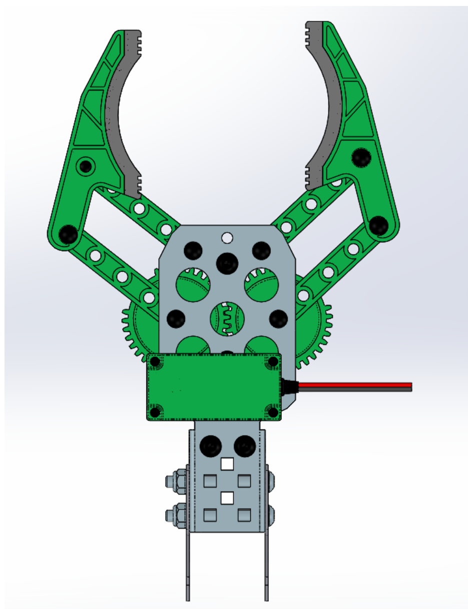
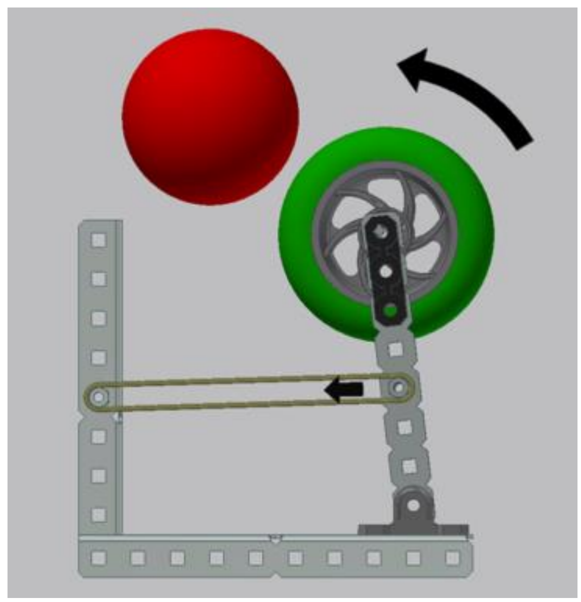
VEX PRO BUILD BLITZ





Claw Design Guide

2015

Introduction

Due to the nature of competitive robotics, nearly every game involves some sort of object manipulation. Whether it's picking up an object and placing it on a goal or gripping onto a field element, claws are an extremely common method of object manipulation that most teams consider at some point during their design process. Claw designs can be as varied as overall robot designs, but most fall under one of three categories: roller claws, pivot/pinch claws, and passive/fixed claws. The purpose of this design guide is to introduce these three primary styles and to help teams evaluate the best manipulator for their needs.

Defining the "Right" Claw

The first step to evaluating a game object manipulator is to step back and look at the factors influencing the design. Some important ones include:

- How **precisely** must the robot be positioned for the manipulator to work well?
- How **quickly** must the manipulator gain control of the object?
- How **firmly** must the game object be held?
- How much can the manipulator **weigh**?
- What **actuators** are available to drive the manipulator?

In many cases, picking and choosing which criteria are important for a specific application can be as difficult as actually designing the manipulator. However, this is the starting point for every project an engineer undertakes.

Any single objective can usually be achieved without much effort. Making a manipulator that can pick up an object is easy – but what about a manipulator that can pick up an object faster than an opponent going for the same one? Or one that can hold onto an object during a full-speed 180-degree turn? Not so easy.

In most cases, it is impossible to create the "ideal" manipulator, so it is important to determine which aspects of a design are important and which ones can be deprioritized. Team capabilities are also crucial – the intersection between an ideal system and what a team is capable of designing and manufacturing is the key to every system on an effective robot.

Choosing a Manipulator Design

After determining which criteria are important (that is, defining the problem) it is possible to intelligently select a design that fits the needs and desires of the user. A few common types of manipulators are discussed below. Each type of manipulator has its own pros and cons that must be considered when making a selection.

As with any design, it is critical to prototype the selected concept to determine key characteristics such as size/geometry, power requirements, desired speed & gearing, etc. These should be tweaked during the prototyping stage to maximize performance before proceeding with a full-fledged design.

Note: The discussions of the claws below are written in broad terms. Any comparisons that are made between different types of claws are generalizations that assume equal constraints and build capabilities between designs. For example, an elite roller claw picking up a 2 lb object may be lighter than a beginner's pinch claw picking up a 10 lb object, but in general, roller claws will be heavier than pinch claws.

