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DESIGN AND IMPLEMENTATION OF THE REMOTE CONTROL OF THE MANIPULATOR

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Abstract

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This article is focused on the design and implementation of the complex solution of the remote control of the industrial manipulator Katana 6M180. The main aim is to increase utilization of the machine and its monitoring, whereas the safety standards won't be affected. Both parts of the design, the hardware as well as the software one, are discussed in this article. The hardware part consists of the protective cage, controllable lighting, power circuits, electronics, server, several cameras used for image processing of the working space and one IP camera used for monitoring. The software tools represent second main part of the described solution of the remote control. This software part of the solution consists of the main control software running on the server, the reservation system and third party software that solves connections between clients and the server. Special attention is paid to the implementation of safety elements, in order to increase the robustness of the whole system. The description of one resolved task that used the designed remote control system, is listed in the conclusion as a proof of concept. The task is focused on determining parameters of the objects in the working space of the manipulator.

Keywords: remote control, manipulator, protective cage

INTRODUCTION

This article summarizes the results achieved within research project "Achieving effective utilization of the manipulator by introducing remote control system." This project is focused on the design and implementation of the remote control system of an industrial manipulator, which leads to higher utilization of the machine. The utilization of the machine is an important parameter, which has a direct influence on the financial costs of the company and can bring significant savings. The presented solution is focused on stationary manipulators that are designed for semi-automatic chain links controlled by people. The manipulator Katana 6M180, that is placed in the laboratory of Intelligent systems at the department of Informatics on Mendel university, is used as the case study. The main goal of the presented solution of the remote control system is to simplify access of the researchers and students to the machine and allow them to work effectively with the machine at any time and place.

Especially implementations of safety standards, switching the machine on/off and monitoring of the activity are solved within the project. Furthermore, the lighting of the working space and its image processing using a few cameras are solved to create stereoscopic image of the manipulated objects. The stereoscopic view enables better orientation of the operators in the working space. Such image can be used for analysis of the manipulated objects as well. Various desktop or mobile clients connected using internal university network or VPN can be used for remote control of the machine. The connection is solved using RDP protocol and third party software like a Teamviewer. The proposed solution also includes reservation system that enables researchers and students to work effectively on the machine 24/7. The working time is not limited to single sift working hours. Therefore the remote control also motivates students to work independently.

