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ORIGINAL ARTICLE

Integrated Wristband using an Inertial Measurement Unit and Electromyography Sensors to Control Robotic Car

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ABSTRACT

Human-computer interfacing is being used widely to make more integrated and user-friendly alternative methods of communication between humans and computers. Various devices have been developed to give a new dimension to the way a user interacts with computers and machines. They allow multiple ways of machine input, unlike conventional human interface devices (HID) such as mouse and keyboards. These devices remove constrictions to allow users to interact with devices in other innovative ways. The focus of this work is to illustrate an example of Human-Computer Interaction (HCI) device using electromyography (EMG) sensors in conjunction with accelerometer and gyroscope placed inside an armband to detect the EMG signals and gestures of forearm. The processed data from the microcontroller is then used to control a robotic car wirelessly. The prototype device can be made more wearable, user friendly and portable with the implementation of a more compact armband in prospective projects.

Keywords: Human-Computer Interaction (HCI), Wireless; Electromyography, Accelerometer, Gyroscope

Author`s Contribution	Address of Correspondence	Article info.
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INTRODUCTION

Technology have shown progress in the usage of software for computers as user interface. However, the devices used to interact with these advanced user interfaces (UI) are still the same few devices like a mouse and keyboard. Therefore, new and innovative methods are being devised that attempt to build human-computer interaction (HCI) as well as communication more user friendly.

The use of biological signals such as Electrooculography (EOG) [1], Electromyography (EMG) [2-4] and Electroencephalography (EEG) [5, 6] to communicate with machines [7-9], monitoring of user actions through the use of Microsoft Kinect and interfacing of user gestures or movements to interact with programs to control a computer cursor or other real-world applications are a few examples of user friendliness of HCI systems [10-12]. These devices have not only changed the way users interact with computers but it has opened up a wide variety of applications in many fields; for instance, in active prosthetics and video games [10, 13, 14]. Current studies have demonstrated that it is exceptionally intuitive to investigate virtual articles utilizing human hands and to point at an object in virtual space utilizing the finger [15-17]. Analysts are planning and testing models of new items in the domain of virtual collaborative environments (VCEs) [18, 19]. Virtual reality frameworks and intuitive gaming stages can be accomplished by utilizing hand signal as a touch less interface in HCI [20, 21]. The best devices for acquisition of hand signals are electro-mechanical or magnetic detection gadgets. In these the sensors are coupled to a glove that translates finger contractions into an electrical sign to depict the movement of the hand. Although they transmit an entire set of instantaneous estimations of the hand, however, they need complicated standardization as well as systems to get exact estimations [22, 23].

As a recent development, to counteract the restrictions forced by glove-based gadgets, a vision-based method to deal with hand focused HCI was introduced. The recommended methodology utilizes an arrangement of camcorders and computer vision systems to decode gestures [24, 25]. Moreover, the application of Microsoft Kinect for face and body tracking can be utilized for outlining natural gesture-based interface. But on the other hand, users found that despite the fact that Kinect functions admirably to trail a substantial major body, for instance human body, it is tricky to precisely identify and perceive a minor body, for example, a human hand [26, 27].

Finger and hand motion identification with computer vision methods, like using the Kinect is still not perfect because of its low resolution [21, 28-30]. Conventional vision-based hand signal identification techniques are a long way from fulfillment because of the impediments of the optical sensors utilized and reliance on lighting conditions and foundations [16, 31-34].

Keeping in mind the shortcomings of above-mentioned interfaces, this research work aims to design a wearable armband which uses EMG signals in combination with motion sensors (i.e. gyroscope for angular movements, and accelerometer for directional movements) which can be useful for controlling various devices, for instance, a robotic car, a wheelchair, media players, fan, light etc. This armband will reduce human efforts by using simple finger gestures and forearm movement to initiate appropriate responses at the output device; a robotic car. Unlike methods of using computer vision to detect human motion, the working condition of our device is free from artifacts that affect the performance of the HID, such as light, background movements and other factors. The advancement of such an armband can be helpful in making prosthetic devices for handicapped individuals who have speech and hearing impairments to communicate more easily. It can help in detecting the sign language gestures as input and give an audio output to those who do not know sign language.

