Motion analysis of a novel robotic wheelchair on climbing winding stairs

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摘 要

本研究主要是設計一新的爬樓梯機器人輪椅，並分析其穩定度，運動狀態及建立相關之動態模型。該機器人輪椅主要是由樞接在支撐基座兩側之多肢節結構所組成，以使該機器人輪椅可以上下階梯；特別強調是具有上下螺旋階梯之能力。此外，構成多肢節結構體之短臂、長臂及三角支座之轉動是由周轉複合行星齒輪系來致動。該具轉動之多肢節機構除應用於階梯上下，並可保持身體基座水平而無需附加之伺服機構，且所提出之機器人輪椅設計更顯示其相關操控程序之簡單性。上下螺旋階梯之動態模型則是依據側滑轉向分析所推導以作為軌跡規畫及運動分析。該運動模型主要是確使操控者可以開模式安全地操控該機器人輪椅。除此，本論文亦提出等效拘束法來規畫該機器人輪椅上下螺旋階梯之運動軌跡。模擬及實驗結果顯示該機器人輪椅可以動態轉向方式上下螺旋階梯。

關鍵詞 : 機器人輪椅、上下階梯、螺旋階梯、動態轉向、等效拘束運動規劃

目錄

參考文獻

[1]Jackson, R.,“ Robotics and its role in helping disabled people ”, Engineering Science and Education Journal, Vol. 2, Issue 6, 267-262, 1993.

[2]Jones, M.L., and Sanford, J.A.,“ People with mobility impairments in the United States today and in 2010 ”, Assistive Technology, 8:43 – 53, 1996.

[3]Cooper, R.A.,“ Engineering manual and electric powered wheelchairs ”, Critical Reviews in Biomedical Engineering, 27 (1&2): 27 – 73, 1999.

[4]Jones, M.K., and Sanford, J.A.,“ People with mobility impairments in the United States today and in 2010 ”, Assistive Technology, 8:43-53, 1996.

[5]Lachmann, S. M., Greenfield, E., and Wrench, A.,“ Assessment of need for special seating and/or electronic control systems for wheelchairs among people with severe physical disabilities ”, Clinical Rehanbilitation, 7:151-156, 1993.

[6]Wheelchair Foundantion was established by Kenneth E. Behring in June 13, 2000 at a ceremony on Capitol Hill in Washington, DC http://www.wheelchairfoundation.org [7]Kettle, M., Rowley, C., and Chamberlain, M.A.,“ A national survey of wheelchair users ”, Clinical Rehanbilitation, 6:67-73, 1992.

