Document details

→ **Export**   ⤓ **Download**   🖶 **Print**   ✉ **E-mail**   📄 **Save to PDF**   ☆ **Add to List**   More... ›

[Full Text]   View at Publisher

Sensory Systems in Micro-Processor Controlled Prosthetic Leg: A Review (Article)

Hamzaid, N.A.[a] ✉,   Mohd Yusof, N.H.[a] ✉,   Jasni, F.[b] ✉   ⊙

[a]Biomedical Engineering Department, University of Malaya, Kuala Lumpur, Malaysia
[b]Mechatronics Engineering Department, Kulliyyah of Engineering, International Islamic University Malaysia, Selangor, Malaysia

Abstract   ⌄ View references (49)

Micro-processor controlled prosthetic legs (MPCPL) offer better functionality than conventional prosthetic legs as they use actuators to replace missing joint function. This potentially reduces the user's metabolic energy consumption and normal walking gait can be mimicked as closely as possible. However, MPCPL require a good control system to perform efficiently, and one of the essential components is the system of sensors. The sensory system must satisfy two important criteria; the practicality in donning and doffing the prosthesis, i.e. the process of putting on and taking off the prosthesis by the amputee user, and the quality in the information provided. In this paper, a comprehensive review was conducted on studies related to the state of the art of sensory system adopted in MPCPL. The publications were searched using four electronics databases within the last 13 years. A total of 31 papers were reviewed. The articles were classified into three main categories: prosthetic-device oriented, user's-biological-input oriented and neuro-mechanical fusion sensory system. Types of sensors used and their application to the prosthetic system were analyzed. This review indicates that the sensors technology reported in the literature still does not fulfil the criteria of an efficient sensory system. Hence, a sensory system that eases the don and doff process of the prosthesis, yet informative in terms of providing enough useful data to effectively control the prosthesis, is needed for a successful MPCPL. © 2019 IEEE.

SciVal Topic Prominence ⓘ

Topic: Knee Prostheses | Prostheses and Implants | Amputation

Prominence percentile: 96.483   ⓘ

Author keywords

(microprocessor-controlled prosthesis)   (Prosthetics)   (sensor)

Indexed keywords

Engineering controlled terms: (Energy utilization)

Engineering uncontrolled terms   (Biological inputs) (Metabolic energy) (Normal walking) (Prosthetic devices) (Prosthetic leg) (Putting on and taking offs) (Sensory system) (State of the art)

Engineering main heading: (Prosthetics)

Metrics ⓘ   View all metrics ›

1   Citation in Scopus
          88th percentile

2.40   Field-Weighted
           Citation Impact

✴ PlumX Metrics   ⌄
Usage, Captures, Mentions,
Social Media and Citations
beyond Scopus.

Cited by 1 document

Classification of standing and sitting phases based on in-socket piezoelectric sensors in a transfemoral amputee
Yahya, T. , Hamzaid, N.A. , Hamzaid, N.A.
(2020) Biomedizinische Technik

View details of this citation

Inform me when this document is cited in Scopus:

[Set citation alert ›]

[Set citation feed ›]

Related documents

A geometry recognition-based strategy for locomotion transitions early prediction of prosthetic devices
Sahoo, S. , Maheshwari, M. , Pratihar, D.K.
(2020) IEEE Transactions on Instrumentation and Measurement

In-Socket Sensory System for Transfemoral Amputees Using Piezoelectric Sensors: An Efficacy Study
Jasni, F. , Hamzaid, N.A. , Muthalif, A.G.A.
(2016) IEEE/ASME Transactions on Mechatronics

References (49)

View in search results format >

☐ All | Export 🖶 Print ✉ E-mail 📄 Save to PDF Create bibliography

☐ 1   Du, Y., Yang, Q., Huang, J.

Soft Prosthetic Forefinger Tactile Sensing via a String of Intact Single Mode Optical Fiber

(2017) *IEEE Sensors Journal*, 17 (22), art. no. 8058428, pp. 7455-7459. Cited 6 times.
http://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=7361
doi: 10.1109/JSEN.2017.2759907

View at Publisher

☐ 2   Tkach, D., Huang, H., Kuiken, T.A.

Study of stability of time-domain features for electromyographic pattern recognition
(Open Access)

(2010) *Journal of NeuroEngineering and Rehabilitation*, 7 (1), art. no. 21. Cited 276 times.
doi: 10.1186/1743-0003-7-21

View at Publisher

☐ 3   Kapti, A.O., Muhurcu, G.