RESEARCH METHODOLOGY

This research work is an extended version of its preceding work which involved the development of EMG circuit to detect each finger's movement and identify their highest strength [35]. In this work, a wearable armband is designed by integrating the EMG circuit with the inertial measurement unit (IMU) having motion tracking sensors collectively under a single band to control a robotic car wirelessly. The system hardware is based on two parts mainly: 1) Arm band circuit and 2) Car controller circuit. The complete system is presented in Fig. 1.

2.1. Arm Band Circuit

This circuit consists of a wearable band that contains EMG surface electrodes and motion tacking sensors with compact circuitry to pick up signals from subject's forearm. These signals act as an input for microcontroller (MC) which are then sent wirelessly to the car controller circuit via Bluetooth transmitter module connected to MC as presented in Fig. 1.

The armband which was placed on forearm contained the EMG circuit and motion tracking sensors. The EMG circuitry was developed in our previous work [35]. The surface electrodes were employed to pick the EMG signal which was then filtered, amplified, rectified for further utilization in different applications, such as, controlling a robotic car here, as shown in Fig. 1.

Motion tracking sensors involve two individual sensors working together using an IMU. The IMU typically comprise of an accelerometer as well as a gyroscope. These sensors are employed to detect an object's directional motion and rotational motion respectively. The InvenSense MPU-6050 sensor is used in this study and it contains a MEMS accelerometer in addition to a MEMS gyro in a single chip [36, 37]. The contraction of fingers, the movement of the forearm, and hand gestures initiate a significant change in the armband's electrode and sensor readings, all of which are processed by ATmega 328 MC. The MC uses all the data from the armband sensors to control the robotic car by using wireless transmission via Bluetooth HC-05 to the cars controlling circuit; the second part of the designed framework [38, 39].

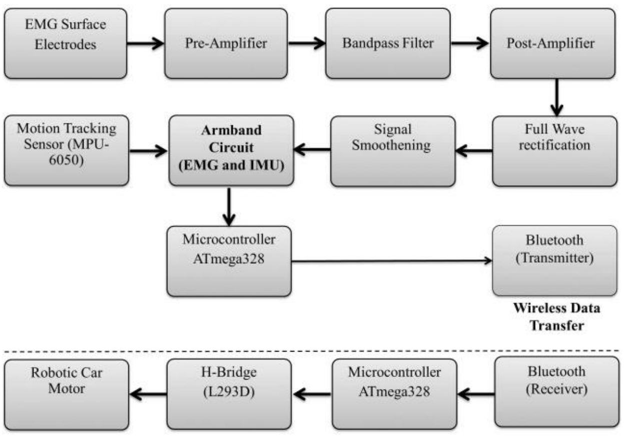


Figure 1. Complete Hardware and Functional flow of HCI based Armband to Control Robotic Car.

2.2. Robotic Car Controller Circuit

The Robotic car controlling circuit is based on Bluetooth module HC-05, MC ATmega328, H-Bridge and driving motors as shown in Fig. 1.

The Bluetooth HC-05 module of the robotic car control circuit receives data from the armband circuit and passes it to the MC. The MC then initiates the proper motor movements and speed in response to the signal received. The microcontroller transmits the logic-levels to drive the motors of the car. The car circuit uses a Half H-bridge IC to control the car much more easily. It achieves the target through the use of a separate supply powering it, and the connected motors then receive the input logics and give the respective output movements. This allows us to control the speed and direction of the car movement's with the armband along with the control of ON and OFF states.

The running software in the MC of the armband circuit receives analog data from all three sensors i.e., EMG and IMU (Accelerometer and Gyroscope). After that, the analog signals are converted into a range of 0-1023 for EMG signal and 0-10 for IMU sensors. Using the Arduino IDE protocols, the sensors are calibrated by detecting the rest state using the numerical values; 0 indicates the rest state, 1023 indicates the maximum amplitude of EMG signal and 10 indicates the maximum values for up, down, right and left `directions. After the calibration of sensors, the data is sent to the robotic car controller circuit using two BT modules. One is connected to the primary MC in the armband circuit as a transmitter, and the other is connected to a secondary MC as a receiver in the car controller circuit. In the secondary MC, the digitized data is received upon contraction of ring finger along with up, down, right, left motions and rotation of forearm which are programmed accordingly to control the robotic car movement, as shown in Fig. 2.

