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The Concept Design of the Stable Linkage Mechanism on the Rough Terrain

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Abstract: The stabile metric of the mobile robots is uncommon in mobile robotics even though stability is important issue for a mobile robot to do its work. Therefore, it is difficult to compare stability of mobile robots on the rough terrain. This paper suggests the stability metric for wheel linkage mobile robots to compare robot's stability on a rough terrain. The stability metric contain the limit height change, the limit angle change, and the height change of the center of mass of a robot when it overcomes a threshold. Well-known wheel linkage mobile robots are unified to compare their stability, and simulations are performed to calculate the robots stability. Base on the comparison, the new linkage mobile robot called "RHyMo" was suggested, and its stability also calculated. The RHyMo has lowest S.M. value, so that the robot has high stability on the rough terrain.

Keywords: wheel -linkage mechanism, rough terrain, the stability metric.

1. INTRODUCTION

As robots are not only work in one place but also moves place to place to do a work, maneuverability of the robot are getting important to mobile robot. For this reason many researches of mobile robots are focusing on overcoming a higher threshold or reduce the required friction coefficient to overcome a terrain. To do the work, mobile robot has to carry an actuators or some stuff in the robot. If the robot are not stable and has large vibration while traveling on a rough terrain, an actuators and stuffs can be damaged. Therefore, it is important that the mobile robot has to have high maneuverability and also have high stability.

Mobile robots can be divided in to two groups; the wheel linkage mechanism and the caterpillar mechanism. The caterpillar mechanism can overcome a high obstacles or rough terrains easily by using tracks attached on both side of a robot. A caterpillar mechanism robot also has high maneuverability on urban environment, therefore it is widely used on mobile robot, especially on rescue robots or army robots [1]. However, since the main body attached with a track (see figure 1), vibration on the track directly effect to a main body and this make a low stability. Therefore the caterpillar mechanism has limited be a mobile robot which has high maneuverability and high stability.

On the other hand, wheel linkage mobile robots have stability though the linkage suspension system. The rocker bogie mechanism is the most famous mechanism for a wheel linkage mechanism [2]. With the passive joint on the linkage, the rocker bogie can overcomes a high obstacles without changes it height a lot. Other rover mechanisms such as RCL-E[3], CRAB[4], ORF-L[5], and wheeled mobile robot (WMR)[6] are studied to improve the rovers maneuverability and stability. Maneuverability of the robots was compared by a maximum friction coefficient when the robots overcome a threshold [7]. However there are no metrics that calculate the stability of the robots.

The rest of the paper is proposing the stability metric for mobile robots and suggest the new linkage mechanism which has high stability on a rough terrain. Chapter 2 described the definition of the stability metric of a mobile robot. Chapter 3 compared the wheel linkage mobile robots though the stability metric. The new linkage mechanism which has stability is suggested on Chapter 4. Lastly, Chapter 5 presents the conclusion of the paper.

2. THE STABLITY METRIC

To compare the stability of mobile robots while traveling on a rough terrain, the metric of stability has to be defined. A rough terrain can be defined as combination of thresholds. If a robot is stable while

Fig 1. I-robot packbot

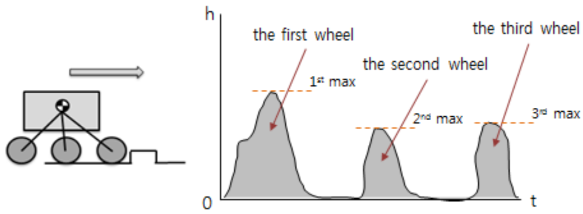


Fig 2. The height change of the center of mass when the robot overcoming a threshold.

overcoming a threshold, it can be said that the robot will be stable on a rough terrain. The maximum height of thresholds was set as the wheel radios, because it is the height that a robot could overcomes without any control.

To compare stabilities of robots, the height and angle changes of a center of masses have to be considered. The limit height change of a center of mass was set to evaluate the stability. If a robot's maximum height change while overcoming a threshold is higher than the limit height change, the robot can be said not stabile. The limit angle change was set also, and the meaning is as same as the limit height change. The H_{limit} and the θ_{limit} is defined as follows;

H_{limit}= the maximum height change of the center of mass when the 4 wheel car overcomes the threshold. (50 % of the threshold height).

θ_{limit}= the angle that does not make high vibration on a stuff inside a robot. (10 degree)

If a robot's maximum height change and maximum angle change are small than its limit value, the stability metric can be considered. The figure 2 shows the height change of the center of mass of a robot when it overcoming a threshold. The height of the center of mass will be change when each wheels contact the threshold. The number of maximum height and the maximum angle are same as the wheel number. By geometric condition of a robot, the maximum heights when the i-th wheel contacts the thresholds and holes can be calculated. To make the data as non-dimensional value, the heights were divided by the height of a threshold.

$$y_{hi_{step}} = {h_{i\_step}} / {H_{threshold}} \qquad (1)$$

Since positive and negative values are existed, the root mean square for the height changes was used for the stabile metric of a mobile robot.

$$S.M. = \sqrt{\left(\frac{\sum (y_{hi_{step}})^2}{n}\right)} \qquad (2)$$

The n is number of wheels on a side. By calculating the S.M. value for the mobile robots, the stability of the robots can be compared.