Roller Claws

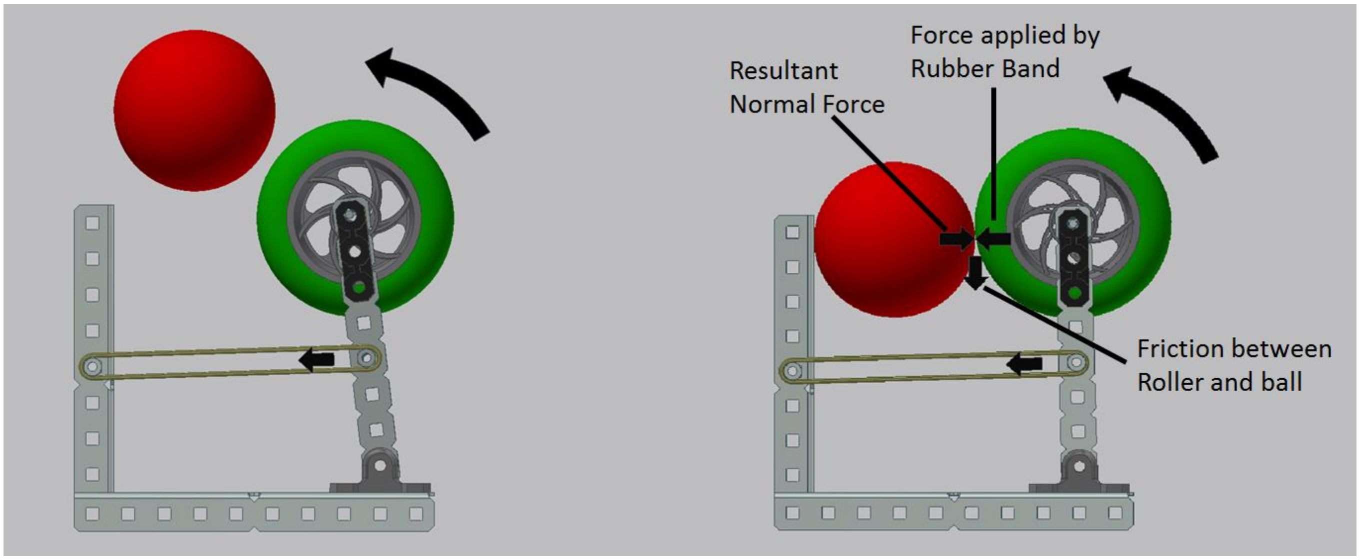
Using a roller claw is one of the fastest and most popular ways to gain control of an item. Roller claws typically have a spinning roller or drum covered in a high friction material that "sucks" an object in when the object comes in contact with the moving roller. The term "roller claw" or "roller intake" is very broad, and the list of their possible configurations is endless. Some can grab an object from the sides, some from the top, some use belts, some use rollers with flaps in them.

Roller Claw	
Pros	**Cons**
Can be much faster than other types of intakes	Can be heavier than other types of manipulators
Can be designed to not require exact alignment before approaching an object	Can be more difficult to design than other types of intakes
	Can cost more than other types of intakes
	Can be difficult to design to control multiple objects

Roller Claw Design

Roller claws rely on friction to control the object they are grabbing. Since friction is a result of applied force, the claw must be able to constantly apply a force to the object as it is being acquired. The easiest way to ensure continuous force application is for either the claw or the game piece to have some "give".

For example, the image below illustrates a roller claw with a simple pivot that allows it to pick up a rigid ball. The pivot allows the roller intake to change size as the ball comes in, ensuring continuous force. If the red ball was easily deformable, the roller claw could be a fixed width (no pivot) and the ball size would adjust as it enters the claw.



As mentioned earlier, a functional prototype is the most powerful tool in a designer's arsenal. Common variables to tweak in a roller claw prototype are:

- Jaw width
- Drum and/or wheel size
- Drum and/or wheel velocity

Something that new designers often "miss the boat on" is the importance of the roller claw's "tip velocity". The "tip velocity" is the tangential speed of the roller (i.e. how fast the roller would travel if it were contacting the ground). The tip velocity can be determined using the following formula where d is wheel diameter in inches and ω is angular velocity in RPM and Tip Velocity is in feet per second.

$$\frac{\pi \times d \times \omega}{720} = Tip\,Velocity$$

The tip velocity must be faster than the robot is traveling. Otherwise, the game object will be plowed until there is a sufficient difference between roller tip velocity and the velocity of the game object.

