The use of Kinect sensor to control manipulator with electro-hydraulic servodrives

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Abstract: The article describes the control of the 2-axis electro-hydraulic manipulator by the human-hand motion. To recognition of skeleton points the Kinect sensor was used. In this application the information about coordinates of shoulder, elbow and hand was used to compute of inverse kinematic in manipulator. In investigation the accuracy of control by human's hand motion was tested. The aim of study was to find a new of control method without commonly used joysticks to create human-machine interface.

Keywords: Kinect, electro-hydraulic manipulator, human-hand control, human posture recognition

Nowadays, many devices like robots, lifts, cranes and manipulators are designed to allow the easier control for human operator. There are performed wide range of research to develop ways of the human – machine communication. The typical control system is based on the different kind of joysticks e.g. haptic joystick. In these structure there were also applies vision systems to analyze human's motion. Obtained data can be used to control mobile robots or manipulators. These movement are also natural for human. Described systems can be potentially used to help in everyday life old people or for sick and disabled persons by e.g. provide medicaments closed them.

1. State-of-the-art

The recognition system based on Kinect sensor for the measure human body position in physical coordinates was described in [1]. This method of recognition can be propose to control robots or manipulators. The kinect sensor is very sensitive for sunlight [2]. This is serious problem when this system is used outdoor. Intense sunlight blinds infrared on the Kinect sensor through to interference of excessive infrared rays. Dynamic hand motion recognition was described by Youven [3]. They used the palm node which is defined by kinect software. They proposed method of HMM (Hidden Marcov Model), extracting valid points and use angle as a distinguishing feature. This method can rapidly and accurately identify definition gestures or reject the undefined gestures. Using the Kinect unit to mimic the motions of a human operator was described by Jason [4]. The low cost chassis was made from the plastic model of skeleton. The joints was made from electric servo drives. The control of a small humanoid robot using Kinect sensor was described by Weibo [5]. They used Kinect sensor to recognition human motion and control the movement of the electric humanoid robot. The Human-Computer interaction was described by Vladimi [6]. They proposed the computer vision-based analysis for interpretation of hand gestures to interaction human with computer. Fukuda [7] proposed a new master–slave manipulator control system without mechanical master controller. A person whose forearm has been amputated can use this manipulator as a personal assistant for the desktop work. A human-assisting manipulator was teleoperated by electromyographic (EMG) signals and arm motions. The use of kinect system for better quality of controlled process for the patient's rehabilitation was described by Fernandez-Baena [8]. The investigation was based on comparison markerless system with the Kinect sensor and expensive vision system. This work proved that the disparity is not big between Kinect unit and expensive vision system. Therefore this system can be used to supervision motion of human.

Nowadays communication between human-machine is very important. Many investigation are directed to improve control of machines by human's gestures. In this case programming of trajectory in machine may be easier rather than with use of some programming languages.

2. Kinect sensor

In this paper, a control of manipulator by human hand movement using 3D human posture recognized by Kinect sensor is presented. The Kinect is a low cost solution for tracking human motion. The Kinect was made by Microsoft to using in Xbox 360 console in November 2010. On 16 June 2011, Microsoft officially released SDK for Kinect support for Windows.

Fig. 1. Sensor Kinect
Rys. 1. Czujnik Kinect

Kinect was the best sold device in the world and has been entered into the Guinness Book of Records as the "fastest-selling consumer electronics device". 18 million units of the Kinect sensor had been shipped by January 2012. 8 million Kinect units were sold during its first 60 days on the market [9].

Kinect consist of:

– color camera RGB (Red, Green, Blue),
– IR Emitter,
– four directional microphone array,
– tilt motor.

