TERRESTRIAL MOBILE ROBOT UNDERCARRIAGE DISAMBIGUATION WITH STRESS ON MECANUM WHEELS

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Abstract: The first step in new mobile robot design is the selection of undercarriage. If you are designing terrestrial robot you have commonly two options how to create movement with your actuators: a legged or wheeled drive. To select on of these categories, you should now the nature of the surface the mobile robot will most often get across. In this article commonly used wheeled drives and a few of legged robot examples are described with special attention to the omnidirectional Mecanum wheel undercarriage.

Keywords: terrestrial mobile robot, differential drive, ackerman drive, omniwheels, mecanum wheels

1 INTRODUCTION

1.1 TERRESTRIAL MOBILE ROBOT LOCOMOTION

Legged locomotion If the ground is covered with uneven-obstacles which cannot be bypassed and your the robot should not be over-sized the legged robot can be the right choice for your application. The disadvantages of legged versus wheeled robot are in most cases travel speed, energy consumption per distance traveled, design and control complexity and last but not least the cost of the solution. There are some legged robot designs which overcome these inconveniences. For example Boston dynamics 4-legged Cheetah robot compensates for the travel speed as it is capable of running with velocity 47 km per hour [4]. Then there is bipedal robot Cassie from Agility Robotics which is trying to overcome the energy consumption of legged robots [7]. However, no official parameters are available. The legged robots are currently in viewfinder of many development teams. What seemed only a few years ago as almost impossible, like high-velocity jumping electric-actuated robot, is now a reality due to the heavy development and advance in the legged locomotion field.

Wheeled robots If your primary objectives are speed, design and control simplicity and your surface is mostly flat, the choice may fall on wheels. The wheel has been with the human kind for a long time now. The oldest exemplar is from 3100 BCE, and other references dating even further[10]. The oldness of the wheel discovery suggest the clue that the wheeled locomotion has been inspected very thoroughly.

Other types As we can see in the nature, there are even more possibilities how to travel on land. Though snake-like [11] and jumping robots (Boston Dynamics - Sand Flea robot [5]) have been constructed, the development in robotics is mostly concerned with the first two types, lately even combination of them (Boston Dynamics - Handle robot [6]).

1.2 WHEELED UNDERCARRIAGES

Differential drive [A] To start chronologically, it is possible the first wheeled undercarriage ever used by human was the 2 wheel differential drive depicted as A in figure 1. Due to its simplicity it is most commonly used undercarriage for small simple robots.

The design is simple with only two motors with axis in one line. This drive is controlled by different speeds applied to the wheels so it can orient itself in any direction on one spot and travel on curved circle-like trajectories. However, it only has 2 wheels so in case of non-self-balancing robot another supporting point is often used. Casters as the points are also called can be in form of castor wheel or spherical ball caster called ball transfer. Caster wheel utilization adds friction and can make the other two wheels skid if in the lock position.

Skid drive [B] The next type of drive is the 4 wheel differential drive depicted in B figure 1. Common wheel color represents control with the same angular velocity. This undercarriage type often called skid drive is commonly controlled with the same algorithm as the 2 wheel drive. It can be equipped with 2 or 4 motors. The second pair of wheels is added mainly for the purpose of superior uneven-surface traversability and better grip to the surface. Nevertheless, independently of surface of the solid terrain skid drive is often accompanied with skidding. Due to the fact that all the wheel axis are parallel, the skidding is the only possibility to travel in different direction or rotate in space.

Skid drive wheels can also be concealed in continuous track. If so they are often called tank tread or caterpillar track. Energy from motors which is going to the friction is wasted even more if using the track and the drive weights more. On the other hand the traversability in slippery environments is much higher with the track.