A friendly word of warning – while roller claws can be a fast, effective way to manipulate game objects, younger teams may find it difficult to design and fabricate an effective and reliable roller claw. However, if a team decides to make a roller claw for the first time, the importance of a functional prototype cannot be stressed enough.

Pinch Claws

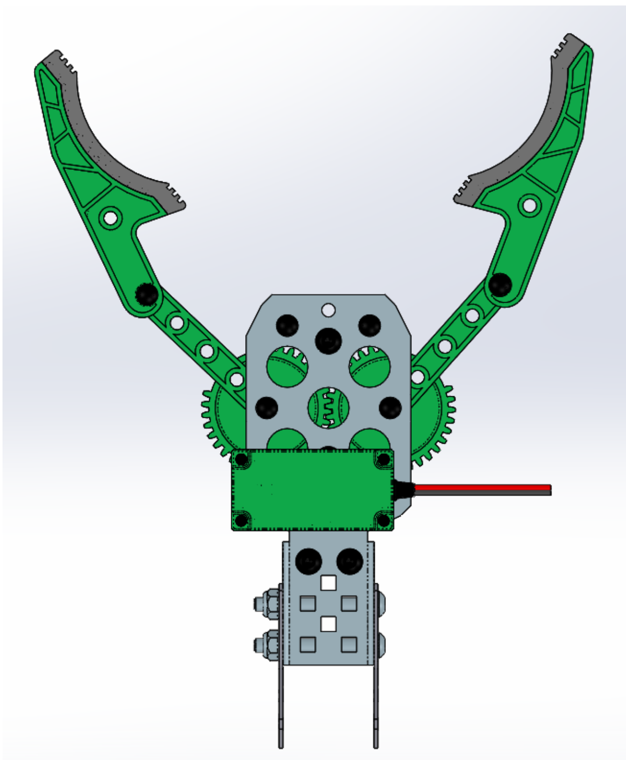
Pinched claws are a simple, yet effective way to manipulate game objects using few moving parts. Pinch claws typically consist of two members that open and close to pick up an object. A major advantage of pinch claws is that they can be designed to pick up a variety of different sized objects. They are also a great solution if simplicity and weight is valued more than speed.

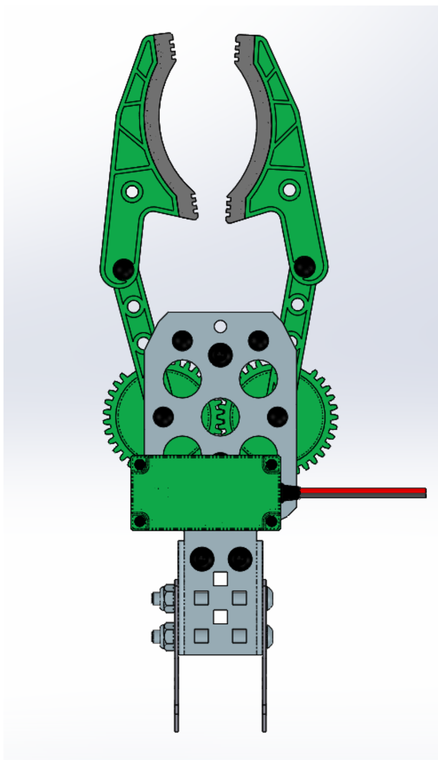
Pinch Claw	
Pro	Con
Simple to prototype & build	Typically require good alignment with object
Can be designed to be very lightweight	Can be slower than other types of manipulators
Can be actuated using a motors or pneumatics	
Can be designed to pick up a variety of objects	

There are two primary types of pinch claws used in competition robotics – pivot pinch claws and parallel pinch claws.

