Proceeding of the IEEE
International Conference on Robotics and Biomimetics
Dali, China, December 2019

Improved Teleoperation of an Industrial Robot Arm System Using Leap Motion and MYO Armband

Yuheng Fan and Chenguang Yang
College of Automation Science and Engineering
South China University of Technology
Guangzhou, Guangdong Province, China

Xinyu Wu
Shenzhen Institutes of Advanced Technology
Chinese Academy of Sciences
Shenzhen, Guangdong Province, China

***Abstract*— Teleoperated robot systems can support humans to accomplish their works in lots of applications. However, the performance of teleoperation is easily influenced by human operator's motor function. In order to reduce the misoperation caused by human operator's unintentional behavior, in this paper, an improved teleoperation scheme combined with Leap Motion and MYO armband is proposed to apply in teleoperating an industrial robot arm. By using the proposed method, we can achieve interaction between human operator and industrial robot arm in real-time. Besides, the proposed method can prevent the misoperation caused by unexpected arm shaking. Experimental results demonstrated the effectiveness of the proposed method for a teleoperated robot system.**

***Index Terms*— teleoperated robot system, Leap Motion, MYO armband, sensor funsion**

I. Introduction

With the rapid development of artificial intelligence and automatic control, robotic systems have made significantly development to meet the scientific and industrial demands. Especially in the last ten years, the emerging advanced automatic technologies accelerate the wheels of robotics systems. Nowadays, telerobots are widely used in some complex and dangerous areas, such as space exploration, deep-sea exploration, and nuclear research program. Therefore, telerobots gradually become one of the most important branches in robotics research. Lots of works have been done to realize a superior teleoperation performance between human and robots. For example, K. Ogawara $et\ al.$ have made some research to figure out the visual occlusion problem in robot remote teaching tasks [1]. P. Berthet-Rayne $et\ al.$ have concentrated on the redundant snakelike robot teleoperation in invasive surgery [2]. G. Feng $et\ al.$ have made some research on teleoperation experiments and proposed corresponding system evaluation method [3]. J. Luo $et\ al.$ proposed a task learning framework to represent the manipulation skill demonstrated by a remotely controlled robot [4], which provides guidance in teleoperation.

This work was partially supported by National Nature Science Foundation (NSFC) under Grants 61861136009 and 61811530281. Corresponding author is C. Yang. Email: cyang@ieee.org

At the same time, sensors technologies in robotics and artificial intelligence areas also made note-worthy progress. For example, Touch X, a haptic device with six degrees of freedom (6-DOF), is used to realize hybrid control and apply force feedback to enhance the teleoperation performance in [5]. Kinect, developed by Microsoft, is widely used in the work of capturing human movements. G. Du $et\ al.$ developed a system which enables the operator's arms to control the robot arm using Kinect sensors [6]. Compared with Kinect, Leap Motion [7], produced by Leap company, has preferable accuracy to track hand movement. Nho Y-H $et\ al.$ have made an imaginative research on the interaction using intuitive hand gestures between human and a mobile robot [8]. MYO armband [9], designed by Thalmic Labs, is used to measure surface electromyographic (sEMG) of human arm. Yang $et\ al.$ conducted a detailed study on personalized variable gain control based on arm's sEMG for robot teleoperation [10]. They integrated Touch X and MYO armband to achieve variable gain control, which largely improves the robustness of teleoperation. In [11], Y. Xu $et\ al$ proposed a teleoperation method based on virtual reality (VR). In their work, they used Leap Motion to control an industrial robot and obtained real-time visual feedback in Oculus [12] through cameras. Compared with traditional master devices like joystick or keyboard, Leap Motion gives more flexibility to operator's hand because it no longer needs operator to put their mind on manipulating the master device. Applied in VR environment, Leap Motion makes teleoperation more imaginative and immersive.

