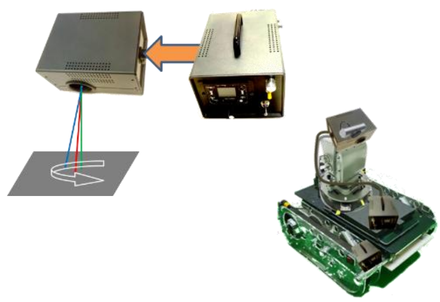

Fig. 2. Mock-up of a laser scanning communication system installed on the Cobot.

It should be noted, that using immersive technologies (AR/VR) often leads to increased operator fatigue, making "glasses-free" approaches more preferable. However, the issue of high cost for such devices and other challenges remain. The figure 3 shows a schematic example of human-cobot interaction through the ManyCam program using a webcam, stereo camera, Kinect 3D scanner, and virtual reality glasses.

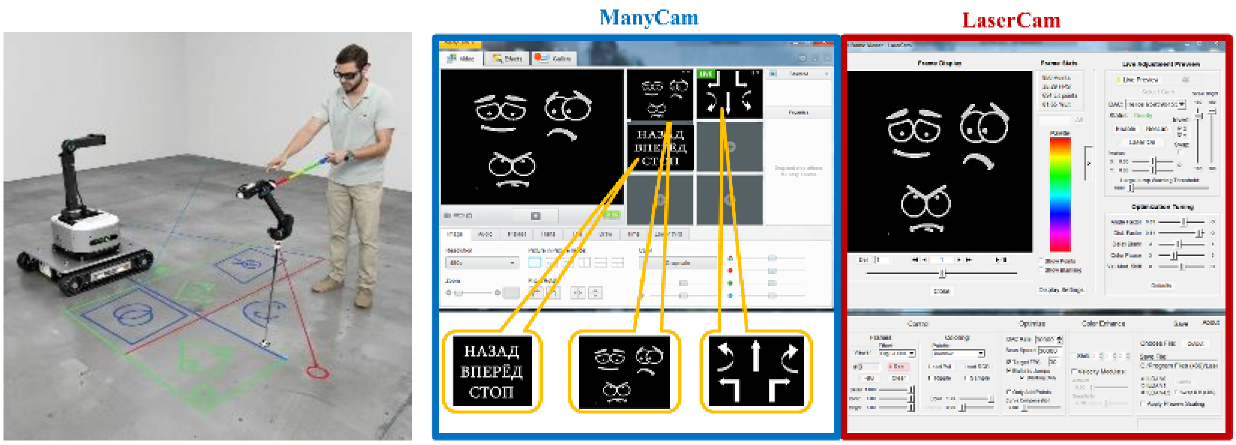

Fig. 3. An example of human-cobot interaction through the ManyCam program.

Simultaneously, the LaserCam application intercepts the video stream from the ManyCam application and controls the laser projector, displaying emotions. This is what we call the common a “video-streaming common webcam field” (Figure 4).

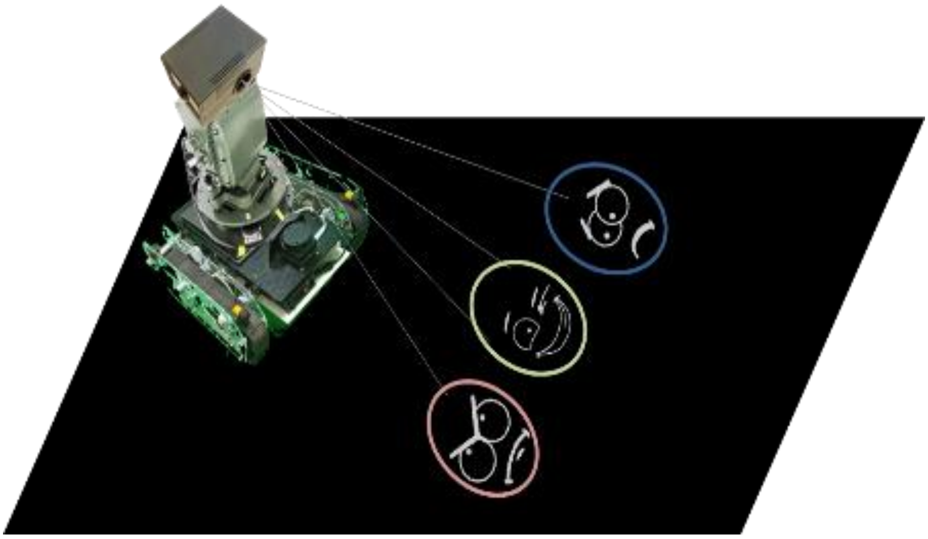

Fig. 4. Emotions laser projections via interaction between ManyCam and LaserCam applications

Developing mobile robots and their algorithms inevitably involves a lengthy debugging process, requiring the creation of integration software and a virtual development environment [7,10]. Simulators using virtual twins of robotic complexes for modelling sensory interaction with environmental objects have become widespread. They provide additional opportunities for debugging intelligent control systems and expanding functionality, including executing loosely defined tasks, orienting the robot using voice commands, moving objects based on indirect operator cues, and providing guidance or information about the equipment being interacted with. As part of the "Intelligent Robotronics" project, we developed robotic complexes for various purposes and implemented route-following algorithms using ArUco markers or external control scripts for logistics operations. Specifically, a universal sensor-control unit was created, that works with data from vision systems, lidars, ultrasonic rangefinders, odometers and features 6 PWM control channels at 30A each. The implementation is designed for use with an STM32-based microprocessor network and neural accelerators. Work is underway on force-torque sensing for dual-arm grippers. Tests are being conducted to assess the operator's ability to navigate using highly compressed images transmitted from the robotic complex, with simultaneous highlighting of target manipulation objects. Implementing such a system became possible on micro-PCs like Raspberry Pi 3/4 due to a new method of forming color clusters and histogram analysis for partial object recognition. Transmitting compressed images allows for a rate of 25 frames per second, even over RS-232 communication channels, due to significantly reduced data volume. A separate research direction involves using short-range microwave sensors to identify moving objects by comparing their spectra against background noise. For this purpose, specialized test benches were developed in our robotics lab to study multi-channel signals.

3. Conclusions

The adoption of collaborative robotics not only enhances productivity and quality, but also improves working conditions, reduces the risk of injury and makes work more productive and creative. Initial steps have been taken on this path towards deeper human-robot integration, creating methods for indicating mutual intentions using the laser, immersive, and other hardware-software technologies presented in this work. The discussed challenges of creating a software environment for developing sensor-control systems for mobile service robots are being actively addressed and applied in our developments [7,9,10,14]. The work was partially supported by the Ministry of Science and Higher Education of the Russian Federation (FFMN-2025-0022 project).

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