A Factor of Human-Robot Interaction on Wearable Robot: A Literature Review

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Abstract— **The robot technology is developing to improve human life and that substitutes human function and capability. The key factor of wearable robot is a human-robot interaction. The purpose of this study is to analyze the ergonomic factors of a human-robot interaction based on literature reviews. To search for ergonomic factors on a human-robot interaction, we looked into four databases in Web of Science, Scopus, IEEE Explore, and Google Scholar. This study reviewed literature including papers, books, international standards published from January 1st, 2000 to May 1st, 2018. The title and abstract of literature was checked by authors. Selected literature was reviewed and the main factors were manually extracted. There were twelve literature that met the inclusion criteria. This study evaluated the ergonomic factors of human-robot interaction categorized as safety, human and robot factors which were warning sign, stability, fail-safe, range of motion, fatigue, contact pressure, motion intention, misalignment, power, closed-loop system, and etc. These ergonomic factors are suggested to the safety and usability evaluation systems by developing ergonomic design specifications of wearable robots.**

Keywords - Wearable Robot; Human-Robot Interaction; Ergonomic; Safety; Usability.

I. INTRODUCTION

The robot technology is developing to improve industry productivity and convenience in human life. The application of wearable robotics is growing in various fields such as industry, rehabilitation, prosthetics, space application and defense. A wearable robot can be seen as a technology that extends, complements, substitutes human function and capability or replaces [1].

Previous studies still have focused on developing and improving the mechanical performance of a wearable robot. However, the key distinctive aspect in wearable robots is their Human-Robot Interaction(HRI). An HRI is a hardware and software link that connects to both human and robot systems [2].

The purpose of this study is to analyze to the ergonomic factors of HRI on a wearable robot through a literature review.

II. METHOD

The purpose of this method is to search main factors in HRI, and to identify potential ergonomic factors. This review details the findings from four electronic databases via keyword searches in Web of Science, Scopus, IEEE Explore, and Google Scholar. For this study, we searched literature related with HRI of wearable robot including papers, public documents, books, international standards and report published from January 1st, 2000 to May 1st, 2018.

Regarding the search keyword, the search criteria used were 'human robot interaction', 'ergonomics', 'human factor', 'usability', 'safety' and 'comfortability'. To avoid literature not falling into the topic under study, the search was performed using the Boolean operator "AND", with the search term 'ergonomics' [3].

The following additional inclusion criteria were used to search the literature:

a. Published as a full text literature, or in press, in peer-reviewed journals
b. Published or in press between January 1st, 2000 and prior May 1st, 2018
c. Literature in this study includes that paper, article, public document, book, international standard and issue report
d. Literature that considered HRI on wearable robot
e. Literature with an ergonomics studies or application purpose

The process of literature review, titles and abstracts were checked separately by three of the authors. Prior to literature review, inclusion criteria were identified and corresponding relevant information required was analyzed. Then, the selected relevant literature was reviewed and the main factors manually extracted.

III. RESULT

A total of 51 literatures were searched, of which 12 literatures that met the inclusion criteria [4]-[15]. Table 1 shows the reviewed literature evaluated for the ergonomic factors. It categorized as safety, human and robot factors as follows: warning sign, emergency stop, stability, temperature, fail-safe, range of motion, fatigue, contact pressure, motion intention, misalignment, power, weight, operation type, closed-loop system, and etc.

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TABLE I. SUMMARY OF MAIN FACTOR REFERRING TO HUMAN, ROBOT AND SAFETY ON WEARABLE ROBOT.

Author and year	Main factor		
	Safety	Human	Robot
Chan and Courtney, 2001	Warning sign Emergency stop		
Copaci et al., 2017		Joint angle Range of motion	Actuator Degree of freedom Torque
d'Elia et al., 2017	Stability	Kinematic coupling Segment length Locomotion	Mechanical power
de Looze et al., 2016		Muscle load Musculoskeletal disorder	Operation type(active/passive)
De Santis et al., 2008	Control architecture	Injury Damage	Actuation Weight Sensor
ISO 13482:2014	Sharp edge Vibration Surface temperature Fail safe	Musculoskeletal disorder Fatigue	Battery Power down
Lenzi et al., 2011		Contact pressure Comfort Interaction force and torque Motion intention	Tactile sensor
Lenzi et al., 2012		Movement intention Muscle activity Muscle torque	Movement accuracy
Nguyen and Sankai, 2013		Strain of contact part Interaction force	Contact part
Nimawat and Jailiya 2015	System architecture Hyper flex human joint	User interface Misalignment Tissue load Tolerance of pressure Size weight	Sensor Actuator Energy storage
Long et al., 2006		Misalignment Discomfort	Closed-loop system Proximal elastic module
Schiele et al., 2006		Degree of freedom Misalignment	Optimal design