Wearable acceleration sensor application in unilateral trans-tibial amputation prostheses

(2014) *Biocybernetics and Biomedical Engineering*, 34 (1), pp. 53-62. Cited 4 times.
doi: 10.1016/j.bbe.2013.10.002

View at Publisher

☐ 4   Wang, H., Totaro, M., Beccai, L.

Toward Perceptive Soft Robots: Progress and Challenges   (Open Access)

(2018) *Advanced Science*, 5 (9), art. no. 1800541. Cited 67 times.
http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2198-3844http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2198-3844
doi: 10.1002/advs.201800541

View at Publisher

☐ 5 Tucker, M.R., Olivier, J., Pagel, A., Bleuler, H., Bouri, M., Lambercy, O., Del Millán, J.R., (...), Gassert, R.

Control strategies for active lower extremity prosthetics and orthotics: A review
(Open Access)

(2015) *Journal of NeuroEngineering and Rehabilitation*, 12 (1), art. no. 1. Cited 246 times.
http://www.jneuroengrehab.com/home/
doi: 10.1186/1743-0003-12-1

View at Publisher

☐ 6 Farnsworth, B.D., Talyor, D.M., Triolo, R.J., Young, D.J.

Wireless in vivo EMG sensor for intelligent prosthetic control

(2009) *TRANSDUCERS 2009 - 15th International Conference on Solid-State Sensors, Actuators and Microsystems*, art. no. 5285488, pp. 358-361. Cited 18 times.
ISBN: 978-142444193-8
doi: 10.1109/SENSOR.2009.5285488

View at Publisher

☐ 7 Martin, J., Pollock, A., Hettinger, J.

Microprocessor lower limb prosthetics: Review of current state of the art

(2010) *Journal of Prosthetics and Orthotics*, 22 (3), pp. 183-193. Cited 14 times.
doi: 10.1097/JPO.0b013e3181e8fe8a

View at Publisher

☐ 8 Fluit, R., Prinsen, E., Wang, S., Van Der-Kooij, H.
A comparison of control strategies in commercial and research knee prostheses
IEEE Trans. Biomed. Eng.
to be published

☐ 9 Downs, S.H., Black, N.

The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions
(Open Access)

(1998) *Journal of Epidemiology and Community Health*, 52 (6), pp. 377-384. Cited 4008 times.
http://jech.bmjjournals.com/
doi: 10.1136/jech.52.6.377

View at Publisher

☐ 10 Nandi, G.C., Ijspeert, A.J., Chakraborty, P., Nandi, A.

Development of Adaptive Modular Active Leg (AMAL) using bipedal robotics technology

(2009) *Robotics and Autonomous Systems*, 57 (6-7), pp. 603-616. Cited 31 times.
doi: 10.1016/j.robot.2009.02.002

View at Publisher

☐ 11 Thatte, N., Geyer, H.

Toward Balance Recovery With Leg Prostheses Using Neuromuscular Model Control
(Open Access)

(2016) *IEEE Transactions on Biomedical Engineering*, 63 (5), art. no. 7222383, pp. 904-913. Cited 31 times.
http://ieeexplore.ieee.org/xpl/RecentIssue.jsp?reload=true&punumber=10
doi: 10.1109/TBME.2015.2472533

View at Publisher

☐ 12   Windrich, M., Grimmer, M., Christ, O., Rinderknecht, S., Beckerle, P.

Active lower limb prosthetics: A systematic review of design issues and solutions
(Open Access)

(2016) *BioMedical Engineering Online*, 15, art. no. 140. Cited 57 times.
http://www.biomedical-engineering-online.com/start.asp
doi: 10.1186/s12938-016-0284-9

View at Publisher

☐ 13   Ambrozic, L., Gorsic, M., Geeroms, J., Flynn, L., Molino Lova, R., Kamnik, R., Munih, M., (...), Vitiello, N.

CYBERLEGs: A user-oriented robotic transfemoral prosthesis with whole-body awareness control

(2014) *IEEE Robotics and Automation Magazine*, 21 (4), art. no. 6990834, pp. 82-93. Cited 35 times.
doi: 10.1109/MRA.2014.2360278

View at Publisher

☐ 14   Xie, H., Li, F., Sheng, Z., Xu, Z., Liu, Y.

The gait system research of intelligent bionic leg

(2009) *2009 Chinese Control and Decision Conference, CCDC 2009*, art. no. 5191693, pp. 4623-4627. Cited 3 times.
ISBN: 978-142442723-9
doi: 10.1109/CCDC.2009.5191693

View at Publisher

☐ 15   Varol, H.A., Sup, F., Goldfarb, M.