However, simply relying on human's forearm to control the robot arm is easily disturbed by some unpredictable and uncontrollable factors, such as unexpected arm shaking caused by physiological tremor [13], which accordingly leads to unexpected movement of slave device. This problem brings some bad effects on the security and accuracy of teleoperation. Therefore, to remove undesirable factors, we apply MYO armband to monitor human sEMG [14]. MYO armband has 8 electromyography (EMG) sensors, which can detect the electric potential generated by forearm's muscles. The electric potential can be rendered as raw sEMG signal with high-frequency noise. To accurately capture the waveshape

978-1-7281-6321-5/19//$31.00 ©2019 IEEE

as unexpected arm shaking occurs, we introduce a novel signal preprocessing algorithm to preprocess the raw sEMG signal so that we can detect the change tendency of human operator's sEMG. Therefore, when unexpected arm shaking accidentally occurs in human operator 's forearm, we can detect the abnormal sEMG signal from MYO armband. As the two processes are proceeding synchronously, the end effector of robot arm can stop moving for the moment when unexpected arm shaking occurs. From the above principle, we can prevent the misoperation caused by unintentionally unhoped hand's movement, which effectively improves the safety and robustness of teleoperation.

Based on the previous work [9], we build up an improved teleoperation system combined with Leap Motion and MYO armband in this paper. The main contributions of this paper are listed below.

(1) A novel sEMG signal pre-processing method is applied in recognition of unexpected arm shaking.

(2) An improved teleoperation system combined with Leap Motion and MYO armband is built up to reduce misoperation in the process of teleoperation.

The rest of the paper is structured as follows: In Section II, the experimental setup of this system is introduced including Leap Motion, MYO armband, industrial robot arm, and the software environment. Section III describes the sEMG signal preprocessed algorithm and introduces the teleoperation system. Section IV demonstrates the experimental result. Finally, the conclusion is presented in Section V.

II. System setup

In this paper, the teleoperation system consists of Leap Motion, MYO armband, a personal computer (PC) and an industrial robot arm. Among them, Leap Motion is used to recognize human operator's hand gesture and to get palm's position and then transmit this data to the industrial robot arm in real-time. The industrial robot arm gets the position data and then tracks operator's hand movement. The PC serves as the communication intermediary between the two components above. Synchronously, MYO armband is used to monitor operator's sEMG signal throughout the whole process.

A. Leap Motion

Leap Motion is an advanced sensor used to capture the operator's palm position and to recognize hand posture. Released by Magic Leap Company, Leap Motion consists of two infrared cameras and three built-in LED lights. Leap Motion's developed software can detect an object with a range of 25mm to 600mm above the device and with a cover area of 150 degrees [15]. The detected space is roughly an inverted pyramid. Leap Motion can generate motion information based on the data detected in each frame and the previous frame.

B. MYO armband

The MYO armband is an electromyographic detection device launched by Canadian company Thalmic Labs in early 2013. The sensors on the armband can detect the biometric changes in the user's arm muscles as they move, determine the wearer's intentions [16], and send the results of computer processing to a controlled device via Bluetooth. Through 8 EMG sensors, we can obtain the electrical impulse signal generated by the operator's forearm muscles. Fig. 1 shows the appearance of Leap Motion and MYO armband.

(a) Leap Motion. (b) MYO armband.

Fig. 1. Leap Motion and MYO armband.

C. Industrial robot arm

Produced by Yijia Technology Co. Ltd, the robot arm has six-degree of freedom. We can control the robot arm through an upper-computer software designed by its own company. The appearance of the robot arm is shown in Fig. 2.

Fig. 2. Industrial robot arm.

D. Software environment

In this system, several different programming languages and integrated development environments (IDE) are used to achieve data fusion between different sensors mentioned above. Leap Motion is programming by Java in Eclipse. sEMG signal from MYO armband is obtained and processing in Matlab. The upper-computer software of robot arm is programming by C# in Visual Studio 2013. We adopt User Datagram Protocol (UDP) to achieve real-time communication between different softwares.

III. Experiment method

This teleoperation system is divided into two separate parts. The first part concentrates on the preprocessing of raw sEMG signal, which aims to convert the high-frequency and high-noise raw sEMG signal into smooth and stable processed sEMG signal. The other part describes the method we use to build up teleoperation between a human operator and an industrial robot arm. In this system, we enable the robot arm's end-effector to track human operator's hand movement in real-time.