Tricycle drive [C] When on rugged terrain and the high-load on differential drive causes need for caster wheel it can be advantageous to make the third wheel yaw-angle controlled as depicted in C figure 1. The control can then prevent lock positions of the wheel and instead of traverse ball it works better in uneven terrain. However, if one wants to use second pair of wheels, the way to control both of them with one angle is not preferable, due to the skid of wheels while traveling on curved path.

Ackermann drive [D] When other pair of wheel with independently controlled yaw-angles is added to the differential drive it is often called car drive. The elimination of skidding due to the common turning center of Ackermann steering is energy efficient. Also, many variations of pure Ackermann drive exist for better performance in different conditions.

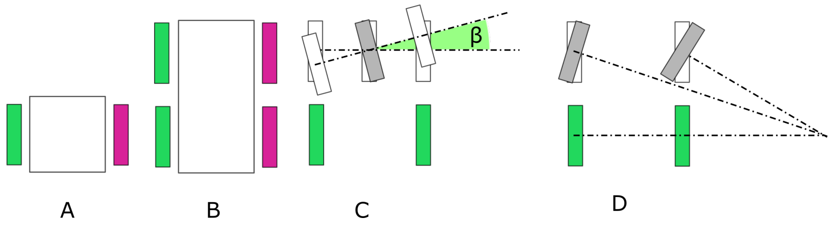

Figure 1: Undercarriage (drive) types: A - 2 wheel differential drive, B - 4 wheel differential drive, C - non-Ackerman tricycle drive, D - Ackermann drive

1.2.1 Holonomic drive definition

None of the drives described so far allows traveling in any direction independently on robot orientation. This means that the undercarriages does not have full degrees of freedom (DOF) for the motion on a plane. There are always constraints which forbids the robot to travel sideways for example.

If the drive can travel in any direction on the plane (x, y = 2 DOF) and orient itself in any direction (yaw angle = 1 DOF) independently on its travel direction it is called holonomic drive.

The biggest advantage is the freedom of movement and manoeuvrability coming from the holonomic drive. The mobile robot would not have to calculate complicated path to drive into narrow garage in contrast with car drive where the apriory robot position and orientation together with surrounding obstacles can cause insolubility of the problem. Among the disadvantages there can be less friction and/or less maximum speed, greater wheel complexity, lesser uneven terrain traversability and more complex mechanical design. Dependently on the wheel type used the driven wheel odometry robot localisation can be impossible to achieve.

1.2.2 Omniwheel types

Omniwheel is a special wheel with smaller auxiliary rollers with axis perpendicular to the turning direction equidistantly distributed on the perimeter. The rollers, commonly barrel shaped, can move freely and are not driven. The wheel was firstly patented in 1919 by J. Grabowiecki and since then multiple variations were created as depicted in A, B, C figure 2. The A and C type has its rollers far from each other which means the outer shape is not completely circular. Due to the shape of the roller there is not always enough space to put more rollers in between, so two or more omniwheels can be used to compensate the non-circular shape as in B type.

Mecanum wheel is variation on omniwheel from Swedish inventor Bengt Ilon which was firstly demonstrated in 1973. The difference from omniwheel is in the angle forming between the roller axis and the wheel. In traditional omniwheel it is 90 deg, in mecanum wheels it is exactly half. The 45degof the rollers allows different omniwheel placement in the undercarriage. Different variants of mecanum wheels have been designed. The traditional type D in figure 2 has problems on triangle tilted surfaces, where the body of the wheel can touch the ground. Types E and F overcomes this troublesome effect by employing two barrels for each roller.

Figure 2: Wheel types for holonomic drive: A,B,C - Omni-wheels, D,E,F - Mecanum wheels

1.2.3 Holonomic drive types

Omniwheel drive [E][F] Utilization of omniwheels for holonomic drive has its restriction in positioning of the wheels. The minimum of 3 wheels must be positioned in the shape of regular polygon as depicted in E and F figure 3 on the next page. If the omniwheels would be used in the type G drive, there would not be any way how to turn the robot utilizing rollers rotation without skidding. The main disadvantage of omniwheel drive is the lower traction of the wheels compared to the non-omniwheels. Together with the fact the highest possible velocity is achieved in diagonal movement [8].