Pivot Pinch Claws

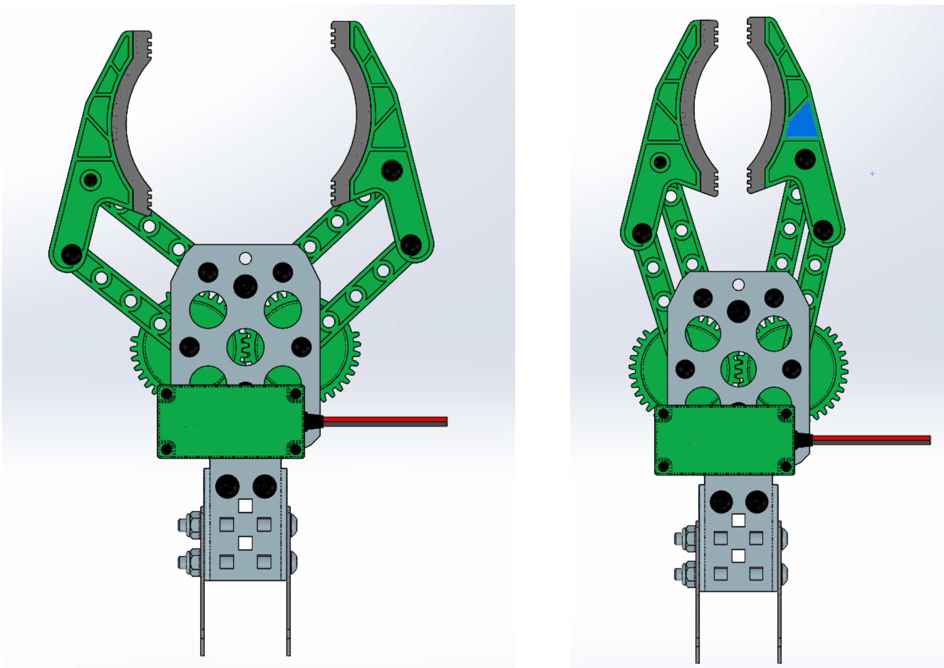
Pivot pinch claws are the lightest and simplest type of pinch claw. The “jaws” of these claws are typically parallel when “closed” but do not remain parallel when “open”. This means that they typically cannot easily pick up items with large variances in size.





Parallel Pinch Claws

Parallel pin claws are the “big brother” of pivot pinch claws. The “jaws” of these claws remain parallel through their entire range of motion, from “open” to “closed”. This type of claw is typically better at picking up items of various sizes than a pivot pinch claw, but will weigh more and be more complicated to build.



No matter what kind of pinch claw is used, jaw design will be a large factor in determining performance. The geometry and material selected for the jaw can make or break a claw. For example, the geometry of the VEX EDR claw pictured above was designed to pick up cylindrical items of a specific size as well as items with two parallel sides (e.g. boxes) of various sizes.

The actuator chosen for a pinch claw will also heavily influence its performance. Both motors and pneumatic pistons are commonly used to operate a pinch claw.

Pneumatic pistons are capable of creating very high linear forces. Unlike motors, pneumatic pistons can provide a constant force for a (theoretically) infinite amount of time without being damaged. This makes them an especially attractive option for pinch claws - they will be able to tightly hold an object for extended periods of time without external spring assistance. The use of pneumatic pistons will also define a set number of positions for your claw, such as “open” and “closed” with no “in-between”.

The major disadvantage of using pneumatic cylinders to power a pinch claw is that the presence of a single cylinder will require the addition of an entire pneumatic system to be added to the robot – this will weigh much more than a single motor. If pneumatics are already included on the robot, using a pneumatic piston to power a claw should be seriously considered.

The other common option for powering a claw is a motor with a high reduction gearbox. Using a motor allows the claw to have an infinite number of positions between open and closed. Depending on the game and the intents of the claw, this may or may not be an advantage. A motor also allows the user to vary the amount of force used to hold an object. However, there are two potential downsides to using a motor to power a pivot claw.

1) When using a motor to "clamp" on an object while using a pinch claw, the motor is actually being stalled. This can lead to very high current draw that will eventually cause the motor's breaker to pop or damage the motor. If a motor is used to power a claw, the claw should include a spring that keeps the claw closed if the motor is not being driven. This way the spring will be providing the force to hold the object, not the motor.

2) If the robot already includes a pneumatic system, the addition of a single pneumatic piston will almost always be lighter than a motor with a gearbox.

In some cases, high friction material is desired for the "inside" of the jaws to increase the grip of the claw. Popular materials for this include polyurethane (available from mcmaster.com), "rough top" or "wedge top" wheel tread (available from VEXpro), and natural gum rubber (available from mcmaster.com). The best way to determine which friction material to use is through side-by-side testing of different materials on your game piece. Different friction materials behave differently on different surfaces – that is, the "best" material for one surface may also be the "worst" material for a different surface.