A. Raw sEMG signal preprocession

The raw sEMG signal represents the action potential of muscular activities, which differs significantly when muscle tightens or relaxes. Since MYO armband has eight EMG sensors, we can get different sEMG signals from eight different channels. Fig. 3(a) shows the raw sEMG signal of eight channels. As shown in Fig. 3(a), the amplitude of raw sEMG signal obviously changes around the third second, which means unexpected arm shaking possibly occurs in operator's forearm at this moment.

In the first step of preprocessing, we use the Root Mean Square (RMS) algorithm [17] to integrate raw sEMG signal in different channels. The sEMG signal can be expressed as:

$$e(t) = \sqrt{\frac{\sum_{i=1}^{M} e_{raw}^{(i)}(t)}{M}}, \quad i = 1, 2, 3, ...\ M \tag{1}$$

where $e_{raw}^{(i)}(t)$ represents the raw sEMG signal of ith channel, M and t represent the total channels and current sampling instant of MYO armband, respectively. For MYO armband, M is equal to eight. As shown in Fig. 3(b), through RMS algorithm, the sEMG signal is integrated into a common channel.

To mitigate the negative effects caused by high-frequency noise, we apply a low pass filter to smoothing the sEMG signal. As shown in Fig. 3(c), the sEMG signal after low pass filter becomes more smooth. In actual operation, the operator's forearm sEMG signal is always changing even without unexpected arm shaking. This type of signal fluctuation is normal but sometimes it is easily misrecognizing this normal signal as the abnormal signal caused by unexpected arm shaking. To obtain more ideal recognition effect for sEMG signal when unexpected arm shaking occurs, we introduce the Exponentially Weighted Moving Average (EWMA) algorithm [18] for further optimization.

As one of the moving average algorithms, EWMA algorithm aims to filter out high-frequency disturbances in time series and retain useful low-frequency trends. Unlike ordinary low pass filters, EWMA is an infinite series that even data from a long time ago can play a role in calculating the current exponential moving average. Compare to the Weighted Moving Average (WMA), EWMA is more sensitive to recent changes because it gives higher weights to recent data. The sEMG signal after EWMA can be expressed as:

$$E(t) = \begin{cases} e(t), & t = 1 \\ \beta E(t-1) + (1-\beta)e(t), & t > 1 \end{cases} \tag{2}$$

where β is a constant that represents the weight of past measurements. The larger β, the faster the past observed value decays. As shown in Fig. 3(d), the sEMG signal after EWMA becomes more distinguishable between abnormal signal caused by unexpected arm shaking (begin at 3s in Fig. 3(d)) and other normal signal fluctuation.

On this basis, we set a threshold to differentiate the sEMG signal fluctuation caused by unexpected arm shaking from the sEMG signal fluctuation caused by arm normal movement, which means that unexpected arm shaking definitely occurs only when sEMG signal is higher than the threshold. After repeated trials, we find that the sEMG signal is always higher than 30 when the operator experiences the misoperation we define, hence we set 30 as sEMG signal threshold in this experiment. Fig. 3(c) and Fig. 3(d) shows the threshold we set.

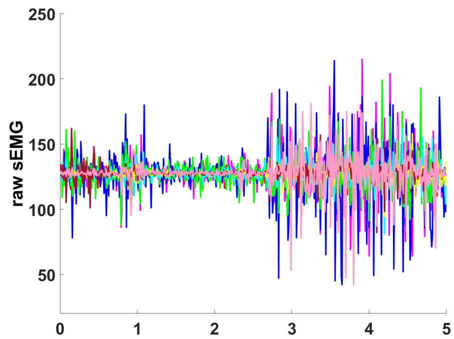
B. Teleoperation system

In this part, we are going to establish a teleoperation system to achieve that a human operator can control an industrial robot arm's effector movement. Leap Motion is used to record the position of the palm in real-time, and then the position data are translated from Leap Motion's coordinate to robot arm's coordinate. As shown in Fig. 4, Leap Motion's coordinate and robot arm's coordinate are different in direction. In order to make coordinate transformation more matchable in this experiment, the transformation formula can be expressed as:

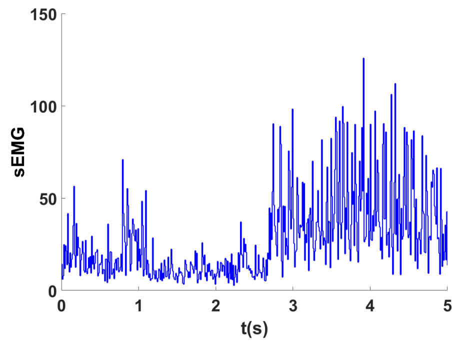
$$\begin{cases} X_r = -Z_l/c + X_{ro} \\ Y_r = X_l/c + Y_{ro} \\ Z_r = Y_l/c + Z_{ro} \end{cases} \tag{3}$$

where X_l, Y_l, Z_l represent the Leap Motion's coordinate index and X_r, Y_r, Z_r represent the robot arm's coordinate index, respectively, c is a constant represents the zoom scale between the two coordinates. X_{ro}, Y_{ro}, Z_{ro} represent the coordinate's origin of robot arm. In this experiment,we set the coordinate's origin (X_{ro}, Y_{ro}, Z_{ro}) as (0, 300, 430).

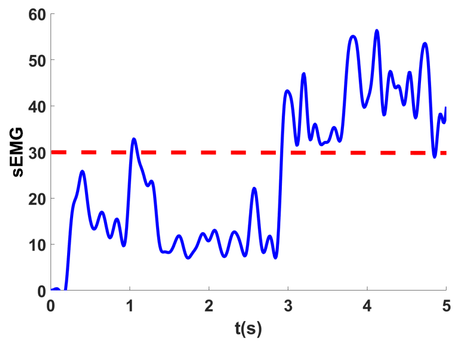
Programming by Java, we obtain palm's position and then transmit this data to the upper computer software of robot arm through UDP communication protocol. Through Leap Motion's hand gesture recognition function, the connection between operator and the manipulator will establish when the operator clenches his/her fist and disconnect when operator



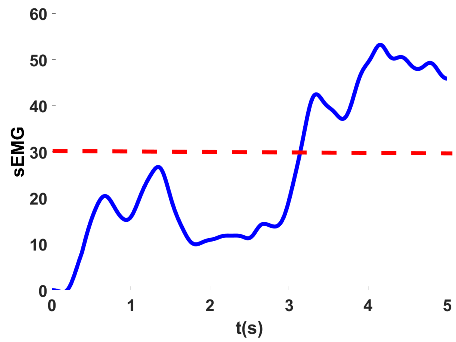
(a) Raw sEMG signal.



(b) The integrated sEMG signal.

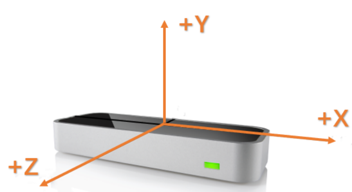


(c) sEMG signal after low pass filter.

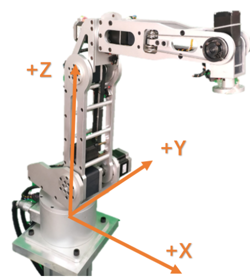


(d) sEMG signal after EWMA.

Fig. 3. Raw sEMG signal preprocession.



(a) Leap Motion's coordinate.



(b) Robot arm's coordinate.

Fig. 4. Two coordinates in this experiment.

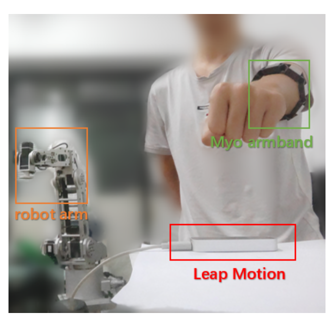
(a) Establish connection.

(b) Break connection.

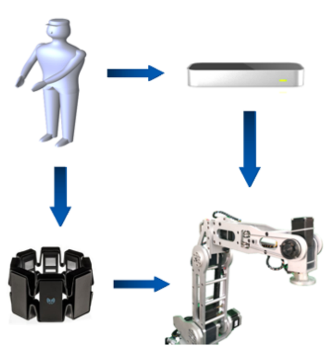
Fig. 5. Leap Motion hand regconition function.

loosens his/her hand (as shown in Fig. 5), thus making the teleoperation system more controllable.

