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ANALIZA MOŻLIWOŚCI ZASTOSOWANIA ROBOTÓW RÓWNOLEGŁYCH DO WIZUALNEGO MONITOROWANIA PROCESÓW PRODUKCYJNYCH

Streszczenie: Artykuł dotyczy możliwości wykorzystania robotów o równoległej strukturze kinematycznej, a zwłaszcza zastosowania robota linowego w zakresie kontroli wizualnej w inżynierii mechanicznej. Powód i potrzebę wizualnej kontroli procesu produkcyjnego opisano we wstępie. Omówiono także proponowany mechanizm o równoległej strukturze kinematycznej. W głównej części artykuł opisuje system robota linowego, jego zastosowanie w przemyśle i podaje dodatkowo przykład zastosowania w transmisjach sportowych. W ostatniej części zaproponowano proste koncepcyjne rozwiązanie wykorzystania robota linowego do wizualnej kontroli procesu produkcyjnego.

Słowa kluczowe: równoległa struktura kinematyczna, sterowanie wizyjne, robot równoległy

THE USAGE POSSIBILITY ANALYSIS OF PARALLEL ROBOTS FOR VISION-BASED MONITORING IN PRODUCTION FACILITY

Summary: The paper deals with the possibilities of use a robot with parallel kinematic structure, specifically the use of cable driven parallel robot in the field of vision based control in mechanical engineering. The reason and need of vision based control of the production process is described in the introduction, and a mechanism with a parallel kinematic structure is also described in introduction. The main part of the paper describes the cable driven parallel robot, its use in industry and also describes an example of use in sports broadcasts. The last part proposes a simple conceptual solution of using a cable drive robot for visual control of the production process.

Keywords: parallel kinematic structure, vision based control, cable driven parallel robot

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1. Introduction

Nowadays, the manufacturing process places high demands on the quality and speed of production, with these demands the manufacturing process is susceptible to various factors. The goal of manufacturing process control is to minimize the risk of these factors and eliminate the risk of production process shutdown. Nowadays, there are many ways to control and monitor the production process in order to avoid the occurrence of scraps or even to stop the production process. One possibility is to use vision based control during the production. When monitoring and controlling the production process, it is possible to monitor various parameters affecting the operation process of the production line by means of vision based control. For vision based control, it is possible to use static cameras located in the production line or a camera which moves in the space above the production line. For moving the camera in space a robot with a parallel kinematic structure should be use.

2. Parallel kinematic structure

A parallel kinematic structure is a mechanism with a closed kinematic chain, the structure consists a base, a platform, and at least two independent guide chains. The guide chains are also aligned parallel to the base and platform. This definition is very open as it includes, for example, redundant mechanisms (mechanisms with a greater number of actuators than the number of controlled degrees of freedom of the end effector). For this reason, criteria have been established which precisely define which characteristics a mechanism must have in order to be considered as a parallel kinematic structure in between of manufacturing machines, industrial robots and manipulators. The parallel kinematic structure in the field of manufacturing machines and industrial robots means a mechanism with the following characteristics [1]:

1. the parallel kinematic structure is composed of a base, a platform and guide chains;
2. the platform is supported by at least two guide strings, each of which comprises at least one simple actuator (an actuator that allows movement with one degree of freedom);
3. the number of actuators is equal to or greater than the number of degrees of freedom of the end effector;
4. if the actuators of the mechanism are locked against movement the mobility is zero. [1]

In terms of the number of independent guide kinematic chains in a parallel mechanism, it is possible to define:

- Fully parallel mechanism: a parallel mechanism with n degrees of freedom of an effector connected to the base by n-independent guide chains, each having one simple actuator.
- Hybrid parallel mechanism: a parallel mechanism with n-degrees of freedom of an effector connected to the base by m-separate guide chains, each having one or more actuators.

- Orientation parallel mechanism: is a parallel mechanism for which all points on the moving platform are described by paths and all these paths are placed on concentric spherical surfaces.

A parallel manipulator is a mechanical system that uses several computer-controlled serial chains to support a single platform, or end-effector. Perhaps, the best known parallel manipulator is formed from six linear actuators that support a movable base for devices such as flight simulators. This device is called a Stewart platform or the Gough-Stewart platform in recognition of the engineers who first designed and used them.[2]

3. Cable Drive Parallel Robot

Cable Drive Parallel Robot can be considered as a new mechanism, although its principle has been known since the 1990s when J. Albus and his team in the National Institution of Standard and Technology project called RoboCrane constructed the parallel rope crane shown in Fig. 1. It was controlled by six ropes and had a triangular construction. Another project was the construction of the parallel crane DARTS SYSTEM used for unloading goods from a ship to a train which was used by August Cargo. [3]