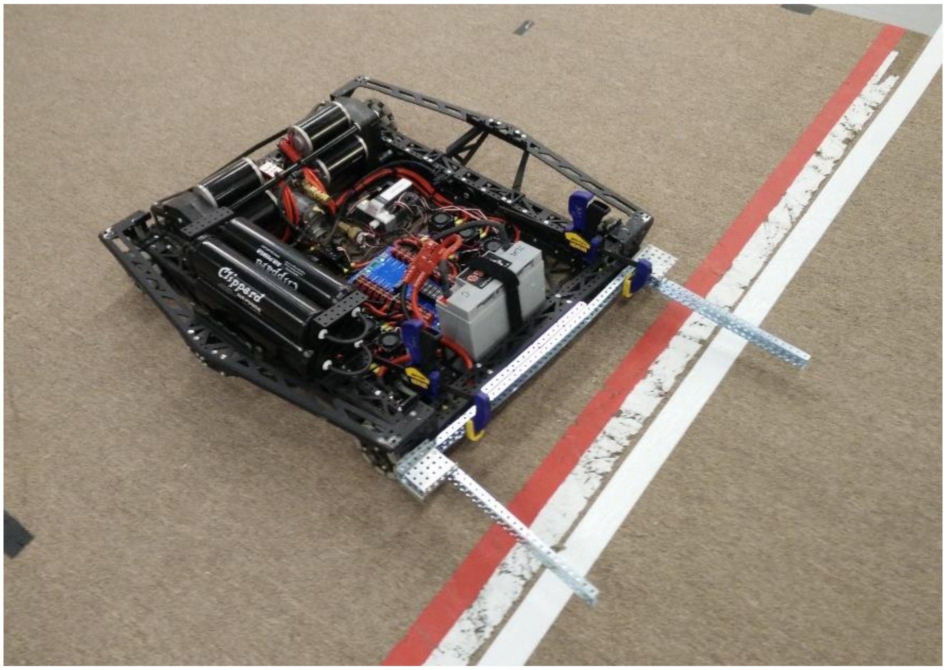
Pinch claws are an effective way to manipulate a wide variety of game objects and they offer a good balance of performance vs complexity. However, do no overestimate their simplicity – the best way to design and build a successful pinch claw is to build a functional prototype first.

Passive & Fixed Claws

The simplest and lightest type of claws are passive and fixed claws. These claws are not actively actuated during use and are primarily designed to manipulate a single object in a single orientation.

A great example of a fixed claw is a forklift – it is great at picking up a pallet in a single orientation, but not very useful for much else. Claws like these are often limited to moving a single game object at a time.

Robot claws can be designed using the same mentality. Below is a photo that was designed during Build Blitz 2015 of a fixed claw (attached to a pre-built drivetrain) that can be used to move Totes. This claw was designed to move plastic Totes across the field while on the ground. This design could easily be added to an elevator and used to lift the same plastic totes. The major drawback to this type of mechanism is that it relies on driver skill to collect an object.



A passive claw is slightly more complicated than a fixed claw. Passive claws are powered by the motion of the robot and "activated" by contacting the item it is designed to pick up. An example of a passive claw that was designed during Build Blitz 2015 is shown in the photo below. The claw "hooks" the top lip of the Tote when it is pushed one direction (to the right in the photo), then is capable of gripping the Tote when it is pulled the opposite direction (to the left in the photo). This is done with a single joint and some elastic tubing to spring load the claw.

Fixed Claw	
Pro	Con
Very easy to prototype and build	Typically require near-perfect alignment with object
Extremely lightweight	Can typically only pick up a single type of object
Can be added to almost any robot	Can be very slow at acquiring object
	Do not actively grip object, making a firm grip nearly impossible

Note: Fixed claws are a type of static manipulator. Most of the pros and cons of a fixed claw also apply to other static manipulators such as hooks and plows.

A passive or fixed claw is a good starting point for any young team. They provide an easy way for teams to score points while giving them time to work on and learn about other important parts of the robot. However, this is not to say that these types of manipulators are only for beginners – many elite-level teams also use passive mechanisms on their robot because of their simplicity and reliability.