Multiclass real-time intent recognition of a powered lower limb prosthesis

(2010) *IEEE Transactions on Biomedical Engineering*, 57 (3), art. no. 5290091, pp. 542-551. Cited 223 times.
doi: 10.1109/TBME.2009.2034734

View at Publisher

☐ 16   Young, A.J., Simon, A.M., Hargrove, L.J.

A training method for locomotion mode prediction using powered lower limb prostheses

(2014) *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 22 (3), art. no. 6650103, pp. 671-677. Cited 73 times.
doi: 10.1109/TNSRE.2013.2285101

View at Publisher

☐ 17   Young, A.J., Hargrove, L.J.

A Classification Method for User-Independent Intent Recognition for Transfemoral Amputees Using Powered Lower Limb Prostheses

(2016) *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 24 (2), art. no. 7061495, pp. 217-225. Cited 42 times.
doi: 10.1109/TNSRE.2015.2412461

View at Publisher

☐ 18   Shahmoradi, S., Shouraki, S.B.

A Fuzzy sequential locomotion mode recognition system for lower limb prosthesis control

(2017) *2017 25th Iranian Conference on Electrical Engineering, ICEE 2017*, art. no. 7985417, pp. 2153-2158. Cited 2 times.
ISBN: 978-150905963-8
doi: 10.1109/IranianCEE.2017.7985417

View at Publisher

☐ 19   Fuhr, T., Quintern, J., Riener, R., Schmidt, G.

Walking with WALK!

(2008) *IEEE Engineering in Medicine and Biology Magazine*, 27 (1), pp. 38-48. Cited 17 times.
doi: 10.1109/MEMB.2007.911408

View at Publisher

☐ 20   Fite, K., Mitchell, J., Sup, F., Goldfarb, M.

Design and control of an electrically powered knee prosthesis

(2007) *2007 IEEE 10th International Conference on Rehabilitation Robotics, ICORR'07*, art. no. 4428531, pp. 902-905. Cited 65 times.
ISBN: 1424413206; 978-142441320-1
doi: 10.1109/ICORR.2007.4428531

View at Publisher

☐ 21   Stolyarov, R., Burnett, G., Herr, H.

Translational Motion Tracking of Leg Joints for Enhanced Prediction of Walking Tasks

(2018) *IEEE Transactions on Biomedical Engineering*, 65 (4), pp. 763-769. Cited 13 times.
http://ieeexplore.ieee.org/xpl/RecentIssue.jsp?reload=true&punumber=10
doi: 10.1109/TBME.2017.2718528

View at Publisher

☐ 22   Torrealba, R.R., Cappelletto, J., Fermín-León, L., Grieco, J.C., Fernández-López, G.

Statistics-based technique for automated detection of gait events from accelerometer signals

(2010) *Electronics Letters*, 46 (22), pp. 1483-1485. Cited 13 times.
doi: 10.1049/el.2010.2118

View at Publisher

☐ 23   El-Sayed, A.M., Hamzaid, N.A., Osman, N.A.A.

Piezoelectric bimorphs' characteristics as in-socket sensors for transfemoral amputees   (Open Access)

(2014) *Sensors (Switzerland)*, 14 (12), pp. 23724-23741. Cited 9 times.
http://www.mdpi.com/1424-8220/14/12/23724/pdf
doi: 10.3390/s141223724

View at Publisher

☐ 24   Zhang, F., Fang, Z., Liu, M., Huang, H.

Preliminary design of a terrain recognition system

(2011) *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS*, art. no. 6091391, pp. 5452-5455. Cited 28 times.
ISBN: 978-142444121-1
doi: 10.1109/IEMBS.2011.6091391

View at Publisher

☐ 25   Presacco, A., Forrester, L.W., Contreras-Vidal, J.L.

Decoding intra-limb and inter-limb kinematics during treadmill walking from scalp electroencephalographic (EEG) signals

(2012) *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 20 (2), art. no. 6171068, pp. 212-219. Cited 66 times.
doi: 10.1109/TNSRE.2012.2188304

View at Publisher

26   Murguialday, A.R., Aggarwal, V., Chatterjee, A., Cho, Y., Rasmussen, R., O'Rourke, B., Acharya, S., (...), Thakor, N.V.

