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Improved Mecanum Wheel Design for Omni-directional Robots

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Abstract

Omni-directional is used to describe the ability of a system to move instantaneously in any direction from any configuration. Omni-directional robotic platforms have vast advantages over a conventional design in terms of mobility in congested environments. They are capable of easily performing tasks in environments congested with static and dynamic obstacles and narrow aisles. These environments are commonly found in factory workshops offices, warehouses, hospitals and elderly care facilities.

This paper proposes an improved design for a Mecanum wheel for omni-directional robots. This design will improve the efficiency mobile robots by reducing frictional forces and thereby improving performance.

1 Introduction

Flexible material handling and movement, with real-time control, has become an integral part of modern manufacturing. AGV's are used extensively in flexible manufacturing systems to move parts and to orient them as required (Kalpakjian, Schmid, 2000). Many designs of omni-directional or near omni-directional vehicles have been proposed. These can generally be broken into two approaches: conventional wheel designs and special wheel designs.

Conventional wheels are mechanically simple, have high load capacity and high tolerance to work surface irregularities. However, due to their non-holonomic nature, they are not truly omni-directional. Designs have been proposed to achieve near omni-directional mobility using conventional wheels. The most common designs are those using steered wheels (Boreinstein, et al., 1996). Vehicles based on this design have at least two active wheels, each of which has both driving and steering actuators. They can move in any direction from any configurations. However, this type of system is not truly omni-directional because it needs to stop and re-orient its wheels to the desired direction whenever it needs to travel in a trajectory with non-continuous curvatures (Dubowsky, Skwersky, Yu, 2000).

Most special wheel designs are based on a concept that achieves traction in one direction and allow passive motion in another, thus allowing greater flexibility in congested environments (West and Asada, 1997). One of the more common omni-directional wheel designs is that of the Mecanum wheel, invented in 1973 by Bengt Ilon, an engineer with the Swedish company Mecanum AB. Many of the other commonly currently used designs are based on Ilon's original concept.

2 The conventional Mecanum wheel

Ilon's Mecanum wheel is based on the principle of a central wheel with a number of rollers placed at an angle around the periphery of the wheel. The angled peripheral rollers translate a portion of the force in the rotational direction of the wheel to a force normal to the wheel direction. Depending on each individual wheels direction and speed, the resulting combination of all these forces produces a total force vector in any desired direction thus allowing the platform to move freely in the direction of the resulting force vector, without changing the direction of the wheels themselves.

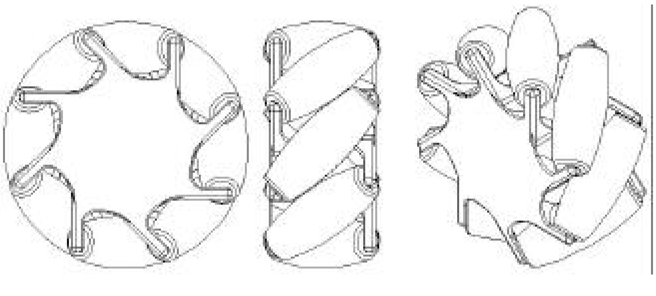


Figure 1: Mecanum wheel based on Ilon's concept

The design in figure 1 shows a traditional Mecanum wheel with the peripheral rollers held in place from the outside. This design, though having a good load carrying capacity, has the disadvantage that, when encountering an inclined or an uneven work surface, the rim of the wheel can make contact with the surface instead of the roller, thus preventing the wheel form operating correctly. This is illustrated in figure 2.

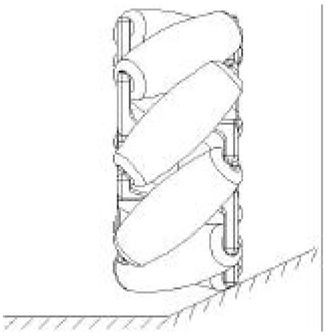


Figure 2: Traditional Mecanum wheel on inclined surface

A simple alternative design, also proposed by Ilon, which alleviates this problem, consists in having the rollers split in two and centrally mounted as shown in figure 3:

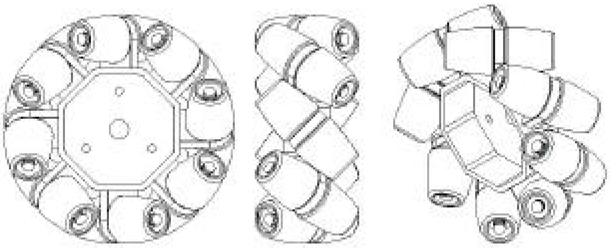


Figure 3: Mecanum wheel with centrally mounted rollers

This design ensures that the rollers are always in contact with the work surface, thus allowing for better performance on uneven surfaces.