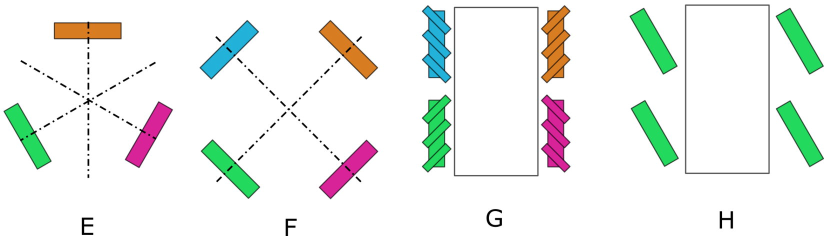

Figure 3: Holonomic undercarriage (drive) types: E - tricycle omniwheel drive, F - 4 omni-wheel X drive, G - 4 mecanum omnidrive, H - swerve drive

Mecanum drive [G] Mecanum drive is different from omniwheel drive in the wheel placement – wheels have parallel axis – as can be seen in G figure 3. As the rollers are angled and not perpendicular to the wheel axis, there are two pairs of wheels. Ones with rollers tilted $+45°$ and the others with $-45°$. The common wheels must be mounted in the opposite corners - diagonally. Special attention must be kept also to which angled wheel should be in which corner. The rollers should always make a X-cross from the top view as it can be seen in G figure 3. Otherwise, the robot would not be able to rotate in place, as the forces applied from the rollers to the surface would cancel this rotation.

The common disadvantage is shared with omniwheel drive. Mecanum drive has lower traction and its wheel design is very complex compared to traditional pneu/rubber wheel. The advantage comes from the parallel wheel axis and angled rollers. The mecanum drive maximum speed is delivered when moving in the direction perpendicular to the wheel axis as in differential drive. Furthermore, the mecanum drive can be placed on the 4 wheel drive chassis as the motors are at the same positions. Also it can be narrower then the omniwheel drive which offers even higher manoeuvrability with holonomic movement in mind. Improved mecanum wheel concepts with rotable rollers and rollers locking mechanisms are discussed in [1].

Swerve drive [H] To get the holonomic drive with the advantages of not omni-directional wheel, the swerve drive can be applied. This drive utilizes 3 or more individual wheels with controllable yaw-angle as can be seen in H figure 3. To traverse with no rotation all the wheels should be driven at common velocity and with the same yaw-angle. To rotate the robot on the spot the wheels should be aligned to the tangent of circle. The swerve drive, sometimes called shift x-drive, is holonomic with the advance of good grip and uneven terrain traversability of normal wheels. The complexity of motor and yaw-angle control calculation can be very high relatively to the other described holonomic drives.

2 CONCLUSION

There are certainly much more parameters than the ones mentioned in this article which influence the selection of the mobile robot undercarriage. In example maximum weight of robot, maximum load, desired speed versus torque, manoeuvrability, control computation simplicity, drive, wheels and chassis cost, wheel grip, preferred actuator type etc. The final choice will often be a compromise of the most needed parameters.

We currently develop mobile robot for Robotic Day in Prague competition depicted in figure 4 on the next page. It is equipped with Mecanum drive as the main goal in the selected competitions were manoeuvrability and the surface of the play field is flat. Manual and automatic motor control[9], sensor measurement and visual processing are to be seen at [3].

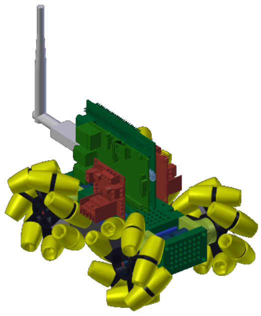

Figure 4: Mobile robot with mecanum drive [3]

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