Obstacle Climbing Improvement of Wheeled Mobile Robots with Extendable Bodies

Saeed Ebrahimi[1], Arman Mardani[2]

[1] *Associate Professor, Department of mechanical engineering, Yazd University, ebrahimi@yazd.ac.ir*
[2] *PhD Student, Department of mechanical engineering, Yazd University,yovas1369@gmail.com*

Wheeled mobile robots have usually comprised of main bodies with fixed geometry. Such mobile robots cannot adjust the tractive friction forces by changing the normal forces of their wheels when facing hard situations. Some previous studies imply that a subtle change in the rover geometry obviously increases the performance of the rovers [1-3]. This research presents a new rover with an extendable body to achieve an overall control on the normal forces of the wheels during obstacle climbing. For this purpose, a couple of scissor mechanisms is exploited in the rover body to achieve a rigid transformation of the main body [4]. Figure 1-a shows the overall form of the new rover. The two scissor mechanisms shown in Fig. 1, which are constrained by a yellow slot part, are the core of the new idea. Variations of the scissors length (variables x_f and x_r) specify the location of the CG with respect to the body coordinate system $X_r Y_r Z_r$ for proper distribution of the body weight on the front and rear axes of the robot. In this way, the normal forces and consequently, the tractive friction forces of the wheels can be controlled to improve the obstacle climbing process.

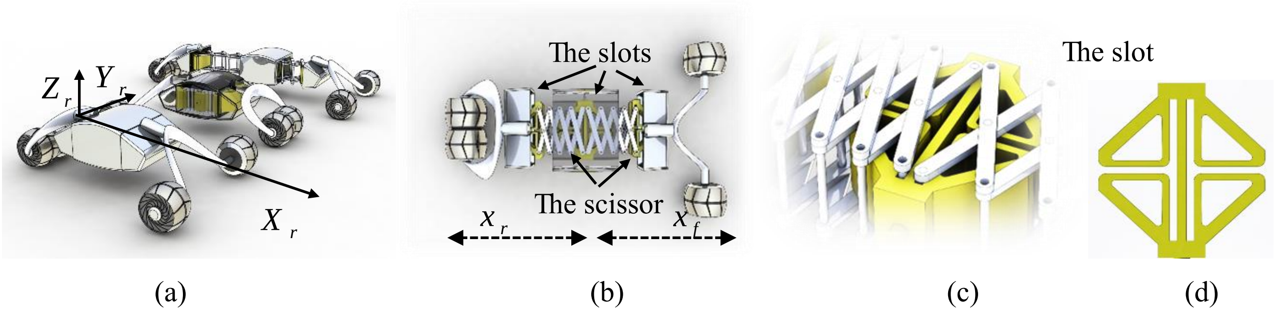

Fig. 1: The new transformable rover. (a): The rover, (b): The scissor mechanisms of the rover, (c): Scissor pin and slot part, (d): Slot part

The control algorithm of the scissor length and slip reduction is illustrated in Fig. 2. The main idea is to control the variables x_f and x_r using the vertical component of the normal force vector $\mathbf{N}_i\,(i=f,r)$ [5] by solving the following system of linear equations

$$[0\ \ 0\ \ 1]\mathbf{N}_f X_f - [0\ \ 0\ \ 1]\mathbf{N}_r X_r = 0\ , \qquad X_f + X_r = \text{constant}. \tag{1}$$

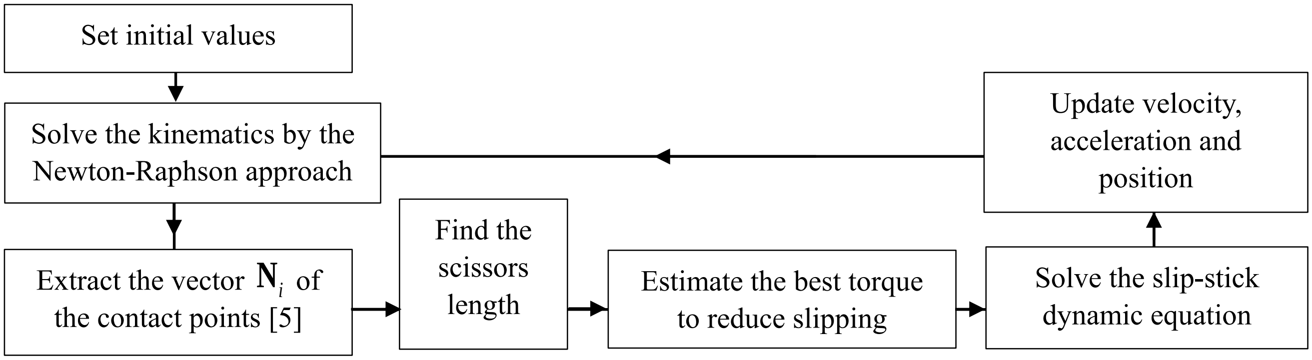

Fig. 2: The algorithm of the simultaneously slip reduction and obstacle climbing

The constant in this equation is a user-defined value which is equal to 2m in this case according to the structural limitation of the scissor mechanisms. The simulation results of the obstacle climbing during 12 seconds indicates the success of the new idea as shown in Fig. 3. The height of the obstacle is 1.5 m, the total mass of the main body is 15 kg and the mass of each wheel is 1 kg. The simulation is 3D but it is illustrated from side view as a 2D plot.

