FLL Workshop – Session 3
Chassis and Attachments

Patrick R. Michaud
pmichaud@pobox.com

University of Texas at Dallas
Summer 2018

Robot design and game strategy

Chassis and attachments

The *chassis* is the part of the robot that is responsible for navigating the field and providing a base for attachments

Attachments are the things added to the chassis to solve missions and manipulate models

Design is about creating a chassis and attachments that will perform well in the Robot Game

Consistency wins

Good programming and strategy are essential to consistently good performance

Programming overcomes the limitations of the hardware

Great robot + poor strategy → inconsistent scores

Fair robot + good strategy → consistent scores

Robot Game Strategy - Base

The robot must always start from Base

Base is the only place where changes can be made

Robot Game Strategy - Time

Matches are 2:30

When the Robot is in Base, it's not scoring
- → minimize time spent in Base
- → don't lose time positioning or aiming robot
- → make attachment changes quickly
  - ◆ or have them permanently on the robot

Travel on the field takes time
- → minimize time spent moving from place to place
- → solve multiple missions in the same region

Robot Game Strategy - reliability

Distance:

Error increases with distance

1 degree is 1.7cm error after 100cm

Missions that are close become easier

Missions that are far become harder

→ Use field elements (lines, walls, models) to guide the robot to make things seem "close"

Size:

Large targets are easy to hit

Small targets are hard to hit

→ Use large attachments to make small targets "bigger"

Robot game strategy - humans

The robot does exactly what physics and programming say to do

Humans (drivers) make mistakes and are inconsistent

Design the robot and strategy to prevent human mistakes

→ *Always* start robot from same location
→ Don't require humans to aim
→ Build safeties into robot
→ Robot should adapt to humans, not vice-versa

Republic of Pi's design mantra

Whenever the robot or humans
make a mistake in scoring,

redesign the *robot* so that mistake
cannot happen again.

Tip: Start every mission from same spot

Put solid edges on robot

Align robot with solid edges, not by sight-aiming

Robot can always start with known location and heading

Faster setup in Base between mission runs

Place flat edge against wall

Pick a marking to align robot

To save match time, always start from same spot

Navigation

A key to scoring is to move robot consistently

Things a program(mer) needs to know to navigate:

- Where the robot currently is
- How precisely you know where it is
- Where the robot is going
- What's in the way, or what can guide you there

Robot needs to be able to move in a straight line

Chassis design

Common FLL robot characteristics

Two motors for drive wheels - one for each side

Multiple attachments for different missions

Attachments may be passive or powered
   Third and fourth motors can be used for power
   Maximum of four motors allowed during match

Robot design characteristics

From the Robot Design judging rubrics:

	Beginning	Developing	Accomplished	Exemplary
Durability	Evidence of structural integrity; ability to withstand rigors of competition			
N D	quite fragile; breaks a lot	frequent or significant faults/repairs	rare faults/repairs	sound construction; no repairs
Mechanical Efficiency	Economic use of parts and time; easy to repair and modify			
N D	excessive parts or time to repair/modify	inefficient parts or time to repair/modify	appropriate use of parts and time to repair/modify	streamlined use of parts and time to repair/modify
Mechanization	Ability of robot mechanisms to move or act with appropriate speed, strength and accuracy for intended tasks (propulsion and execution)			
N D	imbalance of speed, strength and accuracy on most tasks	imbalance of speed, strength and accuracy on some tasks	appropriate balance of speed, strength and accuracy on most tasks	appropriate balance of speed, strength and accuracy on every task

(Mechanical Design)

Evaluate the robot:
Does the robot break often?
Does it seem solid? Does it have a lot of "flex"?
Do the wheels make good contact with the surface?
Does it perform well in the game?

Chassis design considerations

The *chassis* gets the robot from place to place

Size
Smaller robots are easier to navigate
Robot must fit completely in Base when starting

Consistency and reliability
Robot needs to act consistently when moving

Speed
Faster robot → time to solve more missions
Slower robot → more consistent and accurate

Chassis basics

Good motor and wheel design are key to consistency

Motor and wheel frame needs to be solid with very little "flex"
  - "flex" produces inconsistent runs

Use cross bracing, frames, and angle beams to increase structural stability

Wheels

Wheel selection is important

Larger wheels are faster, but may be less accurate

Tire shape, pattern, and field mat surface affect traction and consistency

    Wheels that "slip" on the mat produce inconsistency

Wheels

Wheels should be mounted close to supporting beam (but not rubbing against it):

Good

Poor
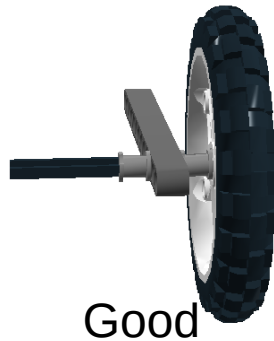
Axles do better when supported by at least two beams. Beams on both sides of wheel are best.