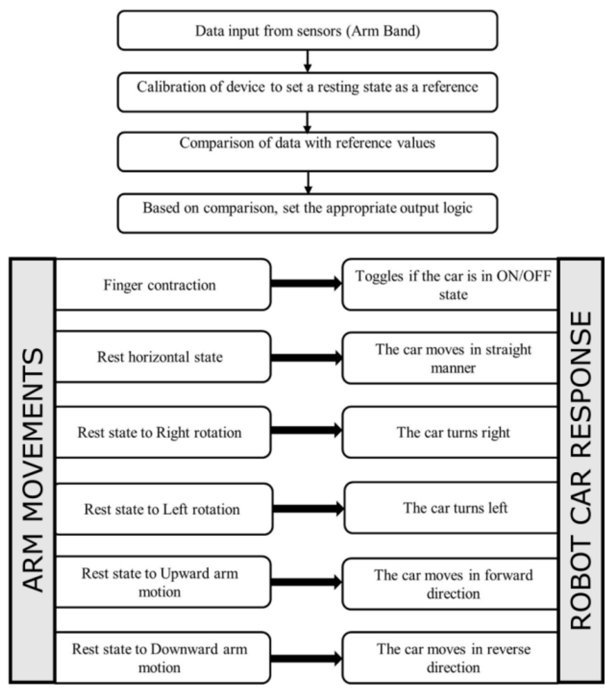


Figure 2. Designed System's Software Flow.

RESULTS AND DISCUSSION

The EMG controlled robotic car is controlled by EMG signals generated due to the movements of finger and forearm, thereby the system utilizes the EMG circuit and IMU sensors which contains the gyroscope and accelerometer together in a single chip. These two circuits are enclosed in a single armband with its circuitry to make it wearable for the user. The other part of the system; the car controller circuit, is mounted on a robotic car to make it move within its Bluetooth wireless range of 10 meters as presented in Fig. 3

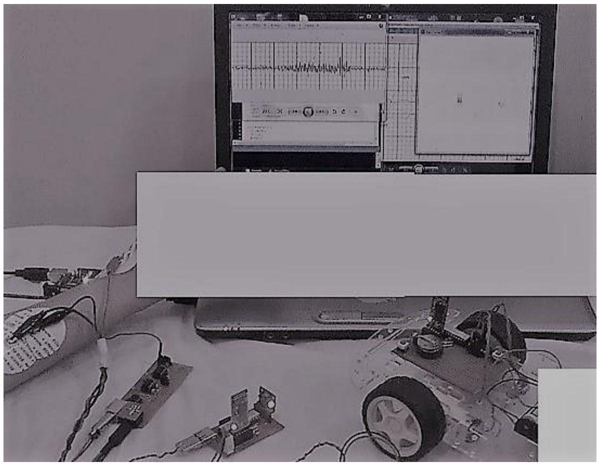
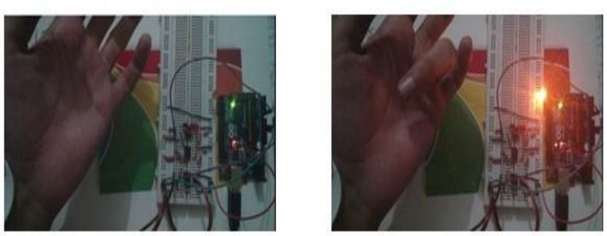


Figure 3. System components with electrode location.

A pair of EMG electrodes is positioned on the forearm near the belly of the flexor carpi radialis muscle and a reference electrode is placed at the bony protrusions of the wrist. The electrodes pick up the signals and transmit it through the EMG circuit into Arduino of arm band circuit, using the ATmega328. The signal is then wirelessly sent to car controller circuit where it is utilized to control and operate robotic car. At rest, the signal has a near to constant value, with very little fluctuations. However, when the subject contracts his finger the signal showed rise in the amplitude which was utilized as a source of signal for the car.

Through this, the circuit was calibrated and a test program was made to use the results of the previous observations to toggle the state of an LED on or off. This can be seen in Fig. 4 where the LED toggled state whenever the ring finger of the subject was contracted.



(a) (b)

Figure 4. (a) and (b) show the effects of finger contraction. The EMG signals generated toggled the state of LED from logic LOW to HIGH and vice versa on each alternative contraction.