3 Controlling a vehicle with Mecanum wheels

For a vehicle using Mecanum wheels to achieve omni-directional movement, the wheels are arranged on the platform in a configuration as shown in figure 4:

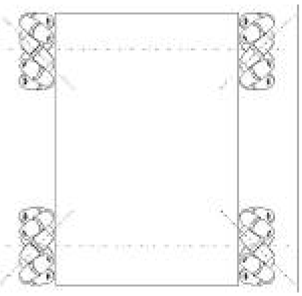


Figure 4: Mecanum wheel configuration for omni-directional vehicle

Depending on the direction of the motors, the wheels always produce both a forward or reverse force, as well as an inward or outward force, caused by the angled peripheral rollers. Depending on the resulting combination of these forces, the platform can be controlled to move in any direction, as seen in Table 1. A variety of other motions are possible by varying the direction and speeds of the wheel.

Though incredibly versatile, the standard Mecanum wheel has an unfortunate side effect which reduces its efficiency considerably. Its wide range of mobility is due to the fact that the peripheral rollers translate a portion of the motor force into a force perpendicular or at an angle to that produced by the motor. This means that are large portion of the force in one direction is lost though the translation into a resulting force by the rollers. As an extreme example of this inefficiency, when the platform travels diagonally, only a front and rear opposing wheels are spinning whilst the rollers on the other two wheels cause direct drag that the motors must fight against.

4 Improved design with a "Twist"

This paper proposes two methods to improve the efficiency of the Mecanum wheels; the first is a mechanically simple method of improving the energy losses when the AGV platform is traveling in a straight line. The second is mechanically more complex, but proposes a model in which the peripheral rollers have the capability of having their angles dynamically adjusted to best suit the direction the platform is traveling in.

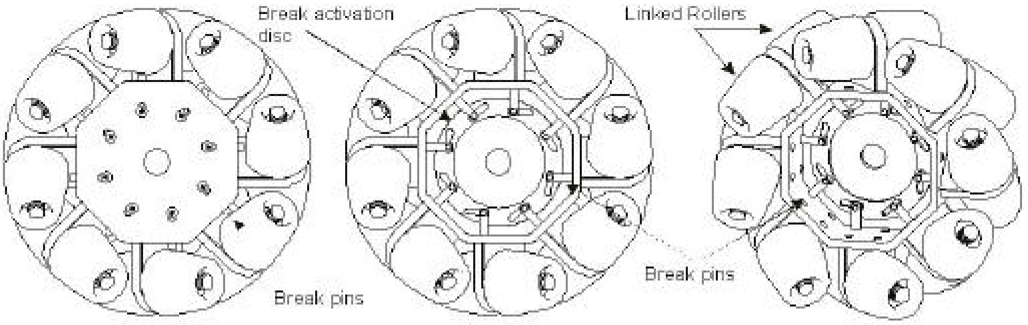


Figure 5: Mecanum wheel with lockable rollers

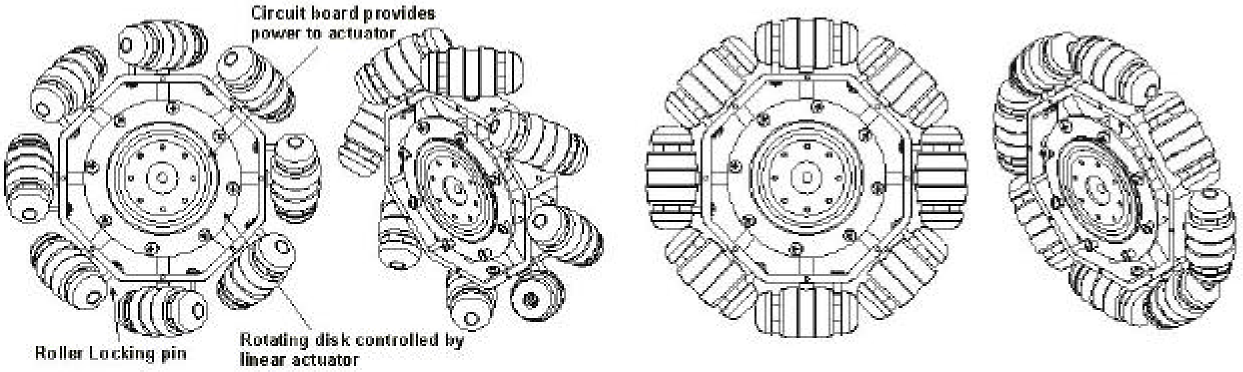


Figure 6: Mecanum wheel with rotatable rollers

Losses of efficiency when traveling in a straight line are due to energy lost in a direction normal to that of travel through the peripheral rollers which bleed off available energy as they rotate. Through the addition of a simple mechanical device that allows us to lock the peripheral rollers, we now have a wheel, which when traveling straight has its peripheral rollers locked, thus effectively forming a normal tire, but when traveling sideways has the rollers unlocked thus allowing for the flexibility of the Mecanum sideways screw motion. This is illustrated in Figure 5.