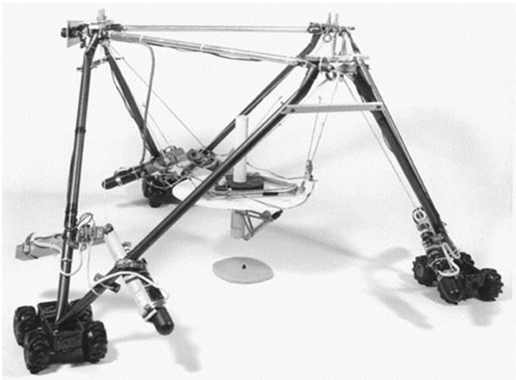

Figure 1. Model of NIST RoboCrane[4]

The main difference from standard parallel robots is the replacement of fixed guide chains (profiles, arms, etc.) by ropes of different materials and diameters. The actuators can't be part of the guide chain. Actuators are located either on the base or on the platform and they consist winding equipment, pulleys, ropes and components used for rope attachment or for more demanding applications more joints are placed on base or platform.

3.1. Use of a Cable Drive Parallel Robot

The biggest advantage of the cable driven parallel robot is extremely low weight and adaptability for working with huge space. Due to low weight, the platform is able to move at high speed and with an overload of up to 40g. [5]

The biggest disadvantage of the cable driven parallel robot are the ropes themselves, the ropes don't allow pressure on the platform. The robot is therefore not able to move in way the rope pushes the platform. For this reason, its necessary all the ropes must be under constant tension to secure the static of the platform in specific position in working space. The rope sagging is unacceptable and it would lead to inaccuracy of position and complications during winding.
The use of cable drive parallel robots is still very rare. However, there are many uses for them. Practically, it is possible to deploy a cable drive robot for any activity whose requirements will be appropriate to its capabilities (accuracy, speed, position availability, etc.). We will list the activities for which the rope robot has already been deployed and has successfully fulfilled its role: [3] [5]

- crane with a large working area (loading of goods on a ship, truck, ...);
- relocating objects;
- measure dimensions, distances and positions;
- flight and other simulators (octahedral arrangement of ropes);
- camera for sports broadcasts over stadiums;
- construction and painting of buildings, bridges, aircraft, ships, etc.

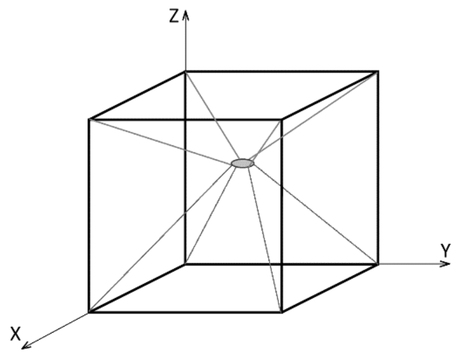

Figure 2. Working space of a Cable drive parallel robot with 8 haul ropes

3.2. Skycam & Spidercam

One of the examples of using a cable driven parallel robot is to use them to capture sports broadcasts over stadiums as the robot can work in a very large work area. Outstanding examples of under-constrained cable drive robot are the SkyCam [6] and SpiderCam systems used in many sporting arenas around the world. These systems provide computercontrolled, stabilized, cable-suspended camera transporters. The systems are manoeuvred through three dimensional space with a set of four computer controlled winches. Both static and dynamic active stabilizations of camera carriers that ensure proper camera orientation are included in the real time control system.[7] The idea of Skycam and Spidercam can also be applied to engineering production where we can place a cable drive robot over the production line and by visual control we can monitor the production process and parameters of production by using a various sensors and probes placed on the platform.

a) b)

Figure 3. Cameras placed on platform, a) Skycam system b) Spidercam system

4. Conceptual design of Cable Drive Robot used in Visual Control

When using a rope robot in engineering production, can be considered the working space is located above the production line. This place is bounded from below by the manufacturing machines used in production and from the top is bounded by the construction of the production hall, respectively by the periphery dimensions of the robot construction. Gantry crane is often used in production halls. For this reason, it is not possible to place the rope winding devices in the corners of the production hall. Because the ropes would hind in movement of the gantry crane. The proposed solution is shown in Figure 4.

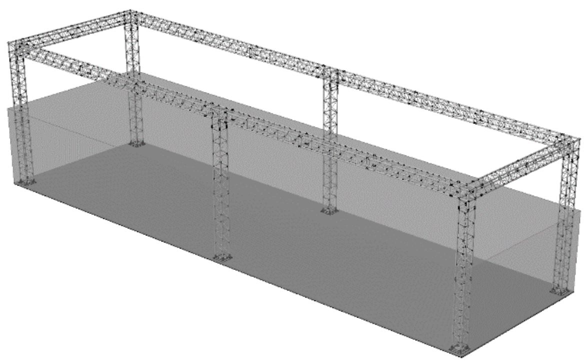

Figure 4. The robot working space and construction made of metal profiles

The design deals with use of a self-supporting structure made of metal profiles, the production line is located inside in the structure, the robot is able to make visual control of the entire production line.
For winding ropes will be used a drum with haul rope placed on the rotating platform. The rotating platform will be placed on the base plate by using axial bearings, four base plates are placed in each corner of the self-supporting construction, on the rotating platform it is necessary to place the rope winding drive, pulley and haul rope drum. The assembly is shown in Figure 5.