Brain-computer interface for a prosthetic hand using local machine control and haptic feedback

(2007) *2007 IEEE 10th International Conference on Rehabilitation Robotics, ICORR'07*, art. no. 4428487, pp. 609-613. Cited 30 times.
ISBN: 1424413206; 978-142441320-1
doi: 10.1109/ICORR.2007.4428487

View at Publisher

---

27   McMullen, D.P., Hotson, G., Katyal, K.D., Wester, B.A., Fifer, M.S., McGee, T.G., Harris, A., (...), Crone, N.E.

Demonstration of a semi-autonomous hybrid brain-machine interface using human intracranial EEG, eye tracking, and computer vision to control a robotic upper limb prosthetic

(2014) *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 22 (4), art. no. 6683036, pp. 784-796. Cited 89 times.
doi: 10.1109/TNSRE.2013.2294685

View at Publisher

---

28   Fatima, M., Shafique, M., Khan, Z.H.

Towards a low cost Brain-computer Interface for real time control of a 2 DOF robotic arm

(2015) *Proceedings of 2015 International Conference on Emerging Technologies, ICET 2015*, art. no. 7389206. Cited 8 times.
ISBN: 978-150900436-2
doi: 10.1109/ICET.2015.7389206

View at Publisher

---

29   Fitzsimmons, N.A., Lebedev, M.A., Peikon, I.D., Nicolelis, M.A.L.

Extracting kinematic parameters for monkey bipedal walking from cortical neuronal ensemble activity   (Open Access)

(2009) *Frontiers in Integrative Neuroscience*, 3 (MAR), art. no. 3. Cited 138 times.
http://www.frontiersin.org/Journal/DownloadFile.ashx?pdf=1&FileId=13661&articleId=501&Version=1&ContentTypeId=15&FileName=003_2009.pdf
doi: 10.3389/neuro.07.003.2009

View at Publisher

---

30   Ma, X., Ma, C., Huang, J., Zhang, P., Xu, J., He, J.

Decoding lower limb muscle activity and kinematics from cortical neural spike trains during monkey performing stand and squat movements   (Open Access)

(2017) *Frontiers in Neuroscience*, 11 (FEB), art. no. 44. Cited 9 times.
http://journal.frontiersin.org/article/10.3389/fnins.2017.00044/full
doi: 10.3389/fnins.2017.00044

View at Publisher

---

31   Bai, O.
A wireless, smart EEG system for volitional control of lower-limb prosthesis
(2015) *Proc. IEEE Region Conf.*, pp. 1-6. Cited 2 times.
Nov.

---

32   Rea, M., Rana, M., Lugato, N., Terekhin, P., Gizzi, L., Brötz, D., Fallgatter, A., (...), Caria, A.

Lower limb movement preparation in chronic stroke: A pilot study toward an fnirs-bci for gait rehabilitation

(2014) *Neurorehabilitation and Neural Repair*, 28 (6), pp. 564-575. Cited 35 times.
doi: 10.1177/1545968313520410

View at Publisher

33   Jamal, M.Z.

Signal acquisition using surface EMG and circuit design considerations for robotic prosthesis
(2012) *Computational Intelligence in Electromyography Analysis A Perspective on Current Applications and Future Challenges*, pp. 427-448. Cited 58 times.
G. R. Naik, Eds. Rijeka, Croatia: InTech

---

34   Hudgins, Bernard, Parker, Philip, Scott, Robert N.

The recognition of myoelectric patterns for prosthetic limb control

(1991) *Proceedings of the Annual Conference on Engineering in Medicine and Biology*, 13 (pt 5), pp. 2040-2041. Cited 8 times.
ISBN: 0780302168

View at Publisher

---

35   Hardaker, P.A., Passow, B.N., Elizondo, D.

State detection from electromyographic signals towards the control of prosthetic limbs

(2013) *2013 13th UK Workshop on Computational Intelligence, UKCI 2013*, art. no. 6651296, pp. 120-127. Cited 2 times.
ISBN: 978-147991568-2
doi: 10.1109/UKCI.2013.6651296

View at Publisher

---

36   Wu, S.-K., Waycaster, G., Shen, X.

Electromyography-based control of active above-knee prostheses

(2011) *Control Engineering Practice*, 19 (8), pp. 875-882. Cited 25 times.
doi: 10.1016/j.conengprac.2011.04.017

View at Publisher

---

37   Nakamura, B.H., Hahn, M.E.

Myoelectric activation differences in transfemoral amputees during locomotor state transitions

(2016) *Biomedical Engineering - Applications, Basis and Communications*, 28 (6), art. no. 1650041. Cited 2 times.
http://www.worldscinet.com/bme/bme.shtml
doi: 10.4015/S1016237216500411

View at Publisher

---

38   Hofmann, D., Jiang, N., Vujaklija, I., Farina, D.

Bayesian Filtering of Surface EMG for Accurate Simultaneous and Proportional Prosthetic Control

(2016) *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 24 (12), pp. 1333-1341. Cited 29 times.
doi: 10.1109/TNSRE.2015.2501979