The IMU is also placed on the forearm and interfaced with the Arduino. When the sensor module is moved in different ways, it shows the response as shown in Fig. 5. The IMU module has many modes, which were observed while testing through the graphs. The mode which seemed to fit our design considerations best and was able to control devices using armband was the yaw, pitch and roll data output mode.

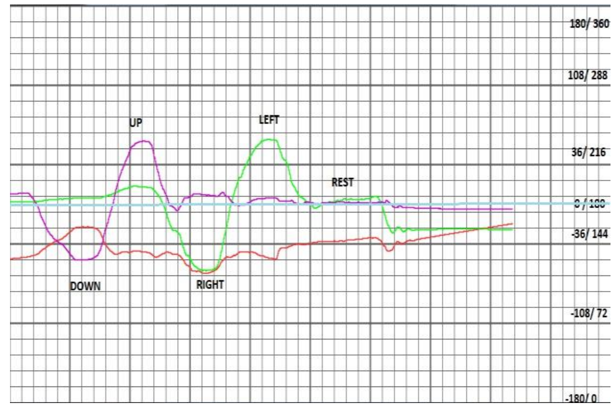


Figure 5. Graphical output of the sensor in response to arm movements (Amplitude is in degrees).

The outputs of EMG circuit and motion tracking sensors are then combined in a program and the readouts are sent to the car controller circuit through Bluetooth to drive the motors that in turn control the car. The programmed responses of the system upon arm movements are shown in Table 1.

Table 1. Response of Software to Armband Inputs

Arm Movement	Program Response
Finger contraction	Toggles when the robotic car on the window is in ON/OFF. In OFF state, the object remains stationary, waiting for the next contraction of finger to turn it ON again.
Rest state to right/left arm rotation	Car turns in right/left direction with rest state = 0 degree and maximum turn = 10 degrees in either direction.
Rest state to Upward arm motion	The car moves in forward direction with its speed being controlled; with rest state being speed = 0 and maximum upward arm rotation giving speed = 10.
Rest state to Downward arm motion	The car moves in reverse direction with its speed being controlled; with rest state being speed = 0 and maximum downward arm rotation giving speed = 10.

This research work can be modified in many different ways to improve the entire system substantially. Minor inaccuracies or instabilities can be minimized like; the EMG circuit is susceptible to environmental noise, which makes the system unstable at times. This can be overcome in the design of software, by the use of Fast Fourier transform algorithm in the program which will separate the EMG signal from the disturbances, allowing for better analysis of the EMG signal, and hence better control from the EMG sensor. The Armband design can be optimized to make it more user friendly and a more comfortable wearable device. This can be done by redesigning the band using materials like stretch conductive fiber strips to replace the use of disposable electrode. The number of EMG electrode sensing channels can also be increased to allow for more than one finger movements to be detected at once. The battery consumption can be improved significantly by the use of higher rating batteries.

CONCLUSION

This paper successfully demonstrates the formulation of a user friendly yet innovative means of human-computer interaction (HCI) using an armband addressing few of the short comings of similar interfaces of this era. This bio-signal (EMG) based project utilized sensors like accelerometer and gyroscope and explained the implementation of a human computer interface device controlling a robotic car in real the world by using hand gestures and arm movements. In terms of utilization, numerous applications can be handled by using the armband. For instance; a wheelchair, a robotic arm, assembling machinery, etc. However, it is also possible to implement this armband for medical applications. The device can be made to monitor the neuromuscular condition, and any degenerative occurrences of a human subject. In future, the results confirm the possibility of making a new innovative method of HCI using an armband.