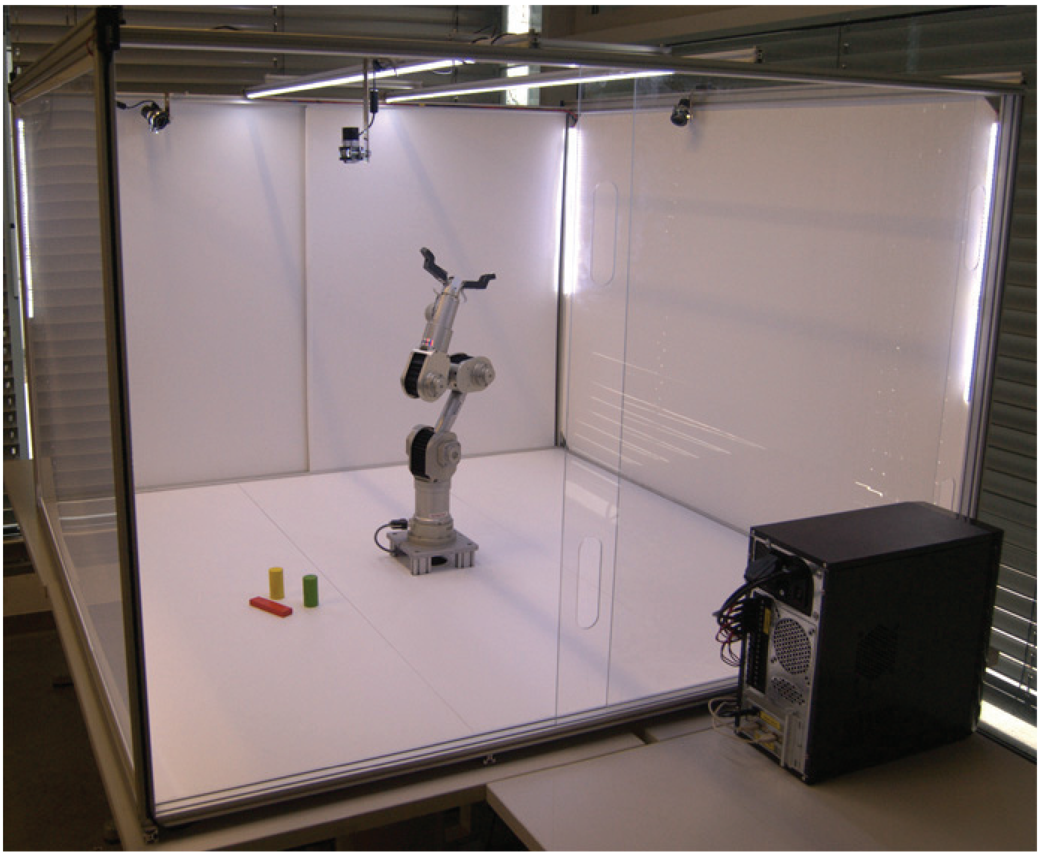
MATERIALS AND METHODS

The whole solution can be divided into the hardware and software part. The hardware part consists of the protective cage, I/O module, server, controllable lighting and cameras. The manipulator is placed into the center of the cage, see Fig. 1. This cage defines the working space of the machine and ensures to avoid any injury. Therefore, this is the first safety element of the solution.

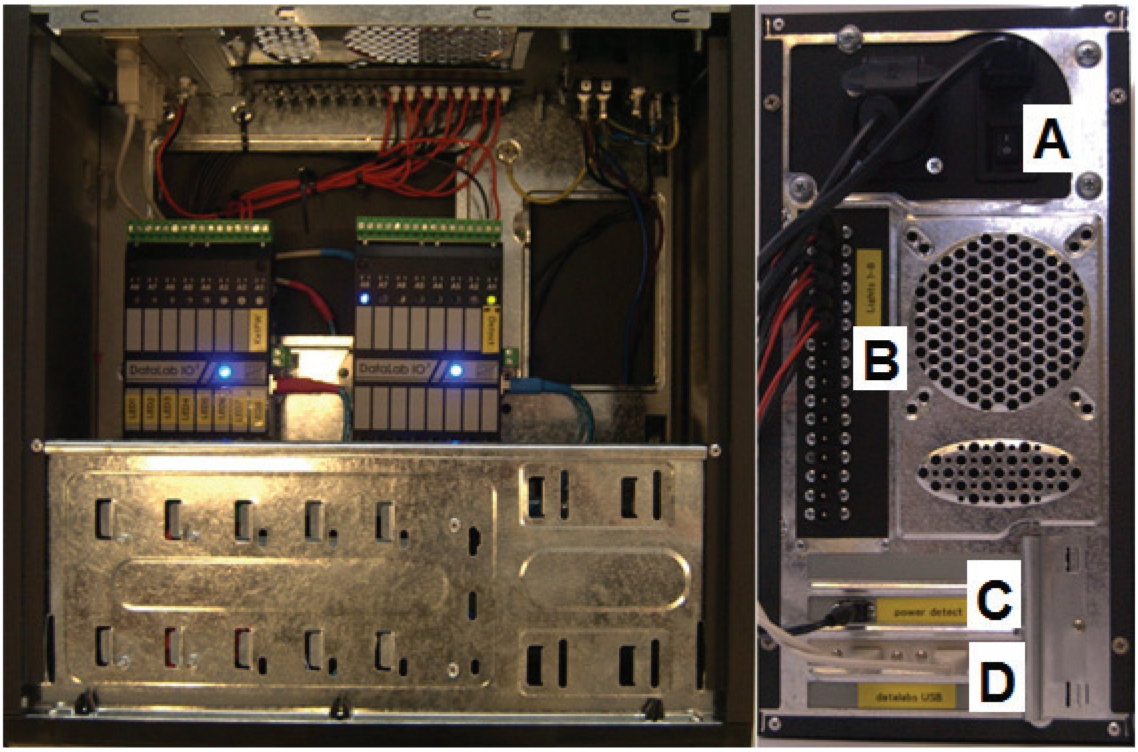
The cage has a square shape and is made of an aluminum frame that is connected to the manipulator. The frame is also used for holding cameras, lights and electrical wiring. Two lateral surfaces are made of a Plexiglas with thickness of 5 mm. The other surfaces are formed using the ABS plastic boards. Furthermore, the boards are fortified with the aluminum profiles that increasing the rigidity of the whole construction. The cage weights 60 kg.

