Unlocking Optimal Drive Systems for Next-Gen Mobile Robots

When designing a drive system for any autonomous vehicle the designer must have a vision for how the machine will behave. It can be helpful to understand the various drivetrain types typically used by mobile robots in the field. This white paper aims to identify and explore the strengths and weaknesses of a few of the most common implementations. There are many ways to drive an autonomous vehicle, but almost all of them start with a wheel drive.

Wheel drives bring together a motor, gear reduction, feedback encoder, and brake into one simple and easy to implement package. Used widely in applications from line following pallet movers to autonomous agricultural equipment, wheel drives provide robot designers with a simple solution to all their locomotion-related problems.

In most cases a single wheel drive is not enough to create the required motion of a mobile robot. Wheels drives must work together with other parts of the drive system (such as other wheel drives, passive follower wheels, or caster wheels) to be able to create stable and controllable motion.

There are 4 common arrangements of wheel drives to consider when designing an autonomous vehicle:

- Skid Steer
- Differential Drive
- Single Steerable Drive Wheel
- Multiple Steerable Drive Wheels

Figure 1. The ASI Drives wheel drive catalog

Skid Steer

This arrangement rigidly places a wheel drive in all 4 corners of the machine. With 4 powered wheels, machines that use this concept usually never have to worry about losing traction. Every wheel is powered, so even over rough, uneven, or sloped terrain the vehicle always has powered wheels touching the ground. This method provides the exceptional power and load capacity of 4 wheel drives and is simple to control. A 4-wheel skid steer machine can pivot around the center point of the machine and drive in reverse, which can be useful features in many applications.

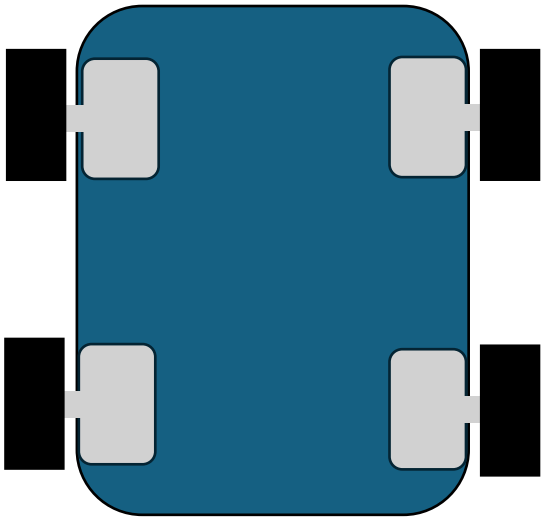

Figure 2. Skid steer drivetrain

When turning, skid steer drivetrains will cause wheel scrub. This can cause turning to be a very power intensive movement, especially in vehicles with long wheelbases and narrow track widths. In the case of very light vehicles sometimes the wheels will even appear to bounce while scrubbing. The scrubbing effect will wear out tires much faster than any other wheel drive arrangement.

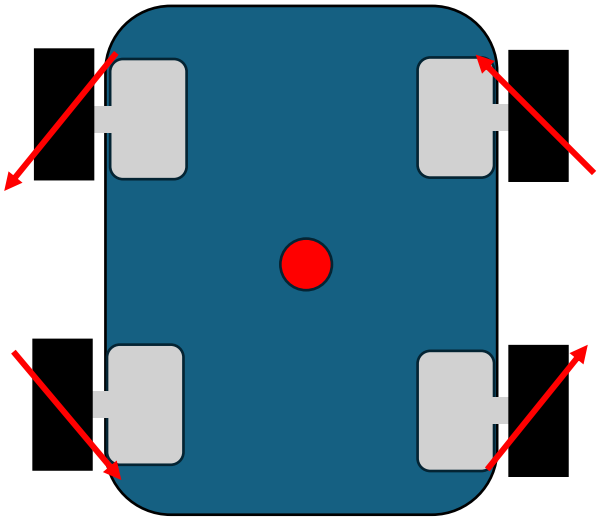

Figure 3. Scrubbing force on the wheels during turning

Skid steer drivetrains are a great solution for: Outdoor, offroad, high load, burden carrying, mecanum, and ramped applications

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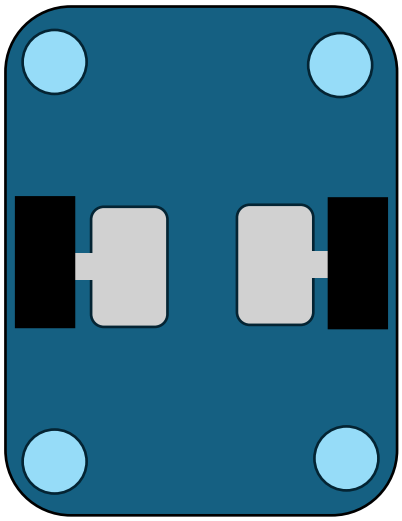

