Annales UMCS Informatica AI X, 2 (2010) 169-176
DOI: 10.2478/v10065-011-0021-8

Annales UMCS
Informatica
Lublin-Polonia
Sectio AI
http://www.annales.umcs.lublin.pl/

Internet-Based Teleoperator System for Remote Video Monitoring

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Abstract – The presented robotic system has been designed and dedicated to remote control video cameras away from monitoring workspaces. The idea of the system is that the camera is installed on the flying platform of the cable driven manipulator. The manipulator is the slave part of the robotic system similar to the standard inverted Stewart platform that features six degrees of freedom. The presented manipulator has been extended with additional three degrees of freedom to increase maneuverability of the camera. The system can be employed in two basic modes, both as an autonomous robot and as a teleoperator instrument.

1 Introduction

There are many cases when we need to monitor workspaces or storage spaces from a distance. For example it can be useful for watching exceptionally hazardous work environments which can be especially dangerous for people's life and health. For example, such situations are found in different laboratories and store houses where radioisotopes, chemicals and harmful biological substances are processed or stored.
The second large area of applications of the systems are during human activities which must be done even if they are dangerous for people who supervise them. The classical example of such operations is the work done by sappers with misfire or security service examining suspicious parcels left in public places. Today in practice terroristic threat is ubiquitous worldwide. Thus

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airports, railway or underground stations and other public places require special monitoring, both local and at a distance.

The basic instruments for the sight monitoring are video cameras. In practice, the camera allows to monitor desired objects from whichever distance. For example, there are many commercially available devices dedicated to deliver audio-video stream wirelessly for Web viewing. For the class of the devices no computers are needed to connect the camera to the Internet. The video devices have an embedded proper stand-alone web servers. In the presented application we have just used the so-called IP network camera with the video server [1, 2]. The camera is equipped with a servomechanism that allows to change the "gaze direction" of the lens. Moreover, it has a built-in microphone for acoustic monitoring. The position changes of the lens are possible in the horizontal plane and the vertical rotation is also available.

As mentioned above the product includes the proper software package for the remote use of the camera by the internet. The package includes the control of the "gaze direction" of the camera and the review of images registered by the camera. Also the stream of images can be sent out to any file server in the network. In practice the devices of the class are dedicated to deliver video and acoustic viewing via web browser at anytime and anywhere for remote surveillance and management.

Practically, the only considerable disadvantage of the devices is the lack of movement only. The use of the standard camera systems allows for monitoring a work field only from one fixed observation point. In other words, the cameras are not equipped with any mechanisms for positioning of the camera platform relative to workspace. The selection of the optimal position of the camera and the lighting relative to the subjects and background is the difficult art in common photography. It is obvious that different details of an examined object can be invisible from one perspective but they can appear to the camera lens from the other one. Of course it is possible to use a lot of cameras in one workspace – the video cameras are relatively low cost devices. But the most often, the idea is not proper to solve the sketched problem. For example, a common hall of an airport can consist of an infinite number of photo scenes. It all depends on a monitored object, existing obstacles, arrangement of the hall and so on. Usually the idea of using a multi-camera system is inconvenient for all dynamically changed environments with various movable obstacles or with a mobile monitored target.

It seems that the one and only good solution of the problem is using a moving platform for the camera. Of course it is a well known solution. But generally the systems with the mobile camera platforms are very expensive.

We have designed and tested the video monitoring system that has been improved with the ability to move the camera by means of the cable driven robot manipulator.

The presented platform system is a relatively low cost and simple solution. As a typical robotic system it can be employed in one of two following modes as needed. One of them is the teleoperation manner and the other is the full autonomous mode. The autonomous mode is dedicated to perform routine procedures of monitoring in regular steady workspaces. The teleoperation mode allows for remote performing all kinds of manipulations with the camera platform and the camera in real time at each distance. In this way the camera operator is well isolated from the workspace if it is only required.

2 Six cable crane

There are many different platforms specially designed for video cameras dedicated to professional movies or video industry. Often the equipment includes special systems to control the space positions and angle orientation of the platforms. The systems are usually very expensive. Below a less expensive cable suspended robotic platform is presented.
Traditional cable cranes are not useful to suspend the camera platforms. Of course, the end effector of the proper one-cable crane can be moved in the horizontal plane XY and also along the vertical axis Z – see Fig. 1.

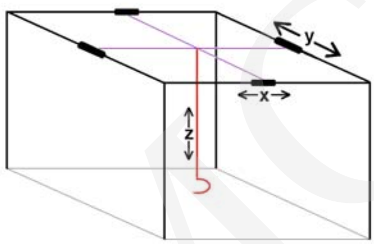

Fig. 1. The example of the conventional crane installed on the X-Y gantry.