REFERENCES

1. C.-T. Lin, J.-T. King, P. Bharadwaj, C.-H. Chen, A. Gupta, W. Ding, et al., "EOG-based eye movement classification and application on HCI baseball game," IEEE Access, vol. 7, pp. 96166-96176, 2019.
2. C. Jian, J. Li, and M. Zhang, "LSTM-based dynamic probability continuous hand gesture trajectory recognition," IET Image Processing, vol. 13, pp. 2314-2320, 2019.
3. U. Côté-Allard, C. L. Fall, A. Drouin, A. Campeau-Lecours, C. Gosselin, K. Glette, et al., "Deep learning for electromyographic hand gesture signal classification using transfer learning," IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 27, pp. 760-771, 2019.
4. M. Yu, G. Li, D. Jiang, G. Jiang, B. Tao, and D. Chen, "Hand medical monitoring system based on machine learning and optimal EMG feature set," Personal and Ubiquitous Computing, pp. 1-17, 2019.
5. S. Borhani, J. Kilmarx, D. Saffo, L. Ng, R. Abiri, and X. Zhao, "Optimizing Prediction Model for a Noninvasive Brain–Computer Interface Platform Using Channel Selection, Classification, and Regression," IEEE journal of biomedical and health informatics, vol. 23, pp. 2475-2482, 2019.
6. S. B. Wankhade and D. D. Doye, "IKKN Predictor: An EEG Signal Based Emotion Recognition for HCI," Wireless Personal Communications, vol. 107, pp. 1135-1153, 2019.
7. D. Kumar and E. Poole, "Classification of EOG for human computer interface," in Engineering in Medicine and Biology, 2002. 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society EMBS/BMES Conference, 2002. Proceedings of the Second Joint, 2002, pp. 64-67.
8. J. R. Wolpaw, D. J. McFarland, G. W. Neat, and C. A. Forneris, "An EEG-based brain-computer interface for cursor control," Electroencephalography and clinical neurophysiology, vol. 78, pp. 252-259, 1991.
9. C. Choi, S. Micera, J. Carpaneto, and J. Kim, "Development and quantitative performance evaluation of a noninvasive EMG computer interface," IEEE Transactions on Biomedical Engineering, vol. 56, pp. 188-191, 2009.
10. Z. Ren, J. Yuan, J. Meng, and Z. Zhang, "Robust part-based hand gesture recognition using kinect sensor," IEEE transactions on multimedia, vol. 15, pp. 1110-1120, 2013.
11. H. Tang, H. Liu, W. Xiao, and N. Sebe, "Fast and robust dynamic hand gesture recognition via key frames extraction and feature fusion," Neurocomputing, vol. 331, pp. 424-433, 2019.
12. C. Tan, Y. Sun, G. Li, G. Jiang, D. Chen, and H. Liu, "Research on gesture recognition of smart data fusion features in the IoT," Neural Computing and Applications, pp. 1-13, 2019.
13. F. Liu, W. Zeng, C. Yuan, Q. Wang, and Y. Wang, "Kinect-based hand gesture recognition using trajectory information, hand motion dynamics and neural networks," Artificial Intelligence Review, vol. 52, pp. 563-583, 2019.
14. N. Mirehi, M. Tahmasbi, and A. T. Targhi, "Hand gesture recognition using topological features," Multimedia Tools and Applications, vol. 78, pp. 13361-13386, 2019.
15. A. G. Hauptmann and P. McAvinney, "Gestures with speech for graphic manipulation," International journal of man-machine studies, vol. 38, pp. 231-249, 1993.