[8]Ashmore, R., “ Personal communication ” , May 2000.
[9]Wellman, P., Krovi, V., Kumar, V., and Harwin, W., “ Design of a wheelchair with Legs for people with Motor Disabilities ” , IEEE Transactions on Rehabilitation Engineering, Vol.3, No. 4, pp. 343-353, 1995.
[10]Hirose, S., Yoneda, K., Arai, K., and Ibe, T., “ Design of a quadruped walking vehicle for dynamic walking and stair climbing ” , Advanced Robotics, Vol. 9, No. 2, pp. 107-124, 1995.
[11]Pack, D.J., “ Perception-based control for a quadruped walking robot ” , in Proceedings of the IEEE International Conference on Robotics and Automation, pp. 2994-3001, 1996.
[12]Martens, J.D., and Newman, W.S., “ Stabilization of a mobile robot climbing stairs ” , in Proceedings of the IEEE International Conference on Robotics & Automation, pp. 2501-2507, 1994.
[13]Kagiwada, T., “ Robot design for stair navigation ” , JSME International Journal, Series C: Dynamics, Control, Robotics, Design and Manufacturing, Vol. 39, No3, pp. 629-635, 1996.
[14]Taguchi, K., “ Enhanced wheel system for step climbing ” , Advanced Robotics, Vol. 9, No. 2, pp. 137-147, 1995.
[15]Uchida, Y., Furuichi, K., and Hirose, S., “ Fundamental performance of 6 wheeled off-road vehicle HELOS-V ” , in Proc. of the 1999 IEEE International Conference on Robotics & Automation, pp. 2336-234, 1999.
[16]Kamen, D.L., Ambrogi, R.R., Heinzmann, J.D., Heinzmann, R.K., Herr, D., Morrel, J.B., “ Control of a balancing personal vehicle ” , US Patent 6 443 250, Sept. 3, 2002.
[17]Sunwa Stair-Ship TRE-52. Sunwa CO. Ltd. Sendagaya, Shiuya-ku, Tokyo Japan. www.sunwa-jp.co.jp.
[18]Lawn, M.J., Sakai, T., “ Development and practical application of a stair-climbing wheelchair in Nagasaki ” , Journal of Human Friendly Welfare Robotic Systems 2 (2), pp. 33_39, 2001.
[19]Hirose, S., Fukushima, E.F., Damoto, R., Nakamoto, H., “ Design of terrain adaptive versatile crawler vehicle HELIOS-VI ” , in: Proceedings 2001 IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS 2001, vol. 3, pp. 1540_1545, 2001.
[20]Yoneda, K., Ota, Y., Hirose, S., “ Development of a hi-grip stair climbing crawler with hysteresis compliant blocks ” , in: Proceedings of the 7th International Conference on Climbing and Walking Robots and the Support Technologies for Mobile Machines, CLAWAR, Madrid, Sept. 22_24, 2004.
[21]Ding, D., Cooper, R.A., Terashima, S., Yang, Y.S., Cooper, R., “ A study on the balance function of the iBOT transporter ” , in: Proc. RESNA 2004 Annu. Conf., Orlando, FL, 2004.
[22]Din, D., and Cooper, R.A., “ Electric-powered wheelchair ” , IEEE Control Systems Magazine, pp. 22-34, 2005.
[23]Miyagi, M., Uchida, T., Komeda, T., Komeda, H., and Funakubo, H., “ Development of stair climbing wheelchair with legs and wheels system (1st Report)-Development of stair climbing mechanism ” , Journal of the Japan Society for Precision Engineering(in Japanese), Vol.64, No.3, pp. 403-407, 1998.
[24]Bourbakis, N.G., “ Kydonas-an autonomous hybrid robots: walking and climbing ” , IEEE Robotics & Automation Magazine, pp. 52-59, 1998.
[25]Grand, C., Benamar, F., Plumet, F., Bidaud, P., “ Stability and traction optimized of a reconfigurable wheel-legged robot ” , The International Journal of Robotics Research 23 (10_11), 1041_1058, 2004.
[26]Hirose, S., Takeuchi, H., “ Study on roller-walk (basic characteristics and its control) ” , in: Proc. IEEE Int. Conf. on Robotics and Automation, pp. 3265_3270, 1996.
[27]Germann, D., Hiller, M., Schramm, D., “ Design and control of the quadruped walking robot ALDURO ” , in: Proc. of the 22nd International Symposium on Automation and Robotics in Construction, ISARC, Ferrara, Sept. 11_14, 2005.
[28]Lawn, M.J., Takeda, T., “ Design of a robotic-hybrid wheelchair for operation in barrier present environment ” , in: Proceedings of the 20th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, vol. 20(5), pp. 2678_2681, 1998.
[29]Lawn, M.J., and Ishimatsu, T., “ Modeling of a stair-climbing wheelchair mechanism with high single-step capability, ” IEEE Transaction on Neural Systems and Rehabilitation Research, Vol. 11, No. 3, pp. 323-332, 2003.
[30]Morales, R., Feliu, V., Gonzalez, A., and Pintado P., “ Kinematic model of a new staircase climbing wheelchair and its experimental validation ” , The international Journal of Robotics Research, Vol. 25, No. 9, pp. 825-841, 2006.
[31]Gonzalez, A., Morales, R., Feliu, V., and Pintado, P., “ Improving the mechanical design of new staircase wheelchair ” , Industrial Robot: An International Journal, Vol. 34, No. 2, pp. 110-115, 2007.
[32]Morales, R., Feliu, V., Gonzalez, A., “ Optimized obstacle avoidance trajectory generation for a reconfigurable staircase climbing wheelchair ” , Robotics and Autonomous Systems, Vol 57, p.97-114, 2010.
[33]Chen, C., Feng, C., and Hsieh, Y., “ Design and realization of a mobile wheelchair robot for all terrains ” , Advanced Robotics, Vol. 17, No. 8, pp. 739-760, 2003.
[34]Chen, C.T., and Pham, H.V., “ Design and Fabrication of a Statically-stable Stair-climbing Robotic Wheelchair, ” Industrial Robot, Vol. 36, No. 6, pp. 562-569, 2009.
[35]Argyros, A., Georgiadis, P., Trahanias, P., and Tsakiris, D., “ Semi-Autonomous Navigation of a Robotic Wheelchair ” , Journal of Intelligent

and Robotic Systems, vol. 34, no. 3, pp. 315-329, 2002.
[36]Kuo, C.H., Huang, H.L., and Lee, M.Y., " Development of Agent-Based Autonomous Robotic Wheelchair Control Systems " , Journal of Biomedical Engineering – Applications, Basis, Communications, vol. 15, no. 6, pp. 12-23, Dec. 2003.
[37]Dalvand, M.M., and Moghadam, M.M., " Stair Climber Smart Mobile Robot (MSRox) " , Autonomous Robots, Vol 20, No 1, pp. 3-14, Issue 1 January 2006.
[38]Morales, R., Feliu, V., Gonzalez, A., and Pintado, P., " Kinematics of a New Staircase Climbing Wheelchair " , Proceedings of the 7th International Conference CLAWAR, 2004.
[39]Wong, J. Y., " Theory of ground vehicles, " John Wiley & Sons, INC., 1993.
[40]Henami, H., and Weimer, F.C., " Modeling of nonholonomic dynamic systems with applications " , Journal of applied mechanics, Vol. 48, March, 1981.