However, the platforms carried by the cranes of this conventional type are unstable and often unsafe. The platform is free to rotate in all directions and it can swing a lot. In practice, the determination of the desired space orientation is not possible.

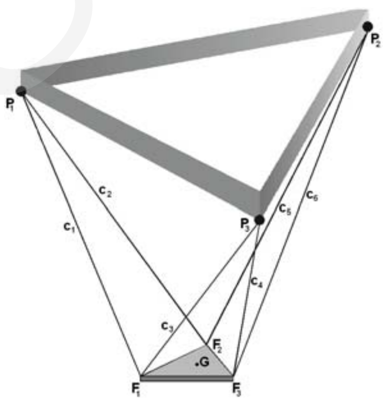

Fig. 2. The simplified scheme of the 6-DOF cable-driven crane – the inverted Stewart platform F_1, F_2, F_3.

We propose a platform design similar to the robotic crane invented and developed at the National Institute of Standards and Technology in the USA (NIST) [3–7]. The crane has been called RoboCrane® and the construction is now the classic example of the very effective and stable cable crane platform. In practice the RoboCrane® is an inverted Stewart Platform [8]

in which a set of six cables is employed instead of struts. The octahedral cable construction is astonishingly stiff and it has robustness for different disturbances [8, 9]. The crane platform has the form of the equilateral triangle F_1, F_2, F_3 – see Fig. 2. Each vertex of the triangle is suspended by the two cables which run to the anchors P_1, P_2, P_3. The gantry above the crane platform is just the "inverted base" of the Stewart platform. The anchors P_1, P_2, P_3 are placed in the vertices of the equilateral triangle located on the base. The set of six cables is important improvement in stability over a conventional crane. The platform uses gravity only to maintain tension in cables but it is absolutely enough.
Six variable-length cables allow to adjust space position and orientation of the platform with respect to the base. The presented platform manipulator has six degrees of freedom. The platform position and orientation are determined by three coordinates **x**, **y**, **z** in the 3D Cartesian space and by three rotation angles: yaw **Y**, pitch **P** and roll **R**.
When the set of the desired values for the six parameters is determined, the inverse kinematic equations f_1 can be written [10]. The function f_1 gives the lengths of the cables for the desired position and orientation of the platform respectively to the space positions of the anchor points. For the described crane platform, the calculations of f_1 function are simple and unambiguous.

In our calculations the platform parameters are expressed in the Cartesian coordinate frame X, Y, Z which has been defined relevantly to the cubic aluminum gantry with installing the anchors points on the construction – see Fig. 3. Thus the fixed positions of the anchor points P_1, P_2, P_3 are expressed by the vectors as follows: $P_1 = [x_{P1}, y_{P1}, z_{P1}]^T$, $P_2 = [x_{P2}, y_{P2}, z_{P2}]^T$ and $P_3 = [x_{P3}, y_{P3}, z_{P3}]^T$. The desired location of the middle of the platform G is given by the position and orientation vector $G = [x_G, y_G, z_G, A_G, B_G, C_G]^T$. To be exact the point G is the middle of the platform triangle F_1, F_2, F_3. For a given G the locations of the vertex points of the platform F_1, F_2, F_3. can be easily calculated and expressed as the vectors: $F_1 = [x_{F1}, y_{F1}, z_{F1}]^T$, $F_2 = [x_{F2}, y_{F2}, z_{F2}]^T$ and $F_3 = [x_{F3}, y_{F3}, z_{F3}]^T$ – see Fig. 2. Then the lengths of the six cables $c_1 \ldots c_6$ can be simply calculated as magnitudes of the differences of the vectors F_i and P_i:

$$
\begin{array}{lll}
c_1 = |F_1 - P1| & c_2 = |F_2 - P_1| & c_3 = |F_1 - P_3| \\
c_4 = |F_3 - P3| & c_5 = |F_2 - P_2| & c_3 = |F_3 - P_2|
\end{array}
$$

In our described crane platform (Fig. 3) the cables attached to the platform are pulled by six separate winches driven by electric motors that can extend or retract the cables. After the calculations the lengths of the suspending cables are adequately changed. Of course the platform system is controlled by means of a PC equipped with the standard USB-to-Serial Hub to link the computer system with external electronics [11] which allows for driving the winches.
In short, the electronics includes the autonomous PID controllers to drive the electric motors of the winches equipped with the proper incremental decoders which allows to control the lengths of the suspending cables.
In this way the platform can be moved in the required place and oriented as needed. In practice, the presented crane platform is the robotic manipulator with the six degrees of freedom.