A simple actuator is used to rotate the brake activation disc enough to raise the brake pins until they make contact with the rollers, thus preventing their rotation. The effect of the locked rollers is similar to that of a tire with a heavy tread. This method is effective in reducing any lost forces in the forward direction to zero, but does not improve the losses in any other directions.

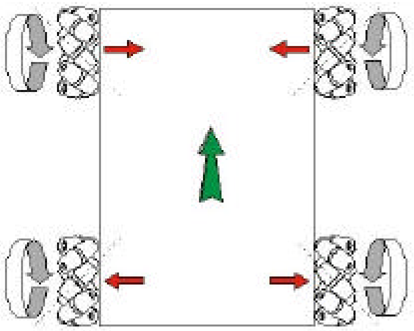
The second method is more effective, but mechanically slightly more complex. Refer to figure 6.

The peripheral rollers are split and centrally mounted on an axle which can be pivoted through 135°. This allows the rollers to be adjusted from a straight position, (in which they are also locked so the rollers cannot rotate on their axles) thus effectively forming an almost normal treaded tire, to an angle of 45° in which case they act as a traditional Mecanum wheels, or to an angle of 135° making diagonal travel easier as it overcomes the resistance given be the traditionally immobile wheels.

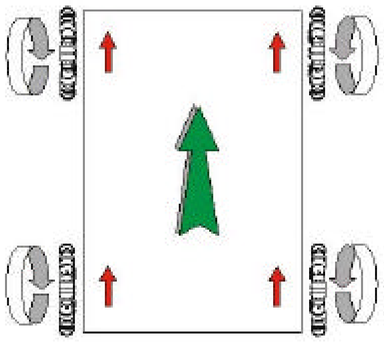
The table below shows a comparison of a conventional Mecanum wheel design with the improved design. The large central green arrows show the direction of travel. The smaller red arrows show the force produced by the peripheral rollers. The outer circular arrows show the wheel spinning direction and thus also represent the force direction caused by the motor direction.

Improved Forward Motion Efficiency

Conventional Design: The peripheral rollers on the front wheel create a resulting inwards force, but the equal and opposite resulting force caused by the rear wheel peripheral rollers cancels this out. The only remaining force is that in the direction the wheels are turning.



Improved Design: Rollers at 0°: The rollers form a conventional tire, allowing the platform to move forward without any losses. The rollers are also locked, thus preventing any undesired sideways motion.



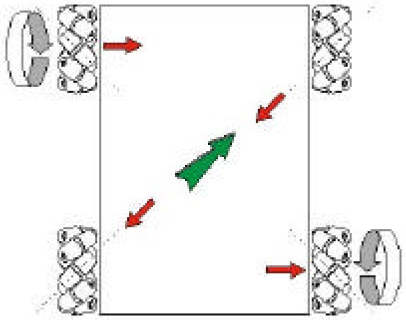
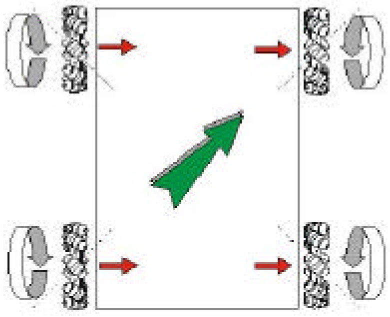
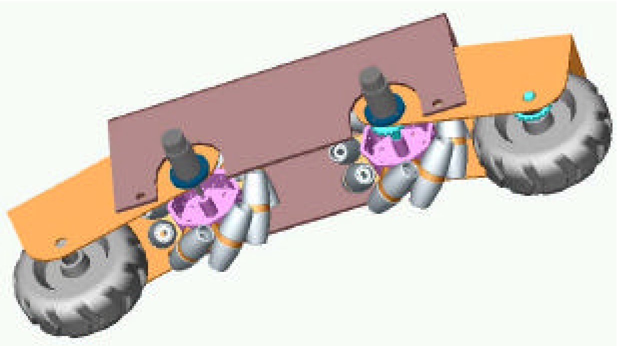
Improved Diagonal Motion Efficiency
Conventional Design: Diagonal travel can be achieved by moving a front wheel and opposite rear wheel at one speed while the other wheels turn at a different speed. The peripheral rollers on the fast turning wheels produce a large force in one direction whilst the slow moving wheels produce a smaller force in the opposite direction. The resulting vector is diagonal. The other 2 wheels do not move and therefore create a drag on the system.

