無人自行車之動態模擬與控制

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摘 要

在本篇論文中，以Lagrange ’ s equations 的方式來推導腳踏 車之動態方程式，以系統之動態方程式來考慮地面和兩輪純滾動 之限制條件，每一輪的微分疊代方程式都有兩個完整和兩個非完 整限制條件，把所有的限制條件以向量形式轉換為Jacobian 矩 陣， 並討論以疊代法搜尋腳踏車之平衡點，當中也提出如何計算 輪胎與地面接觸的曲率半徑和參考點之比較。 為要求解動態的DAEs 和確定模擬數值解之精確性，文中 也提到如何處理限制條件之計算方法。從動態模型的建立，到 PID 和模糊控制器之建立，並產生把手轉動力矩使得傾倒的腳踏 車可以重新再為持平衡，然而再利用另一個模糊控制器控制腳踏 車到想要的平衡點，在保持平衡時，腳踏車會維持在一個參考的 滾動角，並且以腳踏車與參考軌跡的最短距離及腳踏車前進的方 向來計算控制量，因此無人騎乘的腳踏車會跟隨地面的軌跡移 動，由模擬結果可以知道這方法是可行的。 最後，使用基因演算法來訓練模糊控制器於多變的控制任 務，像自我平衡、滾動角跟隨和軌跡跟隨，模擬結果顯示這個方 法有非常快速的訓練效果，在幾代的疊代後，就可以產生極佳的 控制參數，使控制器有極好的控制性能。

關鍵詞 : 腳踏車動態方程式，多體，數值穩定，模糊控制，路徑 跟隨，腳踏車之穩定，基因演算法。

目錄

參考文獻

[1] Abbortt, M.S., Kinematics, Dynamics and Control of Single-Axle, Two-Wheeled Vehicles (Biplanar Bicycles), M.Sc. Thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia,2000.

[2] Amirouche, F.M.L., Computational Methods in Multibody Dynamics, Prentice-Hall, New Jersey, 1992.

[3] Ascher, U.M, Chin, H. and Reich, S., ‘ Stabilization of DAEs and Invariant Manifolds ’, Numerische Mathematik, vol. 67, no. 2, 1994, pp. 131--149.

[4] Baruh, H., Analytical Dynamics, McGraw-Hill, Singapore, 1999.