Fig. 3. The photo of described cable-driven platform.

3 Video camera

The cable driven platform has the form of the circumscribed circle about the equilateral triangle. The platform is adapted for installation of different work equipment.

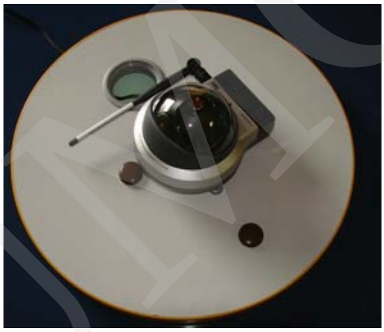

Fig. 4. The photo of the assembling board with the IP camera.

4 Software for computer control

The computer system of the presented crane manipulator is also equipped with the adequate software to control the camera platform. The control can be done fully autonomously or in the teleoperator mode. The presented work includes the second mode – the computer perform the operation ordered by the system operator.

In the teleoperator mode applicability of both the computer keyboard and joysticks (also the 3D joystick) has been tested. They have been employed as input devices to control the position and orientation of the platform. The special computer program named by us "VirtMan" is the basic software tool to control the manipulator platform. The computer application includes several edit fields for the values of different parameters – see Fig. 5. They are dedicated to express the vector G. For example, also the velocity of the movement of the manipulator platform is written there. During writing the parameters in the proper fields the virtual platform on the computer screen is displayed adequately to the entered values. When the set of the desired parameters is entered the system operator can put the platform in motion.

Fig. 5. The photo of the computer screen with the application dedicated to control the manipulator platform.

In the other screen window or on the second computer screen the camera image is displayed. The use of the second screen is not a problem since in practice, today each notebook is equipped with video output for an external computer monitor and a computer operating system is ready to use it.
The manual writing of the platform parameter values is rather less intuitive and effective. Therefore the joystick has been employed to increase the intuitiveness of the control operations. In the presented system the 3D joystick has been employed – see Fig. 5. The motions of the joystick cause the automatic entering number values to the proper edit fields. The values determined a new space position and orientation for the platform and the application automatically actualize the current location of the platform.
The described software has been prepared for the direct use in the web application without any undue efforts.

5 Network control of system

The goal of the work with the cable driven manipulator is to enable handling of the camera at a distance. We have worked out a several ways to perform the task.

The first and the simplest way is based on the MS Remote Desktop Protocol (**RDP**) [12, 13]. The designed and tested computer software applications use the dominant operating system MS WINDOWS (we use WINDOWS XP). In short, the RDP provides an access to another computer equipped with a proper WINDOWS server. WINDOWS XP uses RDP 5.1 for Remote Desktop Connection. The operating system also includes Remote Desktop Web Connection. In other words, using WINDOWS XP the operator can have remote display and input capabilities over network connection especially for the applications running on the WINDOWS XP server installed in another computer.

Then the network connection using RDP allows to use the client computer as the common terminal providing the graphical interface to the computer with the software for controlling the manipulator platform and capturing video of the camera. In practice, in this mode the system operator works exactly in the same way as with the computer physically controlling the manipulator platform.

The second version of Remote Video Monitoring is based on the server-side HTML embedded scripting language. The language is well known and widely used to produce dynamically changed web page documents. In short, the php code is embedded into the HTML document and the code is interpreted by a web server with a PHP module. Commonly the web server equipped with the module generates the proper web document according to the php code. In our case it is not needed.

The system operator can push a desired screen button displayed on the web page document. In practice, any web browser can be used to display the web page with the controls for the platform manipulator. When the operator push the screen button the programming code assigned to the selected key will be processed by the web-server interpreter application. In our case the interpreter writes to the disk file the command for the VirtMan. For example: “move to the left”, “move to the right” and so on. The results can be watched on the screen with the image from the camera.

6 Conclusions

In practice, the presented cable driven platform is the mini model of the crane system for the remote video monitoring systems. It allows to test different variants of the control for the systems. The performed tests confirmed that the presented simple and relatively low cost platform is very stiff and resistant to any oscillations. The manipulator system is controlled by PC equipped with unsophisticated software. It is absolutely enough for web applications. The client user can control the manipulator platform with the camera from any unrestricted distance by using any internet explorer implemented on computers or mobile phones.

7 Acknowledgment

The presented work has been financed by the Polish State research budget as a development project R01 009 03 in the years 2007 – 2010.

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