Better

Best
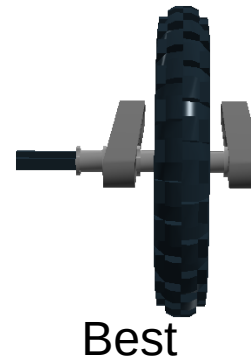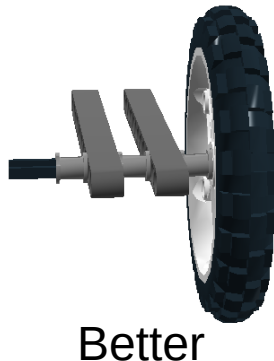
Wheel styles

2 wheels and skid(s)
Works great, may have difficulty with ramps/obstacles
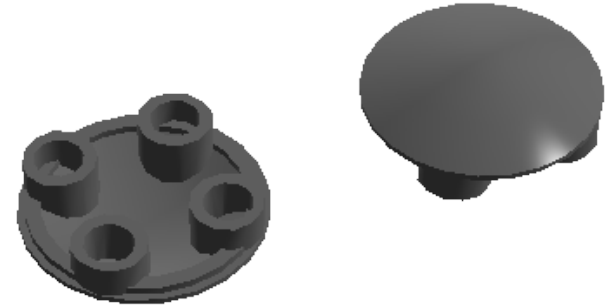
2 wheels and caster
Caster wheel will make driving inconsistent

2 wheels and ball pivot (3-point design)
Works fine, may be a little unstable

2 wheels and 2 balls (4-point design)
Very nice

Wheel styles continued

4 wheels (4-point design)

Make sure non-driving wheels can slide while turning

#41531 Turbine has worked
well for my teams
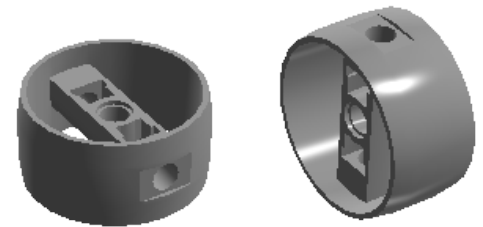
6 wheels

Stable, but generally quite large and turning may be imprecise

Tracks (tanks)

Good for obstacles, hard to predict turns

Exotics

Balance and center of gravity

Balance and center of gravity affects stability and consistency of robot

Center of gravity is the average location of weight of the robot

If the center of gravity is outside the wheelbase, the robot will tip over

High center of gravity will make robot more likely to tip

Weight

Heavier robots are more accurate, but slower and use more battery

Try to keep weight over driving wheels (but watch the center of gravity!)

Other chassis considerations

Put solid edges on robot

Align robot with solid edges, not by sight

Robot can always start with known location and heading

Provides attachment mounting points

Can be used for wall navigation and aligning with mission models

Place flat edge against wall

Pick a marking to align robot

To save match time, always start from same spot

LEGO structures and pieces

Beams

Beams are the basic building pieces for most LEGO robots

Length of beam determined by number of holes

   Often called "M" or "L" units

   Center-to-center distance is 8mm

Can be "thin" or "thick"

2M
3M
5M
7M
9M
11M
13M
15M
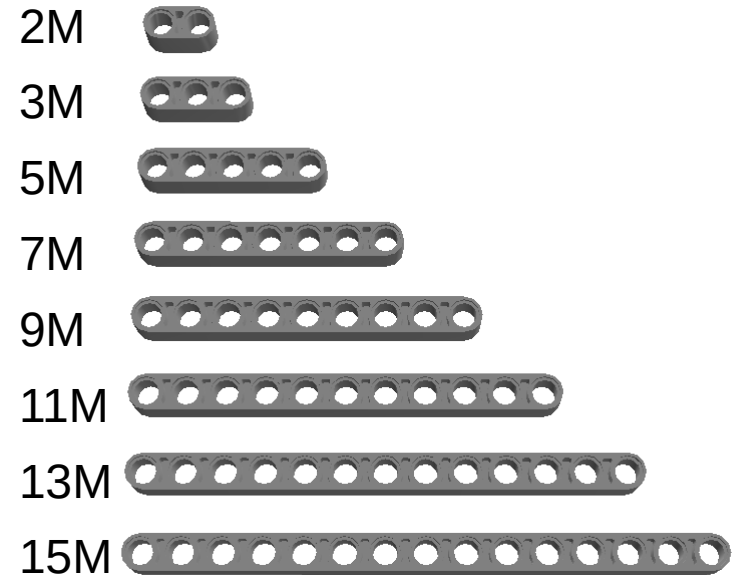
Quickly determining beam size