The designated working space is illuminated using 5 m long LED strip that is separated into 6 parts. These parts are connected using permanent joints to the lateral and upper parts of the protective cage. Each part can be switch on/off separately, which enables setting up the intensity of light in 6 grades. Furthermore, the light strips placed on the upper parts of the cage can be freely moved in the horizontal plane, which enables additional individual setting of the lighting. The light is provided by 160 pieces of white LED. Each of them emits 5 lm with beam angle 120 degrees. The LED strip is rated with IP68 standard, it means that no ingress of dust is possible and the strip is hermetically sealed. This standard represents another safety element of the whole solution.

The I/O module is another important part of control and monitoring chain, see Fig. 1 and Fig. 2. Power circuits and electronics are placed into the module. The module serves for the control of power supply of the manipulator, detection of the voltage drop and for the lighting control as well. This solution is based on the industrial control modules from the Moravian Instruments company. The first module DLAD2 contains 4 isolated differential 16 bit analog inputs, 2 isolated 8 bit analog output, 2 isolated digital I/O. The second one DL-DO1 contains 8 relay outputs with normally open contacts with maximal limited values: voltage 230V AC and 3A. The power supply is also connected to the mentioned modules through the AC adapter, which enables detecting problems with the current supply. This monitoring



1: *The protective cage with manipulator, lights, cameras and I/O module*



2: *The I/O module, inside look and rear panel (A – power input, B – analog inputs, C – power detection, D – connections to the server)*

is necessary for the disconnecting the current remote client from the manipulator and shutdown the whole device in the safe way. The UPS unit is used to providing power during the emergency shutdown. This unit is able to provide the power to the server, manipulator and electronics for a few minutes, which is sufficient for the docking the manipulator to the safe position and shutdown all devices. The whole I/O module is connected to the server using two USB connectors.

The common PC with operating system Windows 7 is used as the server. The web cameras that are used for image processing of the working space are connected to the server. It is possible to connect up to 4 cameras. Each of them has resolution 1280×720 pixels with 30 FPS. Another IP camera is located on the ceiling above the cage and connected directly into the Ethernet. This camera is used for monitoring of the workplace, is independent on the rest of the described solution and is powered directly from the LAN. Therefore the IP camera represents another safety feature.

The software tools represent second main part of the described solution of the remote control. This part consists of the main control software running on the server, the reservation system and third party software that solves connections between clients and the server using the RDP protocol. The control software is developed using the Control Web development system and is designed for Windows operating systems. This tool is running all the time, during which the client is connected to the server. The control software provides essential functionality to the user, e.g. switching the manipulator on/off, controlling the manipulator, regulating intensity of light, providing images from cameras, detecting power drop, etc.

The program also integrates functions and routines that are necessary for the safe operation of the whole remote control. These routines are executed whenever any specific event appears. Some of these events are: switching the manipulator on, inactivity of the user, the power failure, collision of the manipulator with obstacle or user logout. Common user (remote client) cannot shutdown the main control software neither affect an executing of the safety routines, because he has not sufficient user privileges. The main reasons for such restrictions are protecting human's health and life as well as preventing damage of the equipment, which could result in a financial loss.

Detailed information about responding to the mentioned events follows. The correctness of the connection and communication is checked, when the manipulator is switched on. The calibration of the manipulator is performed after this check. These actions are necessary for setting up the initial positions of the drives and cannot be interrupted. Only then is the user allowed to work with the machine.

The warning popup window is shown, when the user is inactive for the defined period. Thereafter the user is prompted to continue on his work. The logout routine is performed, if the user does not comply. The logout routine includes calibration of the manipulator and setting it to the default position. The inactivity can be caused also by loss of the connection on the side of the server or on the side of client. Thus the system must be able to reinstate to the original state, especially initial position of the manipulator and switch the lights off.

The control software is constantly checking possible power failure using the IO module. If the power failure occurred, then user is informed and logout routine is started. The system is able to finish logout routine using the uninterruptible power supply (UPS) that supplies power to the system from the batteries.

The control algorithm that is the part of the main software tool is based on the low level libraries supplied by the manufacturer. These libraries have built in system of exceptions that inform a user about the actual error state of the manipulator. Exceptions inform about e. g. not able to reach a position, physical collision, etc. If the algorithm throws "physical collision" exception, user is informed about this state, the warning message is sent to the administrator and the algorithm is terminated. This is the only case, when the direct intervention of the system administrator is required and cannot be solved remotely. However, whole remote control system can be monitored using the IP camera. The video sequence from the camera is streamed to the dedicated server. Therefore the stream is available to the administrator at any time, even if the remote control is shut down.