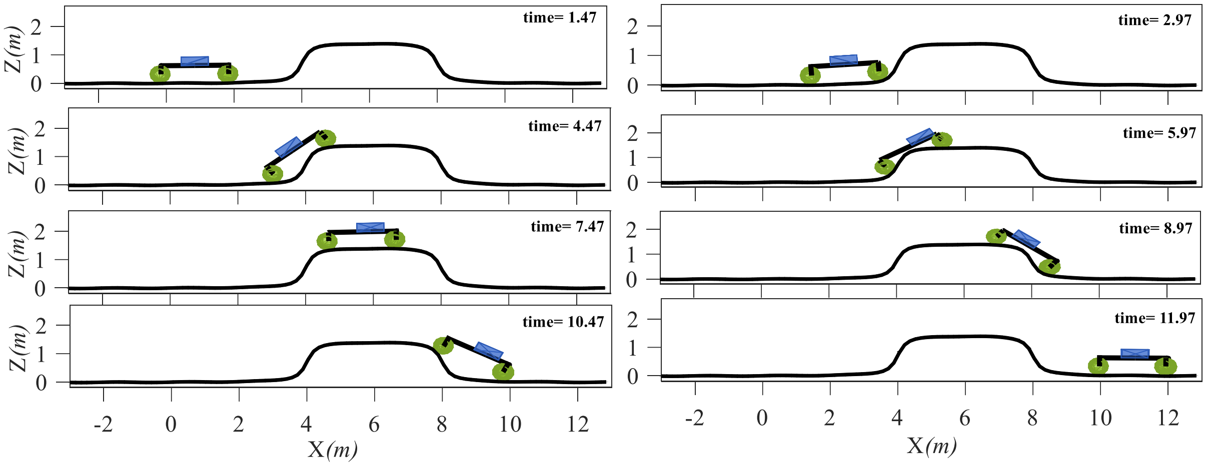

Fig. 3: The sequences of obstacle climbing

The adjusted normal forces of the front and rear wheels and the scissors length are illustrated in Fig. 4. According to these plots, a clear relation between variation trend of the scissors length and the normal forces of the wheels can be seen.

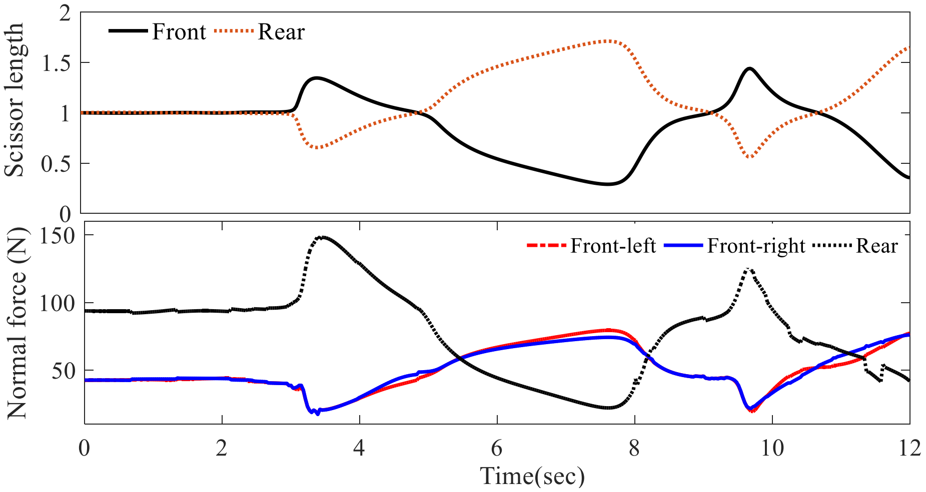

Fig. 4: Variation of the scissors length and the normal forces of the wheels.

References

[1] S. Ebrahimi, A. Mardani, "Terramechanics-based performance enhancement of the wide robotic wheel on the soft terrains, Part I: wheel shape optimization," *The 2017 International Conference on Robotics and Mechatronics, ICROM* October, Tehran, Iran, 2017.

[2] A. Mardani, S. Ebrahimi, "Terramechanics-based performance enhancement of the wide robotic wheel on the soft terrains, Part II: torque control of the optimized wheel," *The 2017 International Conference on Robotics and Mechatronics, ICRoM* , October , Tehran, Iran, 2017.

[3] A. Mardani, S. Ebrahimi: "A Novel Multimode Mobile Robot with Adaptable Wheel Geometry for Maneuverability Improvement", *International Journal of Robotics*, vol. 4, pp. 1-15, 2016.

[4] F. Maden, K. Korkmaz & Y. Akgün, "A review of planar scissor structural mechanisms: geometric principles and design methods," *Architectural Science Review*, vol. 54, no. 3, pp. 246-257, 2011.

[5] A. Mardani & S. Ebrahimi, "Simultaneous surface scanning and stability analysis of wheeled mobile robots using a new spatial sensitive shield sensor". *Robotics and Autonomous Systems*, vol. 98, pp. 1-14, 2017.