To quickly determine the size of a beam
    Place a finger over the center hole
    Count the holes on one side
    Double that and add one

1   2   3   4   5
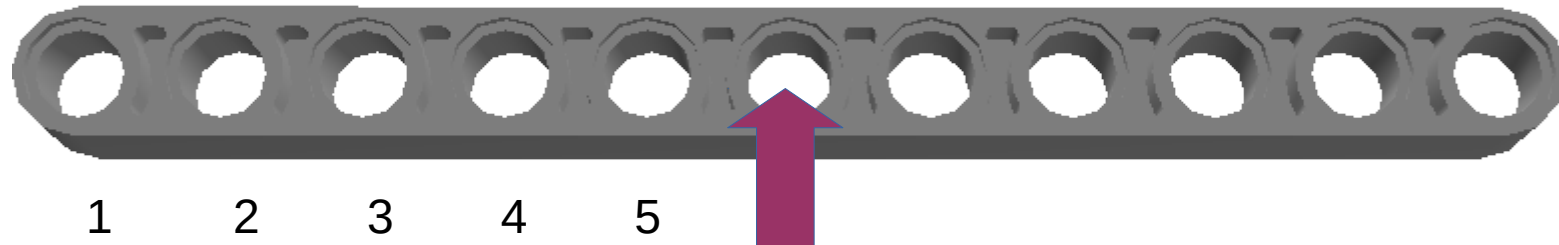
Used to connect beams and other components

Fit inside beam holes

Friction pegs do not turn freely in holes

- Connector peg with friction ("peg")
- 3M connector peg with friction ("long peg")
- Connector peg with cross-axle ("axle peg")
- Connector peg with cross-hole ("bushing peg")
- Ball with friction snap
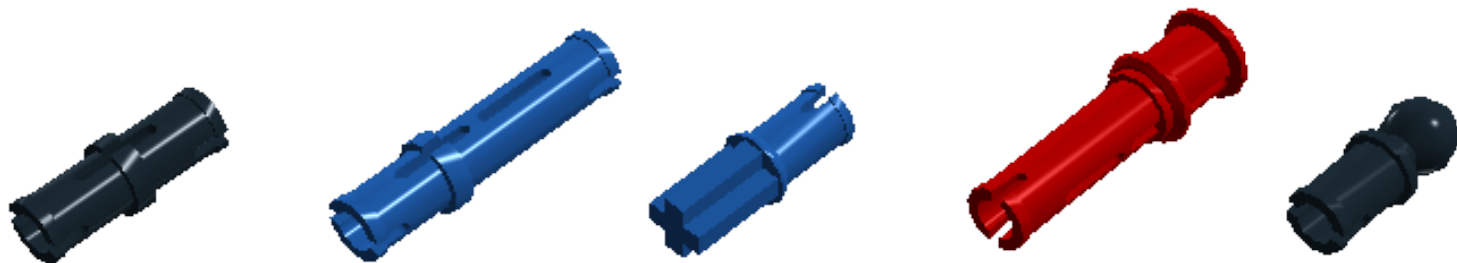
Non-friction pegs will turn in beam holes