IV. DISCUSSION

Based on these results, this study suggested three grouped ergonomic HRI factors including the safety for human-robot interaction, the usability for human, and the mechanical specification to ensure the human safety. A factor of HRI on wearable robot are suggested to the safety and usability evaluation system by developing ergonomic design specifications of wearable robots. This study is based on content literature review techniques that briefly reviews abstracts, key contents and passages. It means that the results of this study do not represent a detailed review of literature, or the impact of their findings.

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REFERENCES

[1] R. Alami et al., "Safe and dependable physical human-robot interaction in anthropic domains: State of the art and challenges", in Proceedings of the Intelligent Robots and Systems, 2006 IEEE/RSJ International Conference, DOI: 10.1109/IROS.2006.6936985, 2006.

[2] J. L. Pons, Wearable robots: biomechatronic exoskeletons, UK: John Wiley & Sons, 2008.

[3] C. Viviani et al., "Accuracy, precision and reliability in anthropometric survey for ergonomics purposes in adult working populations: A literature review", Int J Ind Ergon, Vol. 65, pp. 1-16, 2018.

[4] A. H. S. Chan and A. J. Courtney, "Safety and ergonomics evaluation of hybrid systems in Hong", Accid Anal Prev, Vol. 33, pp. 563-565, 2001.

[5] D. Copaci, E. Cano, L. Moreno and D. Blanco, "New Design of a Soft Robotics Wearable Elbow Exoskeleton Based on Shape Memory Alloy Wire Actuators", Appl Bionics Biomech, DOI: 10.1155/2017/1605101, 2017.

[6] N. d'Elia et al., "Physical human-robot interaction of an active pelvis orthosis: Toward ergonomic assessment of wearable robots", J Neuroeng Rehabil, Vol. 14:29, 2017.

[7] M. P. de Looze, T. Bosch, F. Krause, K. S. Stadler and L. W. O'Sullivan, "Exoskeletons for industrial application and their potential effects on physical work load", Ergonomics, Vol. 59, pp. 671–681, 2016.

[8] A. De Santis, B. Siciliano, A. De Luca and A. Bicchi, "An atlas of physical human-robot interaction", Mech Mach Theory, Vol. 43, pp. 259-270, 2008.

[9] ISO 13482:2014, Robots and robotic devices – safety requirements for personal care robots, 2014.

[10] T. Lenzi et al., "Measuring human–robot interaction on wearable robots: A distributed approach", Mechatronics, Vol. 21, pp. 1123–1131, 2011.

[11] T. Lenzi, S. M. M. De Rossi, N. Vitiello and M. C. Carrozza, "Intention-based EMG control for powered exoskeletons", IEEE Trans Biomed Eng, Vol. 59, pp. 2180-2190, 2012.

[12] M. T. Nguyen and Y. Sankai, "Measurement method of interaction force between human and wearable assistive robot based on strain of contact part" Proceedings of the SICE Annual Conference, pp. 401-406, 2018.

[13] D. Nimawat and P. R. S. Jailiya, "Requirement of wearable robots in Current scenario", Euro J Adv Engg, Vol. 2, pp. 19–23, 2015.

[14] Y. Long, Z. Du, C. Chen, W. Wang and W. Dong, "Development of a lower extremity wearable exoskeleton with double compact elastic module: Preliminary experiments", Mech Sci, Vol. 8, pp. 249-258, 2017.

[15] T. Schiele and F. C. T. van der Helm, "Kinematic design to Improve ergonomics in human machine interaction", IEEE Trans Neural Syst Rehabil Eng, Vol. 14, pp. 456-469, 2006.