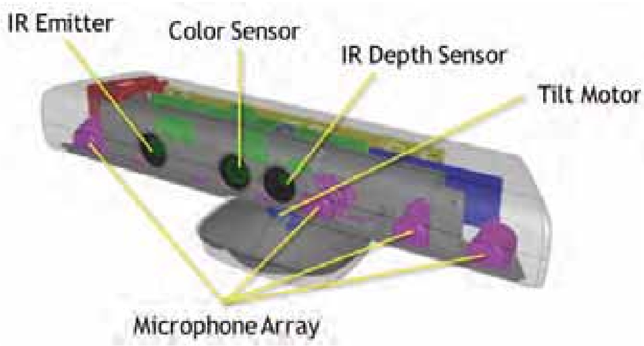

Fig. 2. The construction of Kinect
Rys. 2. Konstrukcja konsoli Kinect

The first of cameras is a standard RGB video camera with resolution 640×480. This camera captures the frame and is used to e.g. face recognition. The second camera is a depht sensor. It has got resolution of 300×200 points. This sensor can measure distanse from range of about 0,4 m to 6,5 m. System provide human posture recognition in this range using this field of depth points. Kinect should be used in indoor application, because sensor is sensitive on sun light. An array of microphone is used to speech recognition. Four microphones are used to filtering signal, which provides cut off background noise.

A software of Kinect use information from camera and depth sensor to provide all coordination points of human skeleton which are shown in fig. 3.

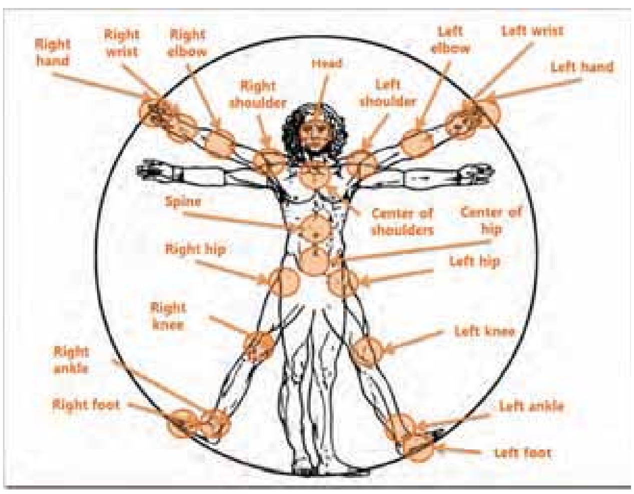

Fig. 3. The recognition points of the human skeleton
Rys. 3. Rozpoznawane punkty ludzkiego szkieletu

Software also provide two option of recognition: first is whole posture of human, while standing and the second one is a sitting posture of human. In second option, Kinect does not require to see a lower part of human body, which are e.g. legs.

3. The structure of the control system

The structure of testbed was shown on scheme block diagram in fig. 6. The system consist of electro hydraulic manipulator (figs. 4, 5, 7), PLC (Programmable Logic Controller), PC computer and vision system like Kinect. PLC was used to controlled the 2-axis manipulator, the working area of it is shown in fig. 4. In manipulator, incremental encoders were used to measure tilt angles. This encoders were placed in joints of manipulator. The resolution of measurement system was 14 400 point per one rotation with quadrature signal.