At the same time as the above process, MYO armband keeps working to monitor sEMG signal in operator's arm. Raw sEMG signal is obtained through the driver software developed by its own company and preprocessed in Matlab. We also adopt UDP to achieve real-time connection between Matlab and the upper computer software of the robot arm. The whole teleoperation experiment system is shown in Fig. 6.



(a) Real system picture.



(b) Conceptual system picture.

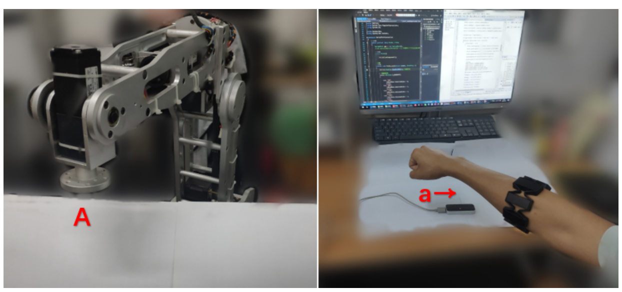
Fig. 6. Total teleoperation system.

IV. Experiment

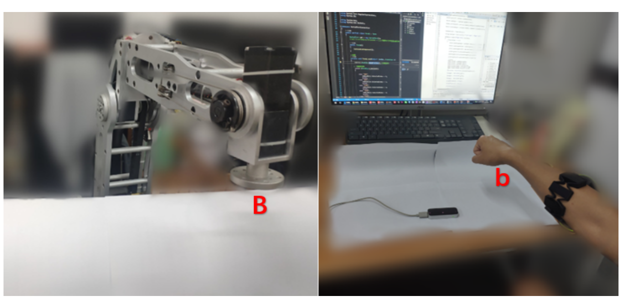
In this section, we set two separated experiments to demonstrate the feasibility of the method mentioned above. The first experiment, which does not involve MYO armband, is designed to test the basic position tracking function in this teleoperation system. The second experiment verifies the teleoperation performance combined with MYO armband.

A. Position tracking teleoperation

In this experiment, the human operator clenches fist and moves hand smoothly from one position to another position. For the convenience of data recording, the operator moves his hand along X-axis direction in Leap Motion coordinate (correspondingly Y-axis direction in robot arm's coordinate). This process is shown in Fig. 7. When human operator moves his hand from position a to position b, the robot arm follows this movement and moves his hand from position A to position B. Fig. 8 shows the position trajectory of both operator's hand and end effector of robot arm, which demonstrates that robot arm can continuously track operator's hand movement in real-time.

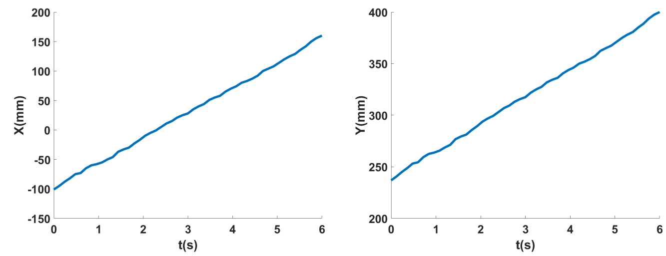


(a) First position.



(b) Second position.

Fig. 7. First experiment

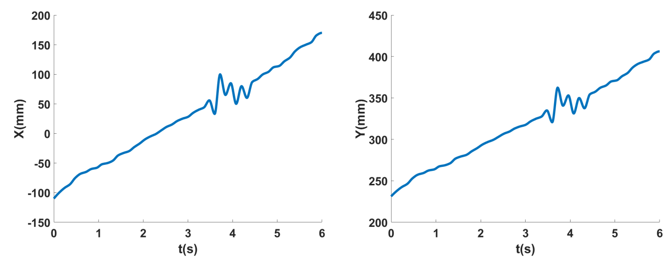


(a) Hand. (b) End effector of robot arm.

Fig. 8. Position trajectory in position tracking teleoperation.

B. Improved teleoperation with MYO armband

We divide this experiment into two parts. In the first part, we test the position tracking effect when unexpected arm shaking occurs in human operator's forearm. It should be noted that the unexpected arm shaking is a spontaneous physiological behavior, hence our experimental results are chose from large number repeated trials. Fig. 9 shows the position trajectory of both the operator's hand and end effector of the robot arm and Fig. 10 shows sEMG signal changes in the process.