View at Publisher

---

39   Zhu, X., Liu, J., Zhang, D., Sheng, X., Jiang, N.

Cascaded Adaptation Framework for Fast Calibration of Myoelectric Control

(2017) *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 25 (3), art. no. 7464360, pp. 254-264. Cited 18 times.
doi: 10.1109/TNSRE.2016.2562180

View at Publisher

40 Huang, Q., Yang, D., Jiang, L., Zhang, H., Liu, H., Kotani, K.

A novel unsupervised adaptive learning method for long-term electromyography (EMG) pattern recognition (Open Access)

(2017) *Sensors (Switzerland)*, 17 (6), art. no. 1370. Cited 21 times.
http://www.mdpi.com/1424-8220/17/6/1370/pdf
doi: 10.3390/s17061370

View at Publisher

41 Zhang, T.Y.
(2016) *The Research on Motion Recognition Based on EMG of Residual Thigh Bioinformatics and Biomedical Engineering: New Advances*, pp. 445-450.
Boca-Raton, FL, USA

42 Tkach, D.C., Hargrove, L.J.

Neuromechanical sensor fusion yields highest accuracies in predicting ambulation mode transitions for trans-tibial amputees

(2013) *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society, EMBS*, art. no. 6610190, pp. 3074-3077. Cited 22 times.
ISBN: 978-145770216-7
doi: 10.1109/EMBC.2013.6610190

View at Publisher

43 Wentink, E.C., Beijen, S.I., Hermens, H.J., Rietman, J.S., Veltink, P.H.

Intention detection of gait initiation using EMG and kinematic data (Open Access)

(2013) *Gait and Posture*, 37 (2), pp. 223-228. Cited 29 times.
doi: 10.1016/j.gaitpost.2012.07.013

View at Publisher

44 Wentink, E.C., Schut, V.G.H., Prinsen, E.C., Rietman, J.S., Veltink, P.H.

Detection of the onset of gait initiation using kinematic sensors and EMG in transfemoral amputees

(2014) *Gait and Posture*, 39 (1), pp. 391-396. Cited 37 times.
doi: 10.1016/j.gaitpost.2013.08.008

View at Publisher

45 Martinez-Villalpando, E.C., Weber, J., Elliott, G., Herr, H.

Design of an agonist-antagonist active knee prosthesis

(2008) *Proceedings of the 2nd Biennial IEEE/RAS-EMBS International Conference on Biomedical Robotics and Biomechatronics, BioRob 2008*, art. no. 4762919, pp. 529-534. Cited 47 times.
ISBN: 978-142442883-0
doi: 10.1109/BIOROB.2008.4762919

View at Publisher

46 Huang, H., Kuiken, T.A., Lipschutz, R.D.

A strategy for identifying locomotion modes using surface electromyography

(2009) *IEEE Transactions on Biomedical Engineering*, 56 (1), pp. 65-73. Cited 283 times.
doi: 10.1109/TBME.2008.2003293

View at Publisher

47 Zhang, F., Huang, H.

Source selection for real-time user intent recognition toward volitional control of artificial legs

(2013) *IEEE Journal of Biomedical and Health Informatics*, 17 (5), art. no. 6395231, pp. 907-914. Cited 44 times.
doi: 10.1109/JBHI.2012.2236563

View at Publisher

48 Jasni, F., Hamzaid, N.A., Al-Nusairi, T.Y., Mohd Yusof, N.H., Shasmin, H.N., Ng, S.-C.

Feasibility of a Gait Phase Identification Tool for Transfemoral Amputees Using Piezoelectric- Based In-Socket Sensory System

(2019) *IEEE Sensors Journal*, 19 (15), art. no. 8685196, pp. 6437-6444. Cited 3 times.
http://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=7361
doi: 10.1109/JSEN.2019.2910161

View at Publisher

49 Jasni, F., Hamzaid, N.A., Muthalif, A.G.A., Zakaria, Z., Shasmin, H.N., Ng, S.-C.

In-Socket Sensory System for Transfemoral Amputees Using Piezoelectric Sensors: An Efficacy Study

(2016) *IEEE/ASME Transactions on Mechatronics*, 21 (5), art. no. 7487057, pp. 2466-2476. Cited 10 times.
doi: 10.1109/TMECH.2016.2578679

View at Publisher

Hamzaid, N.A.; Biomedical Engineering Department, University of Malaya, Kuala Lumpur, Malaysia; email:azah.hamzaid@um.edu.my

‹ Back to results | 1 of 1

∧ Top of page

About Scopus

What is Scopus

Content coverage

Scopus blog

Scopus API

Privacy matters

Language

日本語に切り替える

切换到简体中文

切換到繁體中文

Русский язык

Customer Service

Help

Contact us