- Connector peg
- 3M connector peg
- Connector peg cross axle

Connecting beams

Use pegs to connect beams

At least two pegs are needed to make a rigid structure

Greater distance between pegs reduces flex
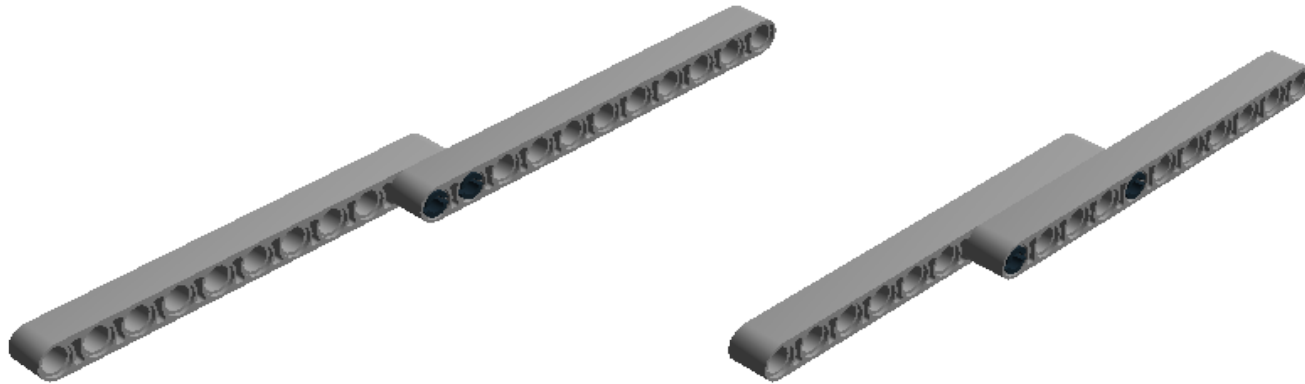
More pegs increases hold between beams

Axles

Used for wheels, gears, and attachments

Length also measured in "M" units

Grey axles are typically odd lengths, black axles are typically even lengths

Axles will rotate and slide in beam holes unless constrained
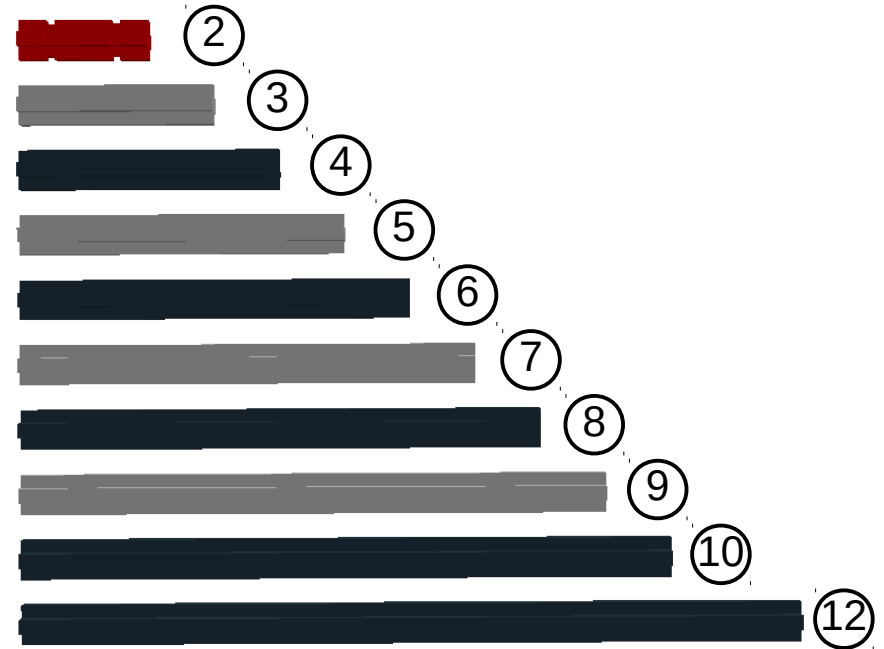
Wheels

Many types of wheels and tires available

Wheel consists of "rim" and "tire"

Tire measurements printed on sidewall

Cross hole attaches to axles
- 56908 Rim wide 43.2 x 26
- 41897 Tyre Low Wide 56 x 28
- 32020c01 Wheel 62.4 x 20, with Black Tire 62.4 x 20

Bushings

Used to hold axles on beams

Also used as spacers to prevent tires from hitting beams or other elements

- ◆ 32123 Half-bushing
- ◆ 6590 Bushing
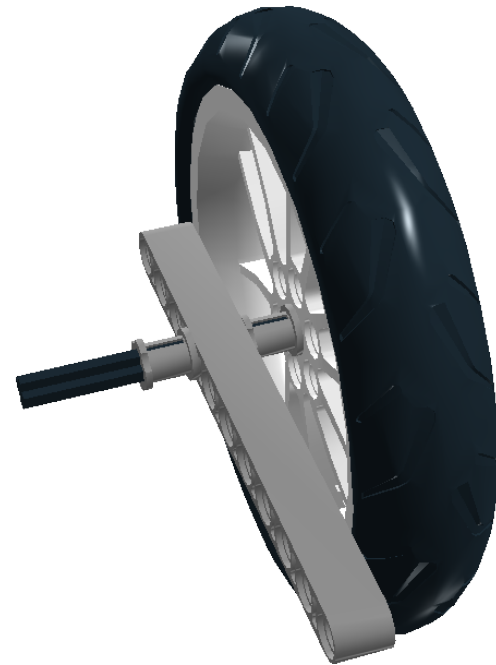
Bushings