(a) Hand. (b) End effector of robot arm.

Fig. 9. Position trajectory in teleoperation in the first part.

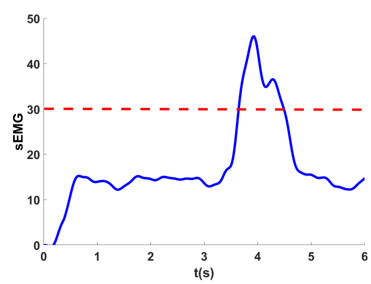
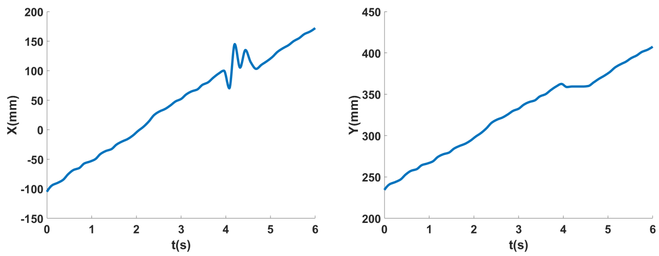


Fig. 10. sEMG signal in the first part.

As shown in Fig. 10, the sEMG signal exceeds the threshold around the fourth second, which indicates that there is an unexpected arm shaking in operator's forearm. As shown in Fig. 9, the hand position trajectory fluctuation which corresponds to the unexpected shaking in operator' hand, also leads to position trajectory fluctuation of the end effector of robot arm. The unexpected movement of the end effector would cause misoperation in the process of teleoperation.

In the second part, we build up communication between MYO armband and the robot arm. When sEMG signal exceeds the threshold, the communication between Leap Motion and robot arm will briefly disconnect and will restore connection once the sEMG signal returns to normal. Fig. 11 and Fig. 12 shows the process mentioned above.



(a) Hand. (b) End effector of robot arm.

Fig. 11. Position trajectory in the second part.

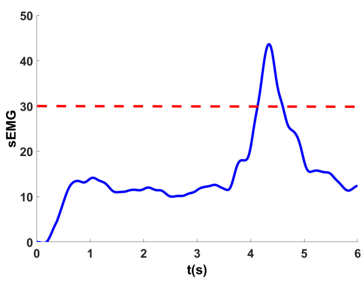


Fig. 12. sEMG signal in the second part.

As shown in Fig. 12, the sEMG signal exceeds the threshold around the moment between the fourth and fifth second. As shown in Fig. 11, the hand position trajectory fluctuation corresponds to the unexpected shaking in operator' hand, but unlike the previous experiment, the end effector of robot arm keeps at steady position even as unexpected arm shaking occurs at the operator's forearm. It can be demonstrated that the teleoperation system combined with MYO armband improves the security and stability of position tracking teleoperation.

V. Conclusion

In this paper, an improved teleoperation of industrial robot arm system using Leap Motion and MYO armband is proposed. The raw sEMG signal is preprocessed to be more distinguishable for unexpected arm shaking. With the help of Leap Motion, the industrial robot arm can follow human operator's hand movement smoothly in real-time. Combined with MYO armband, the sEMG signal is monitored during the whole process of teleoperation. We can detect abnormal sEMG signal when unexpected arm shaking occurs in operator's forearm and then restrain the robot arm's movement. Therefore, undesirable misoperation is prevented to ensure the safety of teleoperation. In future work, we intend to improve real-time performance and accuracy of the algorithm in this system to make it distinguishable for not only unexpected arm shaking but also other physiological misoperations that possibly occur in teleoperation.

References

[1] K. Ogawara, J. Takamatsu, H. Kimura, K. Ikeuchi, "Generation of a Task Model by Integration Multiple Observation of Human Demonstrations", Proceedings of the 2002 IEEE International Conference on Robotics and Automation, 2002, pp. 1545-1550.

[2] P. Berthet-Rayne, K. Leibrandt, G. Gras, P. Fraisse, A. Crosnier and G. Yang, "Inverse Kinematics Control Methods for Redundant Snakelike Robot Teleoperation During Minimally Invasive Surgery," IEEE Robotics and Automation Letters, vol. 3, no. 3, pp. 2501-2508, July 2018.