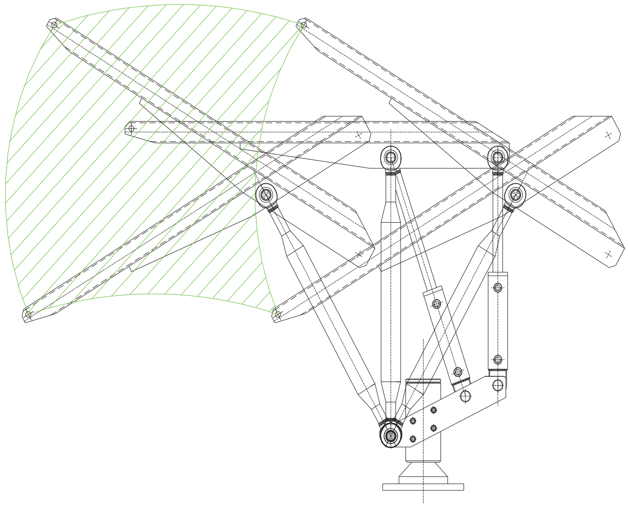

Fig. 4. The working area of the manipulator
Rys. 4. Obszar roboczy manipulatora

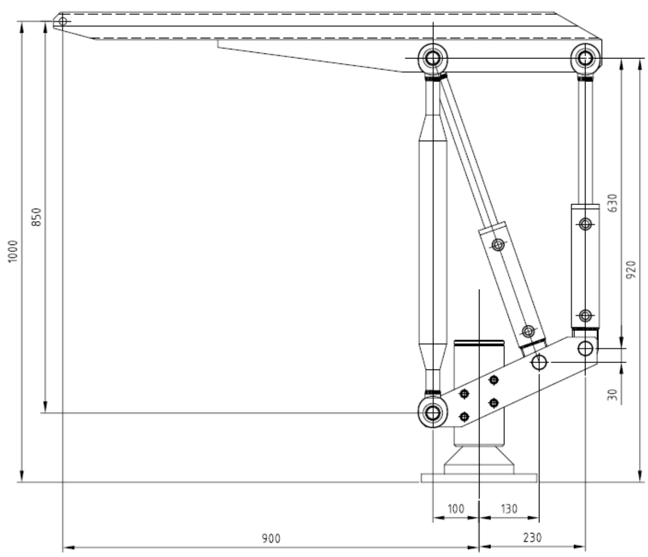

Fig. 5. The dimensions of the manipulator
Rys. 5. Wymiary manipulatora

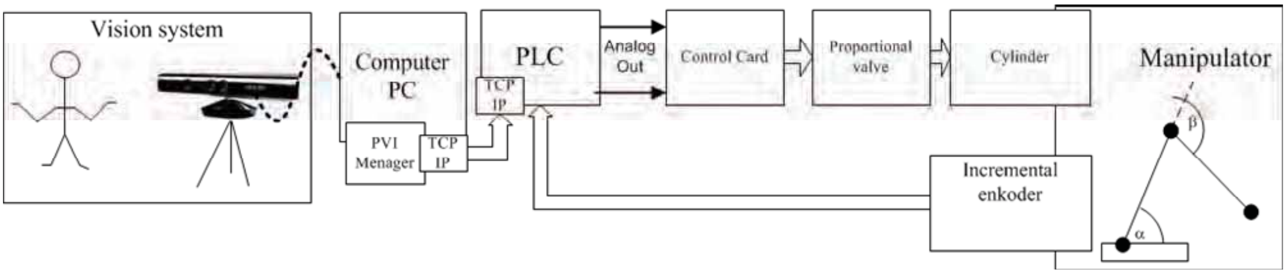

Fig. 6. Schem diagram of the testbed
Rys. 6. Schemat blokowy stanowiska badawczego

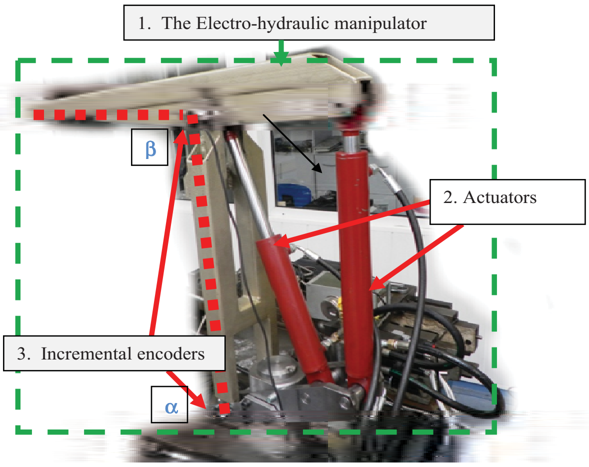

Fig. 7. The electro hydraulic manipulator
Rys. 7. Manipulatora elektrohydrauliczny

In hydraulic system the ratio of force to dimension is the biggest in the world. The used hydraulic pistons can attain force of about 10 kN on the end point of the manipulator.