16. J. Wang, Y. Chen, S. Hao, X. Peng, and L. Hu, "Deep learning for sensor-based activity recognition: A survey," Pattern Recognition Letters, vol. 119, pp. 3-11, 2019.
17. S. Cao and X. Wang, "Real-time dynamic gesture recognition and hand servo tracking using PTZ camera," Multimedia Tools and Applications, vol. 78, pp. 27403-27424, 2019.
18. S. LU, K. SMITH, A. HERMAN, D. MATTOX, M. SILLIMAN, M. LUCENTI, et al., "SWIFT: S YSTEM W ORKBENCH FOR I NTEGRATING AND F ACILITATING T EAMS," International Journal of Intelligent and Cooperative Information Systems, vol. 3, pp. 173-187, 1994.
19. E. J. Haug, J. G. Kuhl, and F. F. Tsai, "Virtual prototyping for mechanical system concurrent engineering," in Concurrent Engineering: Tools and Technologies for Mechanical System Design, ed: Springer, 1993, pp. 851-879.
20. Z. Ren, J. Meng, and J. Yuan, "Depth camera based hand gesture recognition and its applications in human-computer-interaction," in Information, Communications and Signal Processing (ICICS) 2011 8th International Conference on, 2011, pp. 1-5.
21. M. J. Cheok, Z. Omar, and M. H. Jaward, "A review of hand gesture and sign language recognition techniques," International Journal of Machine Learning and Cybernetics, vol. 10, pp. 131-153, 2019.
22. E. Foxlin, "Motion tracking requirements and technologies," Handbook of virtual environment technology, vol. 8, pp. 163-210, 2002.
23. Y. Chen, K. T. Abel, J. T. Janecek, Y. Chen, K. Zheng, and S. C. Cramer, "Home-based technologies for stroke rehabilitation: a systematic review," International journal of medical informatics, vol. 123, pp. 11-22, 2019.
24. V. I. Pavlovic, R. Sharma, and T. S. Huang, "Visual interpretation of hand gestures for human-computer interaction: A review," IEEE Transactions on Pattern Analysis & Machine Intelligence, pp. 677-695, 1997.
25. T. Vuletic, A. Duffy, L. Hay, C. McTeague, G. Campbell, and M. Grealy, "Systematic literature review of hand gestures used in human computer interaction interfaces," International Journal of Human-Computer Studies, vol. 129, pp. 74-94, 2019.
26. D. Pagliari and L. Pinto, "Calibration of kinect for xbox one and comparison between the two generations of microsoft sensors," Sensors, vol. 15, pp. 27569-27589, 2015.
27. J. Qi, G. Jiang, G. Li, Y. Sun, and B. Tao, "Surface EMG hand gesture recognition system based on PCA and GRNN," Neural Computing and Applications, pp. 1-9, 2019.
28. Q. Cai, D. Gallup, C. Zhang, and Z. Zhang, "3d deformable face tracking with a commodity depth camera," in European conference on computer vision, 2010, pp. 229-242.
29. Y. Wang, Y. Sun, Z. Liu, S. E. Sarma, M. M. Bronstein, and J. M. Solomon, "Dynamic graph cnn for learning on point clouds," ACM Transactions on Graphics (TOG), vol. 38, pp. 1-12, 2019.
30. A. S. Al-Shamayleh, R. Ahmad, M. A. Abushariah, K. A. Alam, and N. Jomhari, "A systematic literature review on vision based gesture recognition techniques," Multimedia Tools and Applications, vol. 77, pp. 28121-28184, 2018.
31. C.-S. Chua, H. Guan, and Y.-K. Ho, "Model-based 3D hand posture estimation from a single 2D image," Image and Vision computing, vol. 20, pp. 191-202, 2002.
32. H.-S. Yoon, J. Soh, Y. J. Bae, and H. S. Yang, "Hand gesture recognition using combined features of location, angle and velocity," Pattern recognition, vol. 34, pp. 1491-1501, 2001.
33. F.-S. Chen, C.-M. Fu, and C.-L. Huang, "Hand gesture recognition using a real-time tracking method and hidden Markov models," Image and vision computing, vol. 21, pp. 745-758, 2003.
34. W. Cheng, Y. Sun, G. Li, G. Jiang, and H. Liu, "Jointly network: a network based on CNN and RBM for gesture recognition," Neural Computing and Applications, vol. 31, pp. 309-323, 2019.
35. N. Shaikh, F. Muhammad, M. F. Shamim, N. Shahid, S. M. Omair, and M. Z. U. Haque, "Finger Movement Identification Using EMG Signal on the Forearm," Journal of Biomedical Engineering and Medical Imaging, vol. 4, p. 12, 2017.
36. J. Rowberg, "I2Cdevlib: MPU-6050 6-axis accelerometer/gyroscope," Publicación electrónica: http://www.i2cdevlib. com/devices/mpu6050 Consultada, vol. 12, 2014.
37. M. Hosseini-Pishrobat and J. Keighobadi, "Robust vibration control and angular velocity estimation of a single-axis MEMS gyroscope using perturbation compensation," Journal of Intelligent & Robotic Systems, vol. 94, pp. 61-79, 2019.
38. I. Studio, "HC-05-Bluetooth to Serial Port Module," Datasheet, June, 2010.
39. R. Qi, M. Rushton, A. Khajepour, and W. W. Melek, "Decoupled modeling and model predictive control of a hybrid cable-driven robot (HCDR)," Robotics and Autonomous Systems, vol. 118, pp. 1-12, 2019.