[3] G. Feng, W. Li and H. Zhang, "Space Robot Teleoperation Experiment and System Evaluation Method," 2018 2nd IEEE Advanced Information Management,Communicates,Electronic and Automation Control Conference (IMCEC), 2018, pp. 346-351.

[4] J. Luo, C. Yang, L. Qiang, W. Min, "A task learning mechanism for the telerobots", International Journal of Humanoid Robotics, vol. 16, no. 2, pp. 1950009, May 2019

[5] J. Luo, C. Yang, N. Wang, and M. Wang, "Enhanced teleoperation performance using hybrid control and virtual fixture," International Journal of Systems Science, vol. 50, no. 3, pp. 451–462, Jan 2019.

[6] G. Du and Z. Ping, "Markerless human-robot interface for dual robot manipulators using kinect sensor," Robotics & Computer Integrated Manufacturing, vol. 30, no. 2, pp. 150–159, April 2014.

[7] W. Lu, Z. Tong and J. Chu, "Dynamic Hand Gesture Recognition With Leap Motion Controller," IEEE Signal Processing Letters, vol. 23, no. 9, pp. 1188-1192, Sept 2016.

[8] Y. Nho, J. Seo, W. Seol and D. Kwon, "Emotional interaction with a mobile robot using hand gestures," 2014 11th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI), Kuala Lumpur, 2014, pp. 506-509.

[9] M. Sathiyanarayanan and S. Rajan, "MYO armband for physiotherapy healthcare: A case study using gesture recognition application," 2016 8th International Conference on Communication Systems and Networks (COMSNETS), Bangalore, 2016, pp. 1-6.

[10] C. Yang, J. Luo, Y. Pan, Z. Liu, C. Su, "Personalized variable gain control with tremor attenuation for robot teleoperation". IEEE Transactions on Systems Man and Cybernetics: Systems, vol. 48, no. 10, pp. 1759–1770, May 2017.

[11] Y. Xu, C. Yang, X. Liu and Z. Li, "A Novel Robot Teaching System Based on Mixed Reality," 2018 3rd International Conference on Advanced Robotics and Mechatronics (ICARM), Singapore, 2018, pp. 250-255.

[12] S. M. LaValle, A. Yershova, M. Katsev and M. Antonov, "Head tracking for the Oculus Rift," 2014 IEEE International Conference on Robotics and Automation (ICRA), Hong Kong, 2014, pp. 187-194.

[13] K. C. Veluvolu, S. Tatinati, S. M. Hong and W. T. Ang, "Multi-step prediction of physiological tremor for robotics applications," 2013 35th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Osaka, 2013, pp. 5075-5078.

[14] S. Allouch, M. Al Harrach, S. Boudaoud, J. Laforet, F. S. Ayachi and R. Younes, "Muscle force estimation using data fusion from high-density SEMG grid," 2013 2nd International Conference on Advances in Biomedical Engineering, Tripoli, 2013, pp. 195-198.

[15] Y. Pititeeraphab, P. Choitkunnan, N. Thongpance, K. Kullathum and C. Pintavirooj, "Robot-arm control system using LEAP motion controller," 2016 International Conference on Biomedical Engineering (BME-HUST), Hanoi, 2016, pp. 109-112.

[16] C. Ren, T. Fu, M. Zhou and X. Hu, "Low-Cost 3-D Positioning System Based on SEMG and MIMU," IEEE Transactions on Instrumentation and Measurement, vol. 67, no. 4, pp. 876-884, April 2018.

[17] O. R. Seryasat, M. Aliyari shoorehdeli, F. Honarvar and A. Rahmani, "Multi-fault diagnosis of ball bearing using FFT, wavelet energy entropy mean and root mean square (RMS)," 2010 IEEE International Conference on Systems, Man and Cybernetics, Istanbul, 2010, pp. 4295-4299.

[18] T. Fehlmann and E. Kranich, "Exponentially Weighted Moving Average (EWMA) Prediction in the Software Development Process," 2014 Joint Conference of the International Workshop on Software Measurement and the International Conference on Software Process and Product Measurement, Rotterdam, 2014, pp. 263-270.