Kinect was connected to the computer by USB, the special software was installed to capture skeleton points. We used this points to compute inverse kinematic of the manipulator and send it to PLC B&R connected via TCP/IP (Transmission Control Protocol/Internet Protocol) with PVI Manager (Process Visualization Interface). The PID controller was implemented in PLC and generate voltage signal in special DAC card (Digital Analog Converter). This control signal changed the velocity of movement of hydraulic drives by proportional control card.

4. Calculation of coordinates

The geometry of the whole system was shown in fig. 8. In order to simplify calculation, the original coordinate system of Kinect was scaled to the coordinate system in OPEN CV. The most important parameters are:

- l_1, l_2 – the lengths of the robot arms,
- x_1, y_1 – position of human hand (robot end point),
- x_2, y_2 – position of human elbow,
- x_3, y_3 – human shoulder (basis of the robot),
- β – angle between robot arms,
- α α – angle between the lowest robot arm and the X axe,
- (0,0) – camera base point (origin).

The length of elbow is different rather than length of and shoulder of human coordinate to compute the scale between points of screen in meters. The length between shoulder and hand of the operator has been used to calculate inverse kinematic. The motion of human hand was mapped by manipulator.

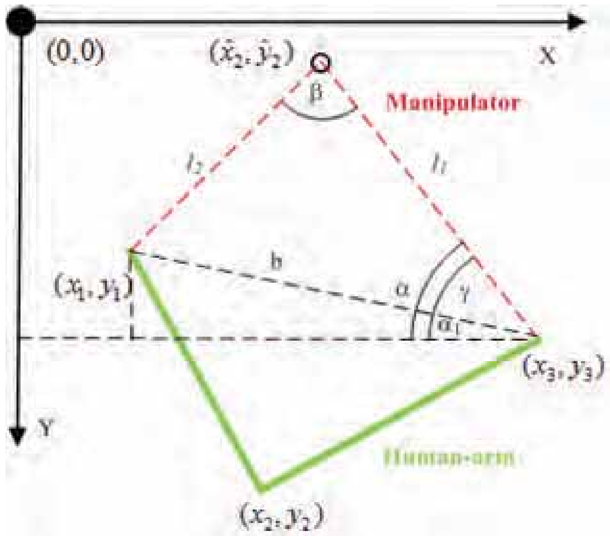

Fig. 8. The geometry of the manipulator and operator's hand
Rys. 8. Geometria manipulatora i ręki operatora

The cosine theorem has been used in order to calculate inverse kinematic. The steps are presented below:

- Distance between hand and shoulder

$$b=\sqrt{(x_1-x_3)^2+(y_1-y_3)^2} \qquad (1)$$

- Angle γ between line b and base point (shoulder)