Figure 4. Center mounted with 4 casters

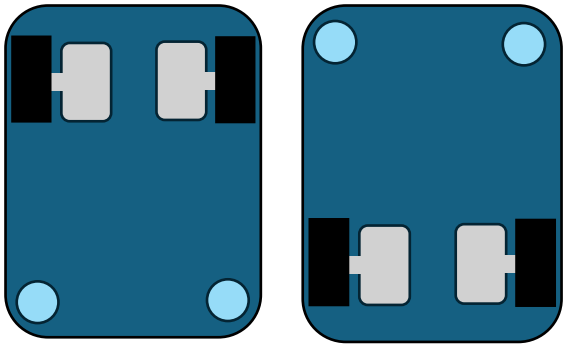

Figure 5. Front or back mounted with 2 casters

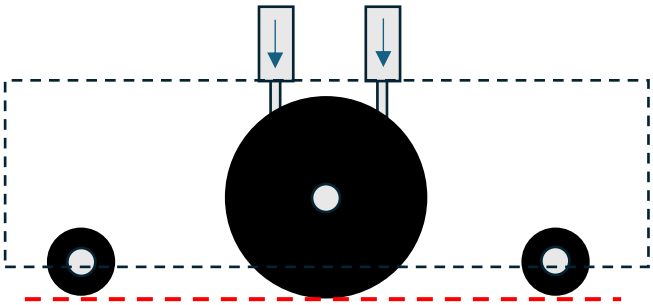

Figure 6. Suspension

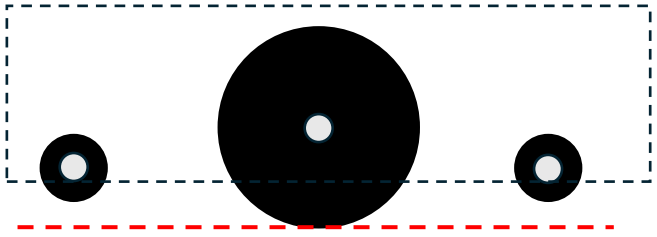

Figure 7. Dropped Wheel

Differential Drive

This arrangement places a wheel drive on each side of the vehicle with additional supporting caster wheels. This arrangement takes advantage of the caster wheels to minimize the scrubbing forces in the corners of the machine. The caster wheels also support half the load of the machine which allows the wheel drives to work more efficiently under high loads. With only 1 wheel to control each side of the drivetrain this arrangement is easy to control, can pivot around the center point of the drives, and can drive in reverse.

With only 2 powered wheels on the vehicle, it is critical that those 2 wheels always maintain solid contact with the ground. A differential drivetrain often struggles on uneven floors and transitioning on and off ramps. To ensure constant contact with the floor the drive wheels should either be mounted on a suspension or “dropped” to be slightly lower than the caster wheels. Dropping the driven wheels results in a slight rock to the vehicle, but in most cases the driven wheels will maintain solid contact with the ground. Another thing to look out for in this arrangement is caster kick. As caster wheels change direction, they can apply a force to the vehicle which may result in some unexpected motion.

Differential drivetrains are a great solution for: Indoor, smooth floors, high load, burden carrying, tunneling, and towing applications

Single Steerable Drive Wheel

This arrangement makes use of a single steerable wheel drive to both power and steer the machine. All other wheels are simply unpowered follower wheels. This concept is typically implemented using only 3 wheels to ensure that the steerable drive wheel always maintains contact with the ground. The motion characteristics of a vehicle powered with a steerable wheel drive is very intuitive as it uses the same principles as an automobile. As a result, this arrangement is great for vehicles that aim to follow lines, magnets, or wires in the floor. However, like an automobile, vehicles controlled this way cannot pivot around the center point of the machine and control differently when moving in reverse.

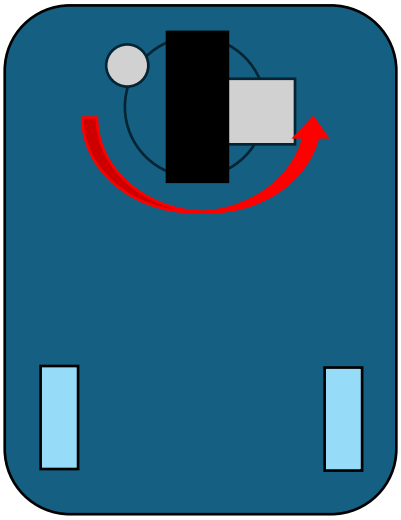

Figure 8. A single steerable wheel drive with 2 unpowered follower wheels

With only a single wheel drive this arrangement has less available power than other options. A steerable wheel drive contains more mechanical and control complexity than a fixed wheel drive. The steering axis gears, the steering motor, and the steering feedback encoder are all critical to the function of the machine. However, a steerable wheel drive also keeps all the components needed for controlled motion in a single package which can simplify the overall machine design.