Other elements can also be used as bushings or spacers
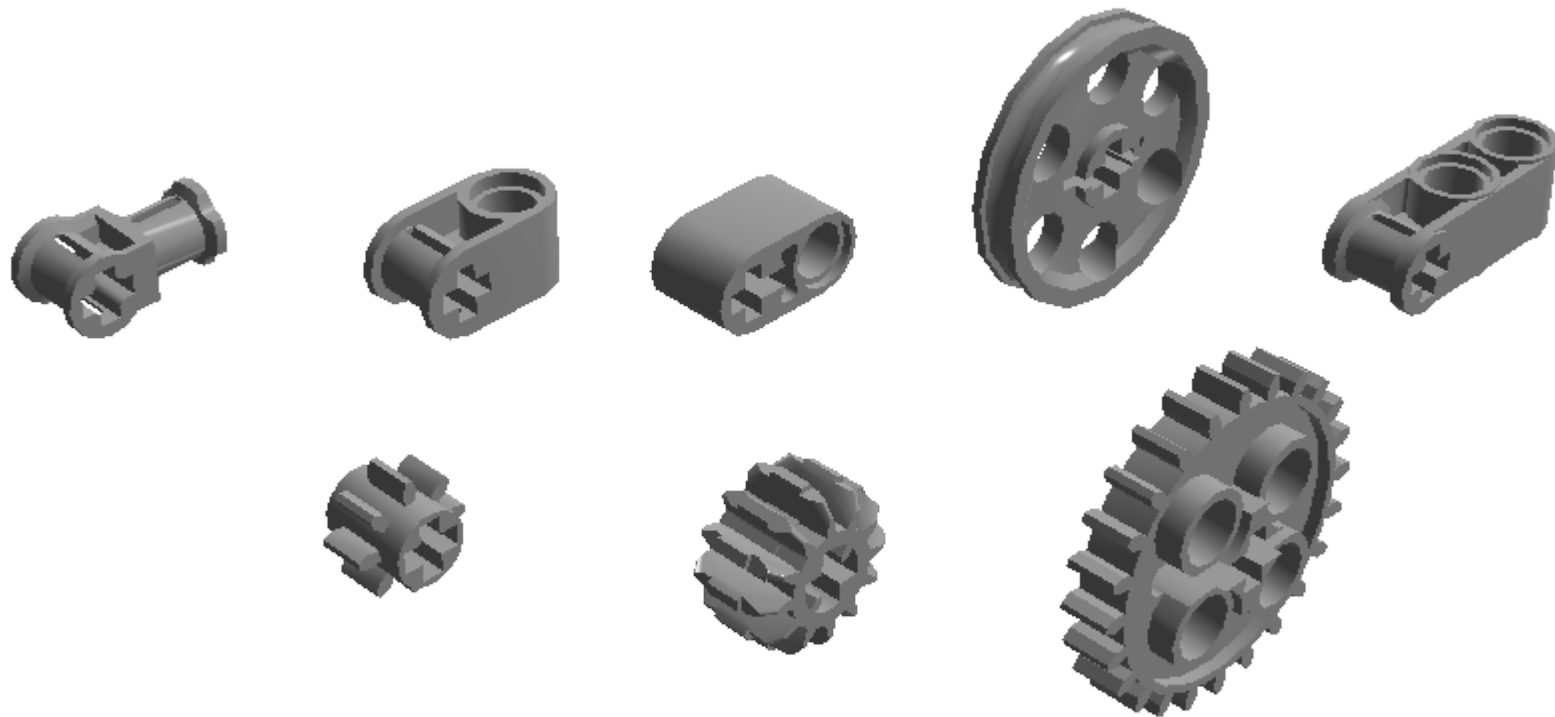
Axle connectors