The reservation system allows users to obtain access to the server, where is running the control software, for a fixed time. This system contains security rules against unauthorized access. It is primarily designed for students and researchers of the Mendel University and can be accessed even outside the university network. Therefore, the built in windows remote desktop application cannot be used. This is the main reason for using a TeamViewer software for the remote access. This third party software is running on the server as a system service. Any user, who wants to use remote control system, obtains unique ID and password using reservation system for accessing the server via TeamViewer client. Users also need to know password to the Control Web tool. Only after these verifications is the software fully accessible for their needs. It is recommended to watch the whole system using IP camera, whenever is the manipulator used.

RESULTS AND DISCUSSION

The system of remote control is largely used by students working on their diploma and PhD theses. A student, who wants to work with the manipulator, has to register himself as the user. After that, he can insert his request to the registration system. The student obtained access to the server based on this request. The routines, described in detail above, are automatically activated, after the student logs in the main control software. The user has now a lot of options how to work with the machine using the Control Web software, see (Rouš, 2012) for more details.

The description of one finished work using the remote control system follows as a proof of concept of the whole remote control system. This work is focused on finding position, orientation and dimensions of the objects that are placed in the working space of the manipulator. The stereoscopic images from two cameras, described above, connected to the upper parts of the protective cage (see Fig. 1), are used for finding these parameters. Moreover, the stereoscopic analysis provides spatial dependencies between objects and also provides required information about the working space, which is useful for planning the motion of the manipulator. This analysis is focused on transformation of the depth map, obtained from the stereoscopic view, to the space of parallel coordinates. There is dualism between the new representation based on parallel coordinates and the Cartesian system, in which the stereoscopic images were taken. The searched lines of the objects are transformed to the points in the parallel coordinates, thanks to the dualism. These points are independent of rotation and can be found easily. The various methods such as thresholding or finding the maximum of the cut of parallel point were successfully tested for finding these points. See more details in our previous work (Kolomazník, 2013).

The resulting solution of the remote control system is fully functional. It allows researchers and students to work with the industrial manipulator Katana KM180 at any time from any place. The utilization of the machine has already increased, which is the main goal of the introduced project. Several safety elements were integrated to the solution of the remote control. The protective cage defines the working space of the machine and prevents the injury of other researchers in the laboratory. The led strip is rated with the IP68 standard, which increases the resistance to the electric failures. A lot of low level software routines can be activated automatically, whenever problems with the control of manipulator or power supply occur. The IP camera, which is independent of the control chain, can be used by the administrator of the system for monitoring. All of these features increase the robustness of the whole system.

Our future work will be focused on improving the reservation system. It is desirable to achieve automated reservations of the students based on the integration of the reservation system to the information system of the university.

SUMMARY

This contribution is focused on the complex solution of the remote control of the industrial manipulator Katana 6M180. The main goal is to increase utilization of the machine as well as monitoring the work of the students and researchers, whereas the safety standards won't be affected. The solution consists of the hardware and software part. The hardware part consists of the protective cage, the I/O module, server, controllable lighting, web cameras and one IP camera. The software part consists of several tools. The most important is the control software that is running on the server. This software provides essential functionality to the user, e.g. switching the manipulator on/off, controlling the manipulator, regulating intensity of light, providing images from cameras, detecting power drop, etc. The other tools include the reservation system and third party software that solves connections between clients and the server using the RDP protocol.

The resulting solution allows registered researchers and students to reserve time period, in which they can work with the manipulator using the remote control system. These users are allowed to connect to the main control tool of the machine in the designated time using the ThinViewer client. Thereafter users can work with the machine in the same way as they would have been in the laboratory. They are allowed to switch the machine on, control motion of the machine, regulate intensity of light and capture images from cameras. Each client is automatically disconnected and the logout routine is performed, when the reserved time period expires. The logout routine moves the machine to the initial position and switches the light off. The logout routine is also performed, when the user is not active for defined period of time or when the power is dropped.

Several fundamental image processing tasks were successfully solved using the described solution as a proof of concept of the designed remote control system. These tasks were focused on determining parameters of the objects in the working space of the manipulator. The stereoscopic view of the scene was used to find position, orientation and dimensions of the objects with whom should be manipulated.

All established objectives were met. The described solution of the remote control is fully functional and is currently used for solving several diploma and PhD theses at the department of Informatics at the Mendel University in Brno.

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