Improved Design: Front right and rear left rollers at 135°. The front right and rear left rollers which were causing direct drag in the conventional design now not only cause no drag, but the wheels can also be rotated to add to the diagonal motion speed.


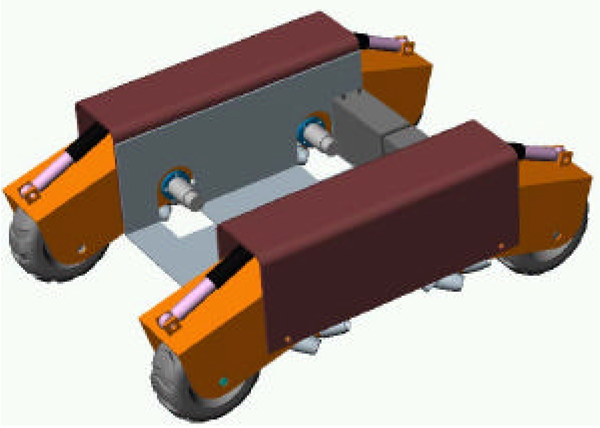
Table 1: Improved motion using Mecanum wheel with rotatable rollers

The angle of the rollers on each wheel is controlled through all the roller shafts being connected through a bevel gear system in such a way that a rotary actuator on one of the shafts controls all the others simultaneously. It then only necessitates a simple software algorithm to determine the ideal angle for each set of rollers depending on the desired direction of travel.

5 Application of improved design Mecanum wheel on a mobile robot

The Mechatronics and Robotics Research Group (MR^{2}G) at Massey University have developed an all-terrain AGV using both a set Mecanum wheels and a set of conventional wheels. Generic Mecanum wheels do not function effectively on rough outdoor terrain in which small objects get caught in the rollers, thus preventing them from rotating freely. MR^{2}G have overcome this limitation by providing a second set of normal wheels with a heavily treaded tire for outdoor use. Any terrain change is automatically detected, and a set of pneumatic actuators is used to change from the Mecanum wheels (for indoor and high mobility requirement usage) to the regular wheels (for outdoor use and rough terrain)





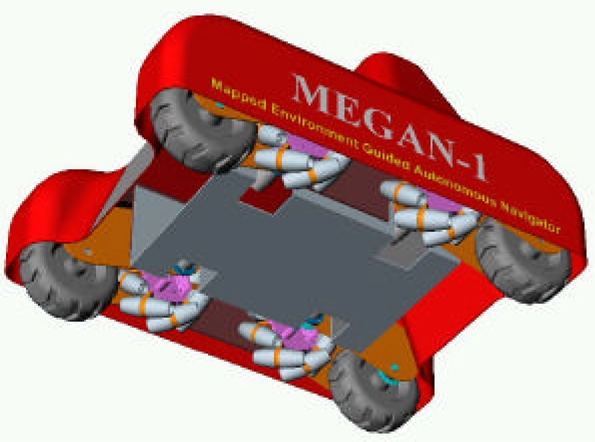


Figure 7: Massey University's Mapped Environment Guided Autonomous Navigator (M.E.G.A.N.)

When the AGV is in travel, the surface roughness of the terrain is a determining factor for efficient wheel selection. Edge-mounted ultrasonic sensors are used to scan the terrain during travel. The appropriate surface information is gathered, and predetermined ultrasonic frequency spectrum boundary conditions are used in the wheel selection and activation process. If the terrain is determined to be rough, a pneumatic cylinder lowers the normal wheels with a heavily treaded tire. The AGV has an onboard air reservoir and 12V compressor, which powers the pneumatic cylinders. A DC servomotor independently drives each wheel so the vehicle can then be steered by changing the rotational velocity of each wheel. This added flexibility in the choice of wheels has proved effective in developing an omni-directional vehicle capable of travel on a variety of terrains.

6 Conclusion

Though an ingenious system, the traditional Mecanum wheel is somewhat inefficient in its use of energy. The addition of the ability to lock the Mecanum wheels peripheral rollers increases this efficiency when traveling in a forward direction. The addition of the ability to dynamically adjust the angle of the peripheral rollers to best suit the direction of travel to a large extent resolves the inefficiencies inherently present in the traditional design. The AGV is able to move and perform complex tasks within a congested factory environment, while having the ability of rapid movement over rough terrain. This ability is invaluable during material transfer and handling.

7 References

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