Axles can be joined using a wide variety of connectors
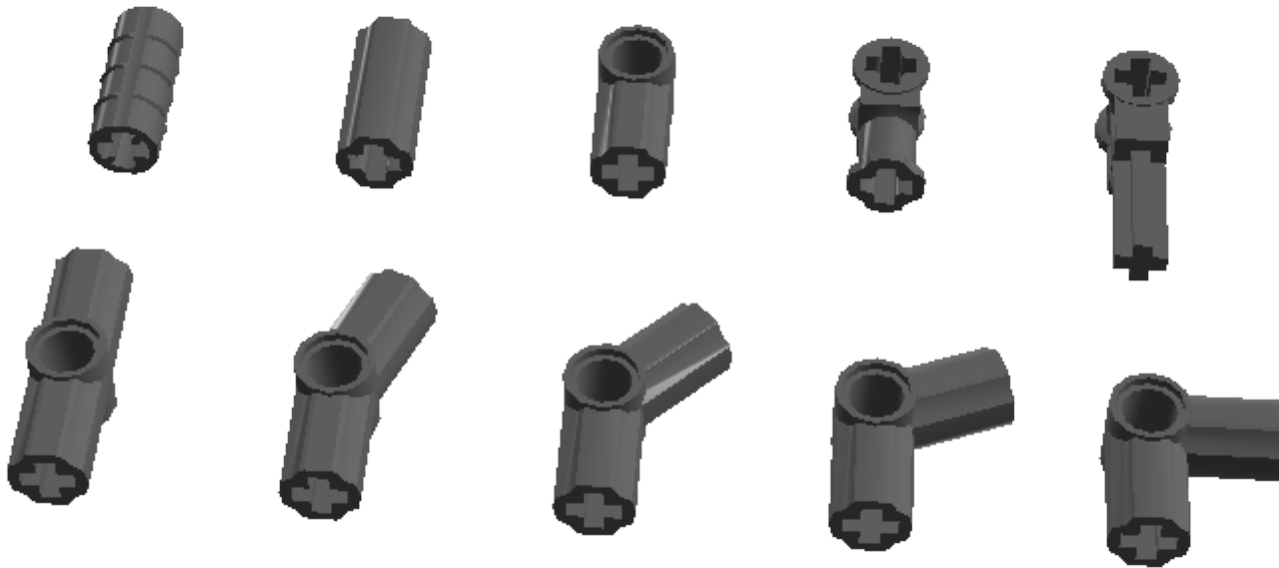
Angle beams

Allow beams to be connected at rigid angles

Excellent for structure

Some beams have cross holes

- ◆ 32526: 3x5 L beam
- ◆ 32140: 2x4 L beam
- ◆ 60484: 3x3 T beam
- ◆ 32009: 3x7 double-angle beam
- ◆ 32271: 3x7 angle beam
- ◆ 6629: 4x6 angle beam
- ◆ 32348: 4x4 angle beam
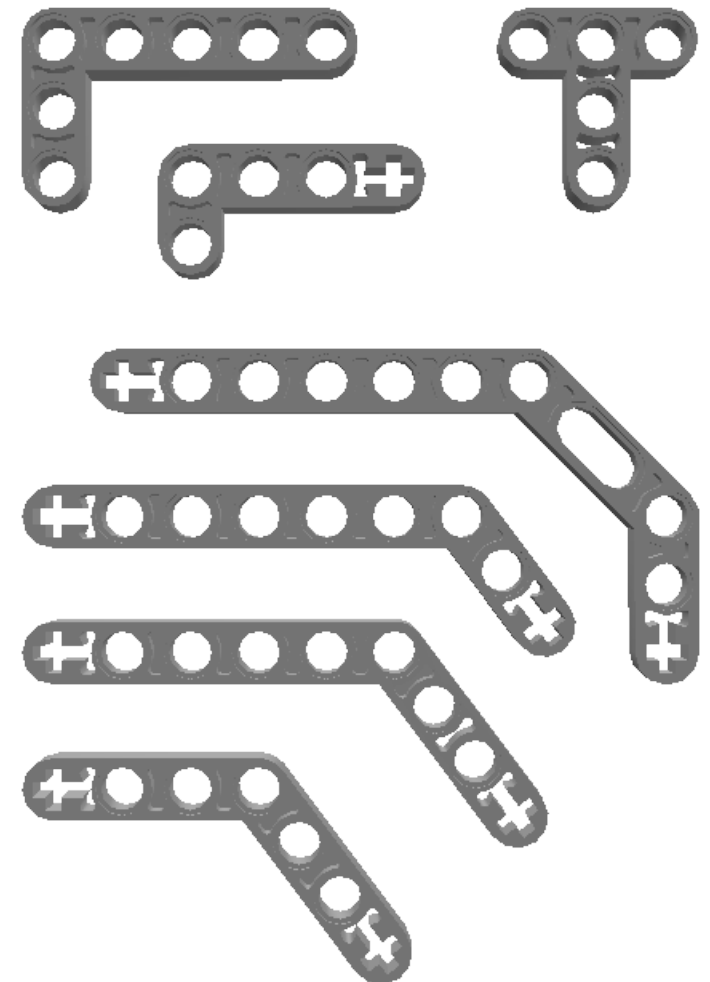
Structural strength