$$\gamma=\arccos\left(\frac{l_1^2+b^2-l_2^2}{2l_1 b}\right) \qquad (2)$$

- Angle α_1 between line b and first arm of the manipulator l_1

$$\alpha_1=\operatorname{atan2}\left(y_3-y_1,x_3-x_1\right) \qquad (3)$$

- *Angle* β from cosine theorem

$$\beta=\arccos\left(\frac{b^2+l_2^2-l_1^2}{2l_1 l_2}\right) \qquad (4)$$

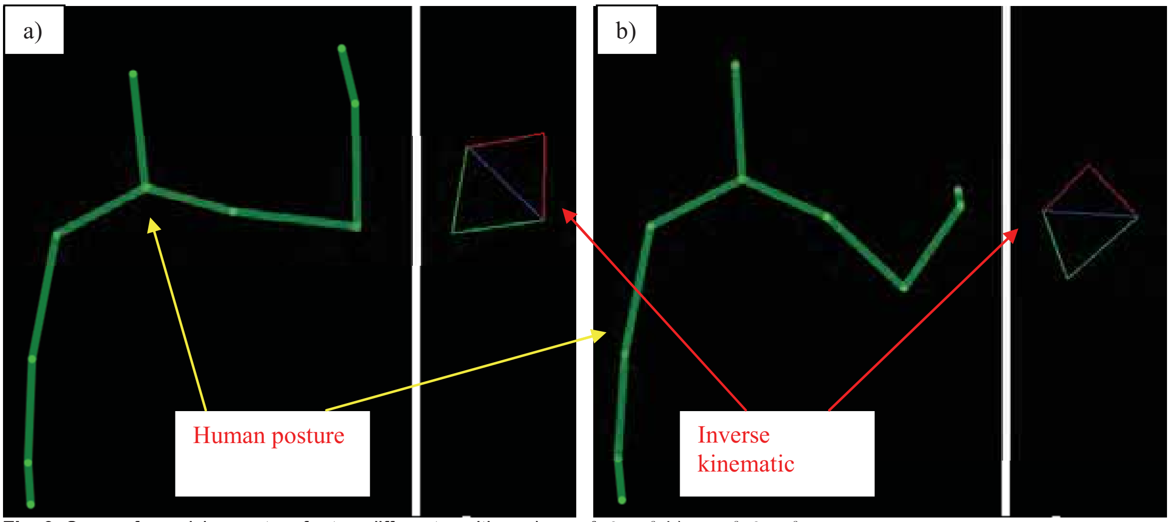

Fig. 9. Screen from vision system for two different position. a) $\alpha=96^o$, $\beta=67^o$, b) $\alpha=53^o$, $\beta=75^o$
Rys. 9. Obraz z systemu wizyjnego dla dwóch różnych pozycji. a) $\alpha=96^o$, $\beta=67^o$, b) $\alpha=53^o$, $\beta=75^o$

5. Experimental Tests

The aim of investigation was the control of electro-hydraulic manipulator by the human hand motion. Many tests of control system were performed. The screen from vision system and simulation system were shown in fig. 9 with two different positions of human-hand. Visualization of manipulator's arm was necessary, because operator had to seen the range of working area of the manipulator. If this range is not possible to achieve, the inverse kinematic cannot be computed. Operator was placed before the manipulator and his right hand was in the same direction as the end point of manipulator (fig. 10).

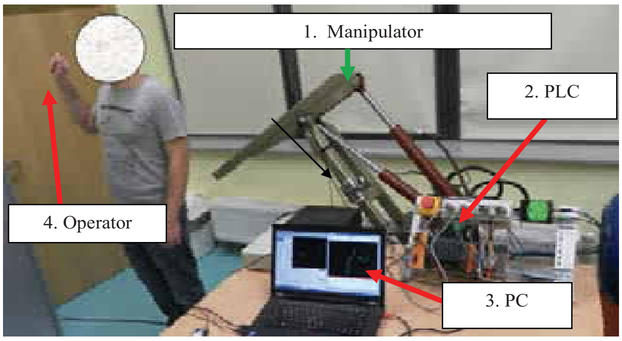

Fig. 10. The geometry of manipulator and operator hand

Rys. 10. Geometria manipulatora I ręki operatora

In experimental test the operator was doing slow and fast motion of his hand. The first test provide important information about correctness of recognition of the human posture by Kinect. The results are bad and have been shown in fig. 11. Some time, Kinect lose the information about skeleton and returns invalid position of captured points. To avoid incorrect points the special filter was programmed in range of –90...90 degrees of angle.

The speed of the manipulator's movements was limited by flow of hydraulic fluid for valve and time delay is visible between signal from human-hand and the manipulator (fig. 12). In figures 12 and 13, fast movement of the operator's hand and smooth trajectory of the manipulator were shown. On the end points of the movement path an error can be seen. It occurred, because the authors used PID controller with settings: K = 30, Kd = 1, Ki = 0.1. With bigger gains the manipulator achieves errors equal to zero, but the control by hand motion was not natural and the whole manipulator vibrated. This is caused by not sufficient precision of the depth sensor in the Kinect. When an operator is opposite to the Kinect, without any movement and recognition software is used, the positions points of skeleton were changed with time.