3. THE STABILITY OF WHEEL LINKAGE MOBILE ROBOTS

3.1. The wheel linkage mobile robots

Many kinds of the wheel linkage mobile robots are studied to improve the rover mechanism. The RCL-E is the linkage mechanism which has parallel bogie on the rocker bogie mechanism [3]. The parallel bogie make the robot could overcome a sharp terrain that the rocker bogie cannot overcome. The CRAB has parallel bogie on the front and the back, therefore the CRAB shows high performance while moving backward [4]. The ORF-L is the mechanism name from "Obverse reverses four-linkage mechanism". With obverse linkage mechanism and reverse four-linkage mechanism, the ORF-L has high climb ability and small height changes on the center of the mass [5]. For the last, the wheel mobile robot (WMR) modified the rocker mechanism, so that it increases the stair climbing ability [6].

The robots pictures and the schematics are showed in table1. For comparing the S.M., all sizes of the robots are unified. Wheel radiuses, distance between wheels, and the position of the center of mass are set as same dimension. The main point is comparing the S.M. on different suspension mechanisms, therefore all other parameters are set-up in an objective way.

Table 1 The pictures and the schematic of the wheel linkage mobile robots

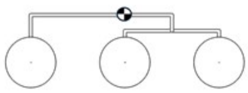
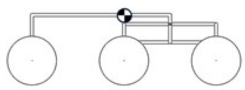
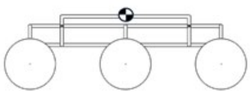
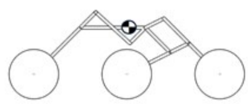
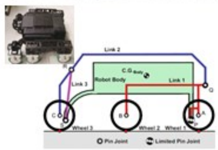
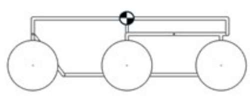
	Robot picture	Schematic
Rocker Bogie [2]		
RCL-E [3]		
CRAB [4]		
ORF-L [5]		
WMR [6] Wheeled mobile robot		

Table 2. The height change, the angle change, and the S.M. value of the wheel linkage mobile robots

Robot mechanism		The height and angle change of the C.M. when the first wheel on the threshold		The height and angle change of the C.M. when the second wheel on the threshold		The height and angle change of the C.M. when the third wheel on the threshold		S.M.
		Height (mm) h_{1_step}	Angle (degree) θ_{1_step}	Height (mm) h_{2_step}	Angle (degree) θ_{2_step}	Height (mm) h_{3_step}	Angle (degree) θ_{3_step}	
1	Rocker bogie	23.97	4.68	23.97	4.68	25.39	10.40	0.3057 X (large angle change)
2	RCL-E	26.07	5.10	26.07	5.10	24.28	10.24	0.3186 X (large angle change)
3	CRAB	27.68	7.04	35.87	2.68	27.68	8.42	0.3832
4	ORF-L	32.03	6.30	13.95	2.70	31.08	9.02	0.3375
5	WMR	48.89	5.00	7.14	3.38	43.41	9.82	0.4747 X (large height change)
6	RHyMo	22.72	7.23	21.02	0.06	25.40	7.30	0.2890

3.2. The stability metrics of the mobile robots

The stability metric of the mobile robots were calculated for each mechanism. To calculate the height and angle change of the center of mass, each mechanism is modeled by three-dimensional (3-D) modeling tool (Version 2012, SolidWorks, Dassault Systems, Concord, MA, USA). The radios of wheels are 80 mm, the distances between wheels are 300 mm, and the center of mass is located 150 mm above from the middle wheel.

By changing the wheels height, the height and angle change of a center of mass can be measured. The value of the height and the angle, value of the S.M. of each robot are showed in table 2. If S.M. is small, it means the height change will be small when traveling on rough terrain. From the table 2, the maximum angle change of the Rocker bogie and the RCL-E is larger than the limit angle change, so that the robots are not stable on the rough terrain. On the case of the WMR, the maximum height change is higher than the limit height change, therefore the robots are not stable on the rough terrain also.

The CRAB has the small S.M. value than the ORF-L, and it means the CRAB's height change on the rough terrain will be smaller than the ORF-L's change. The CRAB's average height change on the rough terrain will be 38.32 % of the terrain obstacle.

4. THE STABILE LINKAGE MECHANISM

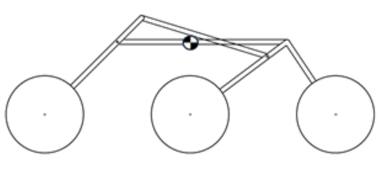


Fig 3. The Schematic of the RHyMo

Base on the analyze data above, new linkage mechanism call "RHyMo" was suggested. (Fig. 3) See the rocker bogie's height and an angle change value on the table 2, the rocker bogie has small height change for all wheels. However the angle change when the third wheel on the threshold is large. Therefore, starting from the rocker bogie mechanism, one additional linkage is attached on the rocker linkage to reduce the angle change of third wheel. The new linkage mechanism includes reverse four bar linkage mechanism which makes small angle change on the center of mass.

The S.M. value of the RHyMo was calculated in a same way, and the result is on the table 2. The RHyMo has small height changes like the rocker bogie mechanism and also has small angle change like the CRAB mechanism. The S.M. value is smallest, so that the stability on the rough terrain of the RHyMo will be best for the mobile robots.

5. CONCLUSION

The mobile robot has to be has not only high maneuverability but also has high stability on the rough terrain. To calculate the stability of mobile robots, the stability metric was defined on the paper. With the stability metric, stabilities of the mobile robots are calculated and the stabilities of the robots were compared. The new linkage mechanism called "RHyMo" was suggested and the S.M. value was measured. The RHyMo has smallest S.M. value which means the robot make small height change while traveling on a rough terrain. For the future work, a prototype of the RHyMo will be manufactured and the stability of the robot will be tested.

6. ACKNOWLEDGMENT

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