Weak

Strong
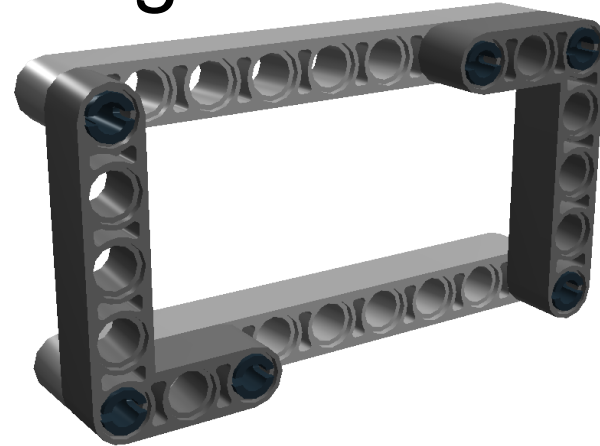
Strong
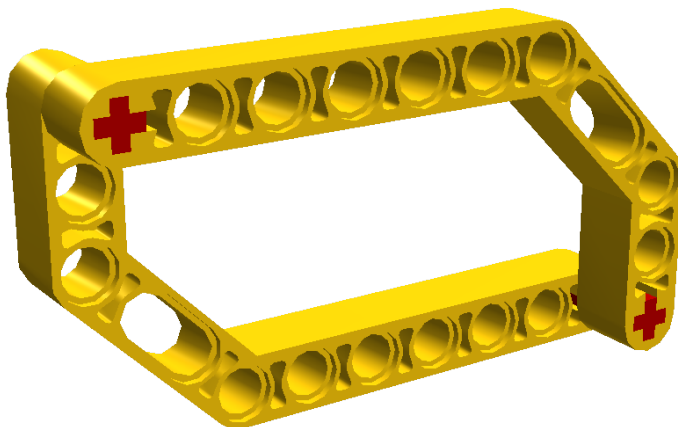
Strong
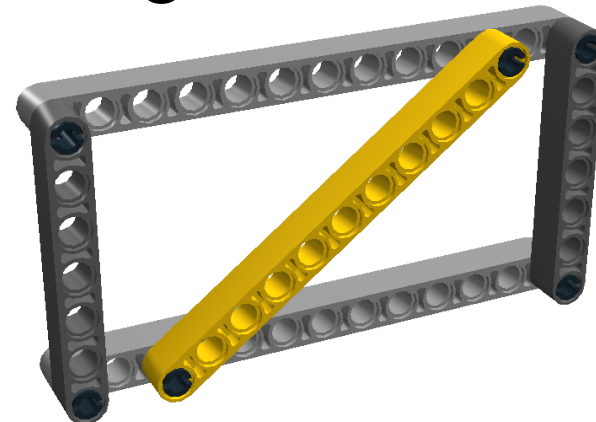
3:4:5 triangles