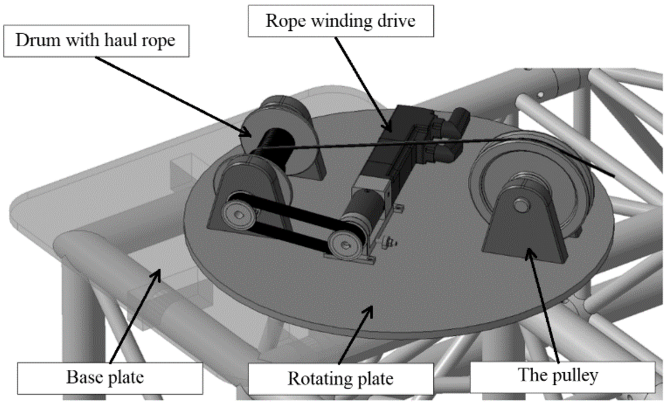

Figure 5. Rope winding assembly

On the effector of the cable robot is necessary to place the equipment with the required sensors, the installation and use of the sensors depends on the monitoring requirements which will be specifically monitored in the production process. Practically is possible to place any type of scanning devices and visual control components on the end platform - it can be simple camera with live video transmission to the operator, thermal imaging camera, various types of temperature sensors, air quality sensors above individual machines of the production line, etc. This is the reason is necessary to provide data and power supply to the equipment used. This supply can be secured using the automatic winding device shown in figure 6.

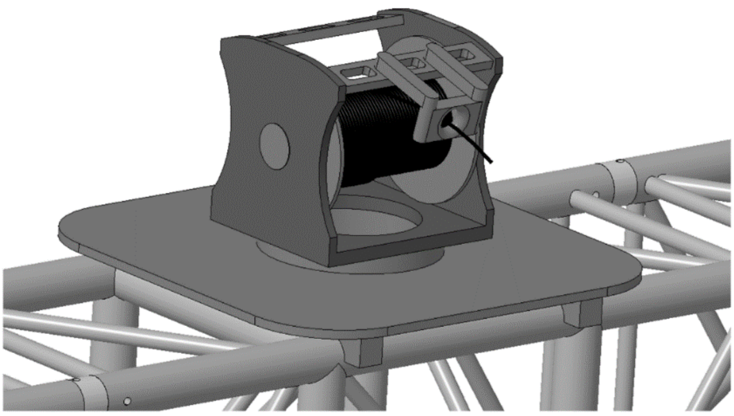

Figure 6. Design of an automatic wiring machine

On the figure 7 is shown all the assembly of the conceptual design of cable robot used in visual based control in manufacturing process.

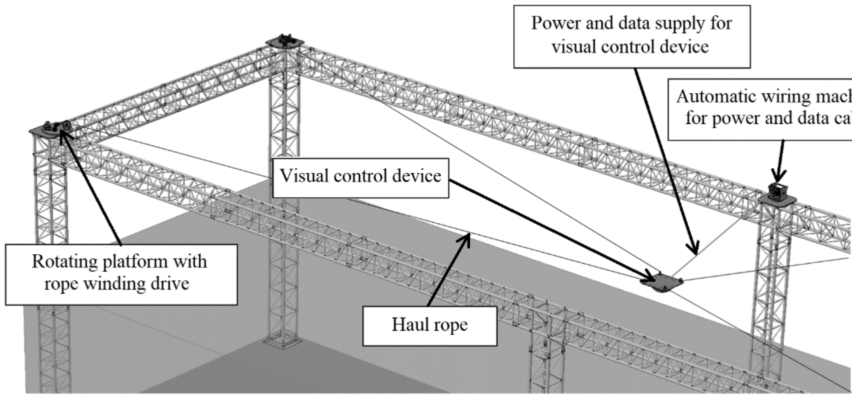

Figure 7. Assembly of the conceptual design

5. Conclusion

With increasing demands on the quality of production, the requirement to control the production process is increasing, this is the requirement why the production process must be monitored. In this paper we made a theoretical review of parallel robots usage for vision-based monitoring in production process. We analyzed a robot with a parallel kinematic structure and we selected a suitable type of parallel robot for the application in production process monitoring. As the most suitable type of robot we chose a cable drive parallel robot which we have described in the next part, we also have specified the possibilities of its use in sports and also in industrial applications. In the last part of the paper we created a simplified construction of cable drive parallel robot used for vision-based monitoring of the parameters in the production process in the production line. The design itself consists of individual parts that can be used in the future when the robot will be build.

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