[5] Baumgarte, J., ‘ Stabilization of Constraints and Integrals of Motion in Dynamical Systems ’ , Comput. Methods Appl. Mech. Eng., vol. 55, 1972, pp. 1--16.
[6] Berriah, S. and Lachiver, G., ‘ Control of Equilibrium and Trajectory of a Remotely Controlled Bicycle ’ , in Proc. of the IEEE Canadian Conference on Electrical and Computer Engineering 2,1999, 1014--1019 (in French).
[7] Beznos, A.V., Formal ’ sky, A.M., Gurfinkel, E.V., Jicharev, D.N., Lensky, A.V., Savitsky, K.V. and Tchesalin, L.S., ‘ Control of Autonomous Motion of Two-Wheeled Bicycle with Gyroscopic Stabilization ’ , in Proc. of the 1988 IEEE International Conference on Robotics & Automation 3, Leuven, Belgium, 1988, 2670--2675.
[8] Chan, P.T., Rad, A.B. and Tsang, K.M., ‘ Optimization of Fused Fuzzy Systems via Genetic Algorithms ’ , IEEE Trans. Industrial Electronics, vol. 49, no. 3, pp. 685-692, 2002.
[9] Chen. C.K., Dao, T.S. and Yang, C.K., ‘ Turning Dynamics and Equilibrium of Two-Wheeled Vehicles ’ , to appear in KSME Int. J.
[10]Chen, P.H., ‘ A Scheme of Fuzzy Training and Learning Applied to Elebike Control System ’ , in Proc. of the Ninth IEEE International Conference on Fuzzy Systems 2, 2000, 810--816.
[11] Chin, H.S, ‘ Stabilization Methods for Simulations of Constrained Multibody Dynamics ’ , Ph.D dissertation.
[12] Chipperfield, A., Fleming, P., Pohlheim, H. and Fonseca, C., Genetic Algorihm Toolbox for Use with MATLAB, Version 1.2.
[13] Choi, M.H., Min, H. and Welch, S., ‘ Implicit Constraint Enforcement for Stable and Effective Control of Cloth Behavior ’ , A Technical Report from Univ. of Colorado at Denver, Computer Science and Engineering Department TR-03-01, 2004.
[14] Cline, M.B. and Pai, D.K., ‘ Post-Stabilization for Rigid Body Simulation with Contact and Constraints ’ , Proc. of IEEE International Conference on Robotics and Automation, ICRA ’ 03, vol. 3, 2003, pp. 14--19.
[15] Getz, N.H., ‘ Control of Balance for a Nonlinear Holonomic Non-Minimum Phase Model of a Bicycle ’ , in Proc. of the American Control Conference, Baltimore, American Control Council, 1994.
[16] Getz, N.H., ‘ Internal Equilibrium Control of a Bicycle ’ , in Proc. of the 34th IEEE Conference on Decision and Control, New Orleans, 1995, 4285--4287.
[17] Getz, N.H. and Marsden, J.E., ‘ Control for an Autonomous Bicycle ’ , in Proc. of the IEEE International Conference on Robotics and Automation 2, 1995, 1397--1402.
[18] Goldberg, D.E., Genetic Algorithms in Search, Optimization, and Machine Learning, Addison-Wesley, 1989.
[19] Han, S., Han, J. and Ham, W., ‘ Control Algorithm for Stabilization of Tilt Angle of Unmanned Electric Bicycle ’ , Transaction on Control, Automation and Systems Engineering 3,2001, 176--180.
[20] Hu, Y. and Yang, S.X., ‘ A Fuzzy Neural Dynamics Based Tracking Controller for a Nonholonomic Mobile Robot ’ , in Proc. of the 2003 IEEE/ASME Int. Conference on Advanced Intelligent Mechatronics, 2003, vol. 1, pp. 205-210.
[21] Hubbard, J.H. and Hubbard, B.B., ‘ Vector Calculus, Linear Algebra, and Differential Forms: a United Approach ’ , 2nd ed., Prentice Hall, 2002.
[22] Jeon, H., Choi, M.H. and Min, H., ‘ Numerical Stability and Convergence Analysis of Geometric Constraint Enforcement in Dynamic Simulation Systems ’ , Proc. of International Conference on Modeling, Simulation and Visualization Methods, 2004.
[23] Johns, D.E.H., ‘ The Stability of the Bicycle ’ , Physics Today 23(4), American Institute of Physics, 1970, 34--40.
[24] Klein, R.E., ‘ Using Bicycle to Teach System Dynamics ’ , IEEE control system magazine 9(3), 1989, 4--9.
[25] Lee, S. and Ham. W., ‘ Self Stabilizing Strategy in Tracking Control of Unmanned Electric Bicycle with Mass Balance ’ , in Proc. of the 2002 IEEE/RSJ International Conference on Intelligent Robots and Systems 3, 2002, 2200--2205.
[26] Lee, T.H., Lam, H.K., Leung, F.H.F. and Tam, P.K.S., ‘ A Practical Fuzzy Logic Controller for the Path Tracking of Wheeled Mobile Robots ’ , IEEE Control Systems Magazine, vol. 23, no. 2, pp. 60-65, 2003.
[27] Lee, Y. and Zak, S.H., ‘ Genetic Fuzzy Tracking Controllers for Autonomous Ground Vehicles ’ , in Proc. of the 2002 IEEE American Control Conference, 2002, vol. 3, pp. 2144-2149.
[28] Min, H., Choi, M.H. and Yelluripati, R., ‘ Intuitive Control of Deformable Object Simulation using Geometric Constraints ’ , Conference on Imaging Science, Systems, and Technology (CISST), 2003.
[29] Passino, K.M. and Yurkovich, S., Fuzzy Control, Addison-Wesley, 1998.
[30] Schwab, A.L., Meijaard, J.P. and Papadopoulos, J.M., ‘ Benchmark Results on the Linearized Equations of Motion of an Uncontrolled Bicycle ’ , in Proc. of the ACMD, Korea, 2004, 143--151.
[31] Suryanarayanan, S., Tomizuka, M. and Weaver, M., ‘ Dynamics and Control of Bicycles at High Speeds ’ , Proc. of the American Control Conference 2, 2002, 845--850.
[32] Tan, G.V. and Hu, X., ‘ On Designing Fuzzy Controllers Using Genetic Algorithms ’ , in Proc. of the Fifth IEEE International Conference on Fuzzy Systems, 1996, vol. 2, pp. 905-911.
[33] Timoshenko, S. and Young, D.H., Advanced Dynamics, McGraw-Hill, New York, 1948, 239--240.
[34] Yavin, Y., ‘ Stabilization and Control of the Motion of an Autonomous Bicycle by Using a Rotor for Tilt Moment ’ , Compute. Methods Appl. Mech. Engrg. 178, 1999, 233--243.

[35] Yen, J. and Langari, R., Fuzzy Logic: Intelligent, Control, and Information, Prentice Hall, New Jersey, 1999.
[36] Zhou, Y.S. and Lai, L.Y., ‘ Optimal Design for Fuzzy Controllers by Genetic Algorithms ’, IEEE Trans. Industrial Applications, vol. 36, no. 1, pp. 93-97, 2000.