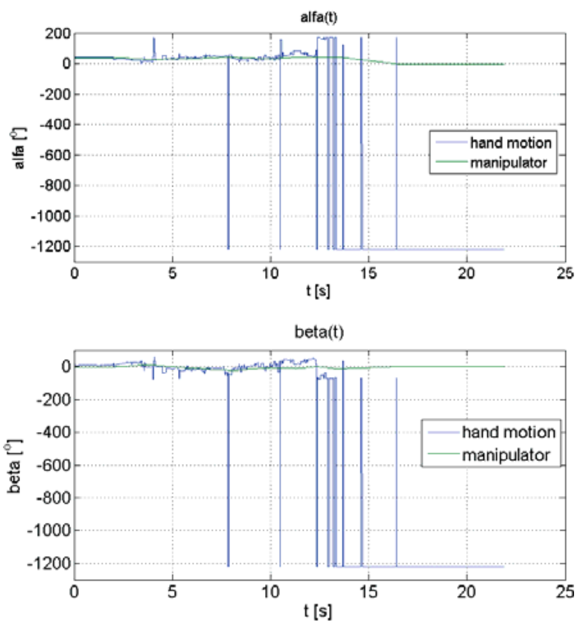

Fig. 11. A movement with noise

Rys. 11. Ruch z zakłóceniami

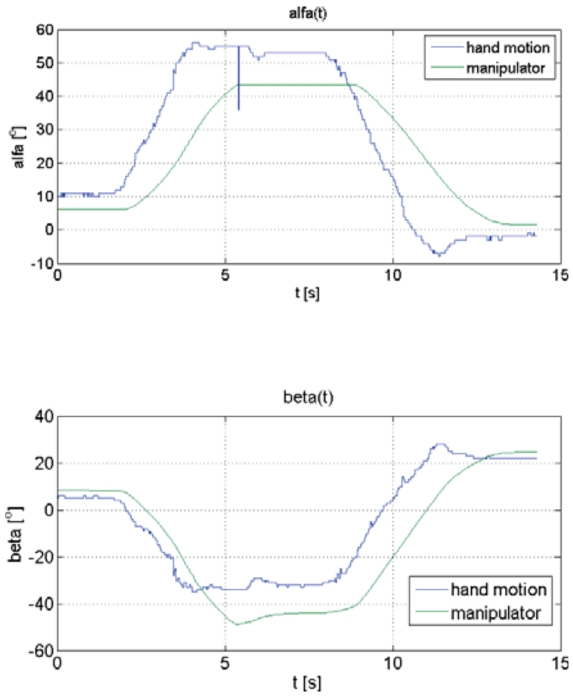

Fig. 12. A slowly motion of control

Rys. 12. Wolny ruch sterowania

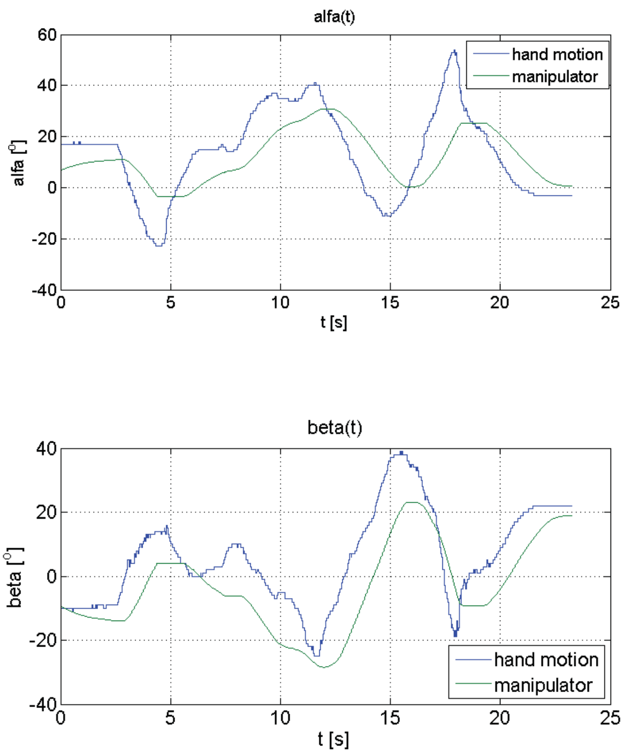

Fig. 13. An average speed of the motion control

Rys. 13. Średnia prędkość sterowania

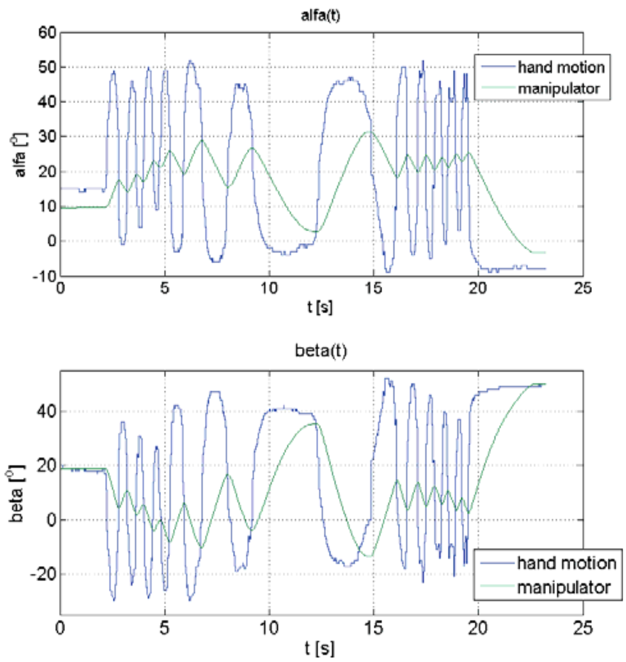

Fig. 14. A fast motion of control

Rys. 14. Szybki ruch sterowania

6. Conclusion

The human-hand movement was used to control of the electro-hydraulic manipulator with servodrives. The human posture recognition was implement by Kinect sensor. The necessary points like shoulder, elbow and hand was used to scaled and compute inverse kinematic for manipulator. The investigation prove the Kinect can be used to control any kinds of manipulators, but in case when the precision control is not important. In case the movement of human-hand was stoned, the recognized skeleton points were changed in time, this is biggest disadvantage of this sensor. However the price of this device is advantage. This method of control can be used to control of manipulator, which can be help sick people with any activities of everyday life e.g. give medicaments or rehabilitation activities. In another case this system can be used to program a trajectory of robots in easier way, rather than joystick.

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Zastosowanie sensora Kinect do sterowania manipulatora z napędami elektrohydraulicznym

Streszczenie: Artykuł opisuje sterowanie 2-osiowym manipulatorem z napędami elektro-hydraulicznymi za pomocą ruchów ręki człowieka. Do rozpoznawania punktów szkieletowych człowieka wykorzystany Kinect-a. W tej aplikacji informacje o współrzędnych barku, łokcia i ręki wykorzystywane były do wyliczenia kinematyki odwrotnej manipulatora. W badaniach testowano precyzję sterowania przez ruch ręki człowieka. Celem pracy było znalezienie nowej metody sterowania urządzeniami bez użycia powszechnie stosowanych joysticków, aby utworzyć interfejs komunikacji pomiędzy człowiekiem a maszyną.

Słowa kluczowe: Kinect, manipulator z napędami elektro hydrauliczymi, sterowanie ruchem ręki, rozpoznawanie postury człowieka

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