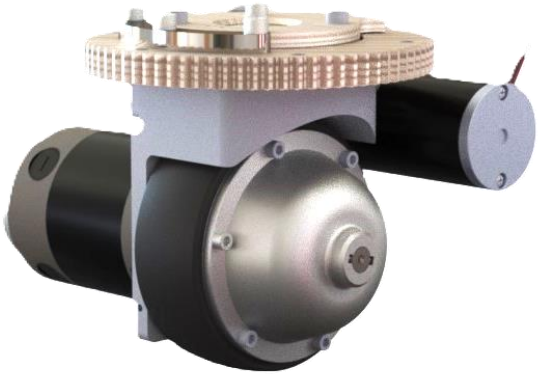

Figure 9. ASI's Cyclone 150 steerable wheel drive

Steerable drivetrains are a great solution for: Indoor, smooth floors, low load, line following, and towing applications

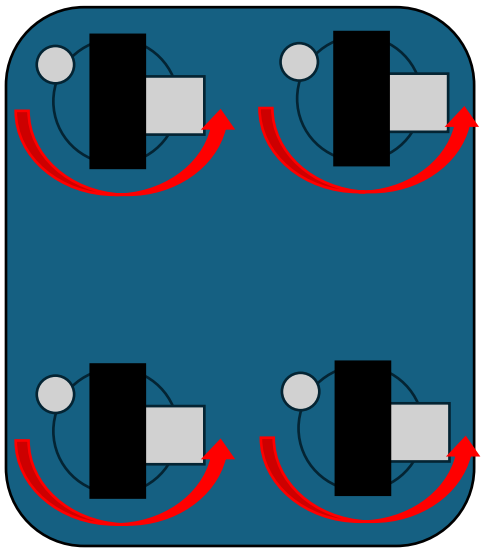

Figure 10. 4 steerable wheel drives

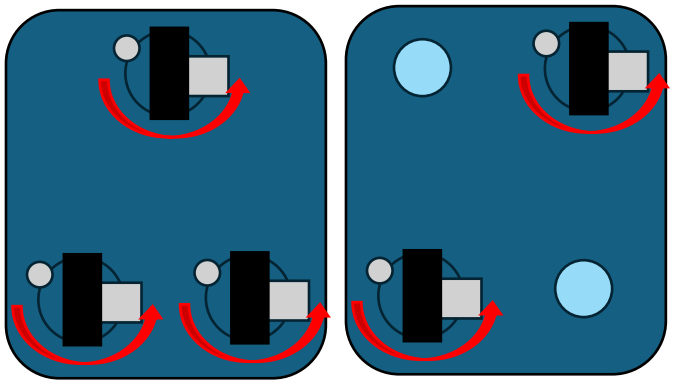

Figure 11. 3 steerable wheel drives and 2 steerable wheel drives with 2 unpowered caster wheels

Multiple Steerable Drive Wheels

This arrangement makes use of 2-4 steerable wheel drives working together to create a holonomic system. This combines the power and load capacity of multiple driven axles with the controllability of steerable wheels to enable full power motion in any direction at any time. This can allow powerful precision movements that other arrangements are not able to perform. This drivebase can slide sideways into a parking space with no front to back clearance, align to a target position on the floor perfectly in both axes and angle, and turning can be achieved with minimal scrub because the wheels can be aligned in the optimal direction at all times. This arrangement is also able to handle ramps and uneven floors, pivot around its center point, and drive in reverse.

Vehicles that use this type of drive arrangement depend on a lot of critical parts and a robust control system. The function of this system requires 2-4 sensors and 4-8 motors functioning properly and being well controlled. It is not a trivial control exercise to manage the angle of each steerable drive and ensure that all the wheels are working together.

Multiple steerable wheel drivetrains are a great solution for: tight spaces, smooth floors, high precision, high load, line following, burden carrying, and tunneling applications

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Wheel Drive Arrangement	Pros	Cons	Applications
Skid Steer	• Powerful • High load capacity • Simple control • Center point pivot • Reversing • Uneven terrain	• Wheel scrub • Tire wear	• Uneven terrain • Burden carrying • High load • Mecanum wheels
Differential Drive	• Powerful • High load capacity • Simple control • Center point pivot • Reversing • Minimal wheel scrub	• Caster kick • Drive wheel traction requirements • Prefer level terrain	• Indoor • Smooth floors • High load • Burden carrying • Tunneling • Towing
Single Steerable Drive	• Intuitive motion • Line following • Single unit to control • Simple implementation	• High per unit complexity • Only 1 drive motor • Turning radius • Reversing	• Indoor • Smooth floors • Low load • Line following • Towing
Multiple Steerable Drives	• Up to 4 powered wheels • High load capacity • Center point pivot • Reversing • Uneven terrain • Minimal wheel scrub • Holonomic • Precision movements	• High per unit complexity • Lots of critical components per system • Control complexity	• Tight spaces • High precision • High load • Line following • Burden carrying • Tunneling