創新型機器人輪椅上下螺旋階梯之運動分析

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ABSTRACT

This study presents the mechanical design, stability analysis, the locomotion and the associated dynamic models of a new robotic wheelchair on climbing stairs. The prototype stair-climbing robotic wheelchair is constructed comprising a pair of rotational multi-limbed structures pivotally mounted on opposite sides of a support base so that the robotic wheelchair can ascend and descend stairs; especially, capability of climbing winding stairs is addressed. In additional, the short arm, long arm and triangular support structures within each rotational multi-limbed structure rotate under the actuating effects of epicyclical gear trains. The rotational multi-limbed mechanisms are developed to solve for the stair-climbing whilst ensuring the stability of the sitting base at all stages of the stair navigation maneuver without the need for additional servo-mechanisms, and the proposed robotic wheelchair shows the simplification of the associated operation process. Based on the skid-steering analysis, the dynamic models for climbing winding stairs are developed for the trajectory planning and motion analyses. These models are required to ensure a passenger ’ s safety in such a way that the robotic wheelchair is operated in an open mode. Moreover, an equivalent constraint method is proposed for the prescribed motion of the robotic wheelchair on climbing winding stairs. The results of the simulation and maneuver are reported that show the behavior of the prototype as it climbs a winding stair in a dynamic turning.

Keywords : Robotic wheelchair、stair-climbing、winding stair、dynamic turning、equivalent constraint motion planning

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REFERENCES

[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.