Angled bracing is very strong

Use 3:4:5 spacing to ensure right angles and proper alignment
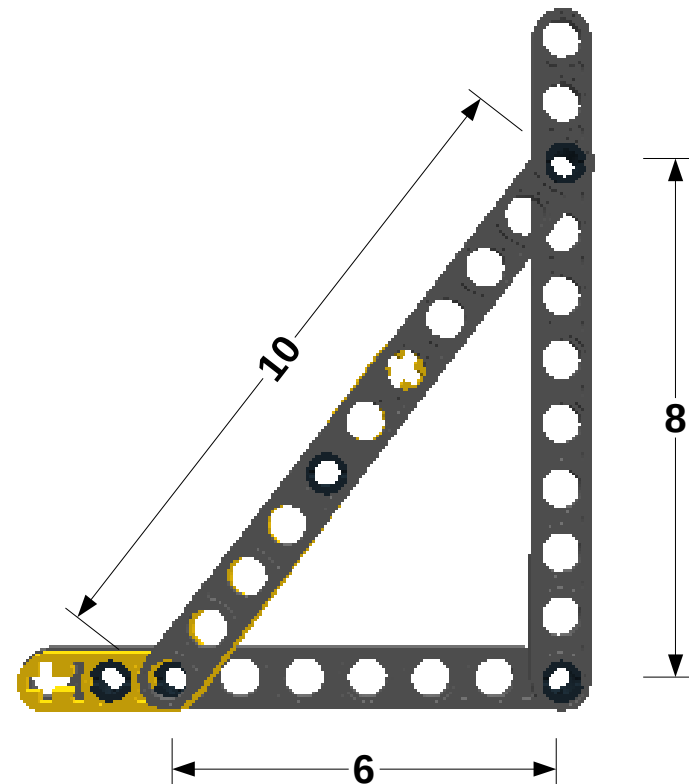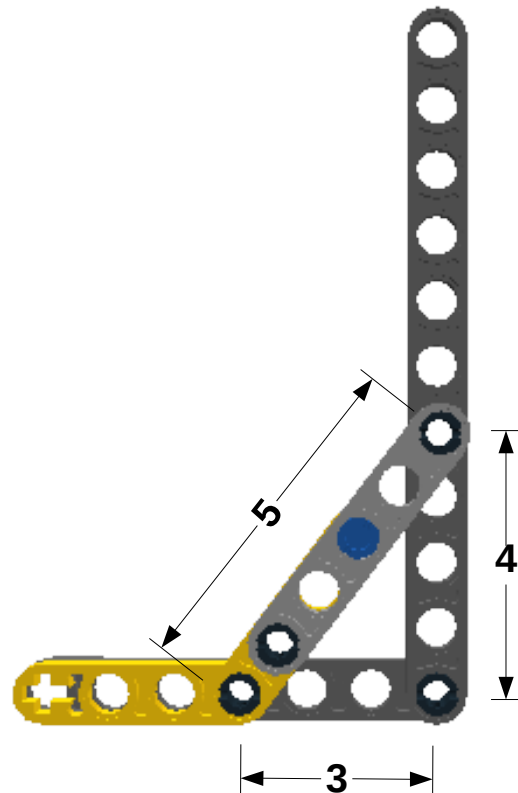
Useful LEGO pieces - frames and panels

These pieces are excellent for building large structures and boxes

Holes in all three axes for multiple mounting options

- 64179: Beam frame 5x7 ("box frame")
- 64170: Beam H frame 5x11 ("H frame")
- 64782: Flat Panel
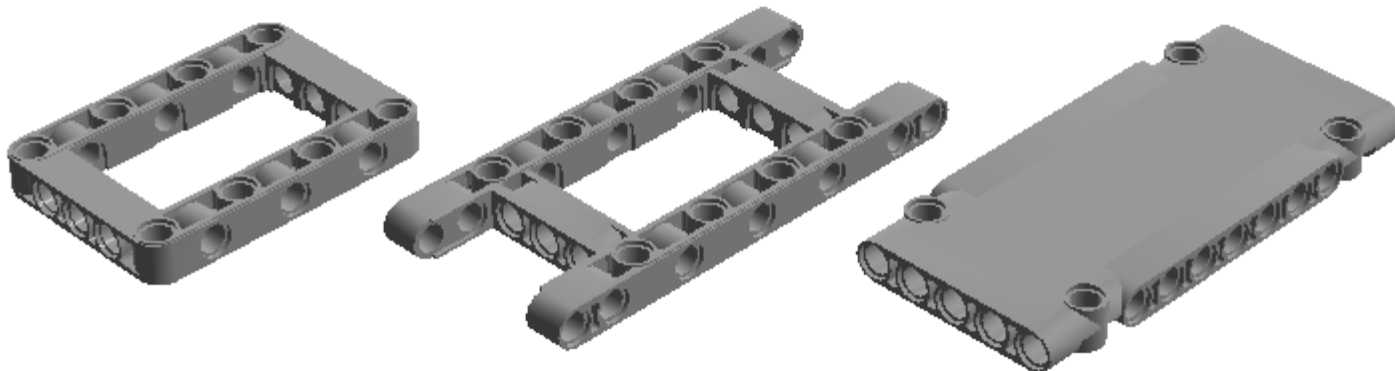
Useful LEGO pieces – cross blocks and beams

These allow connections in multiple directions

- 42003: Cross block 3M
- 32184: Double cross block
- 48989: Beam 3M with 4 snaps
- 55615: Angular beam 90 degrees with 4 snaps
- 14720: Beam I-Frame 3x5 90 degrees
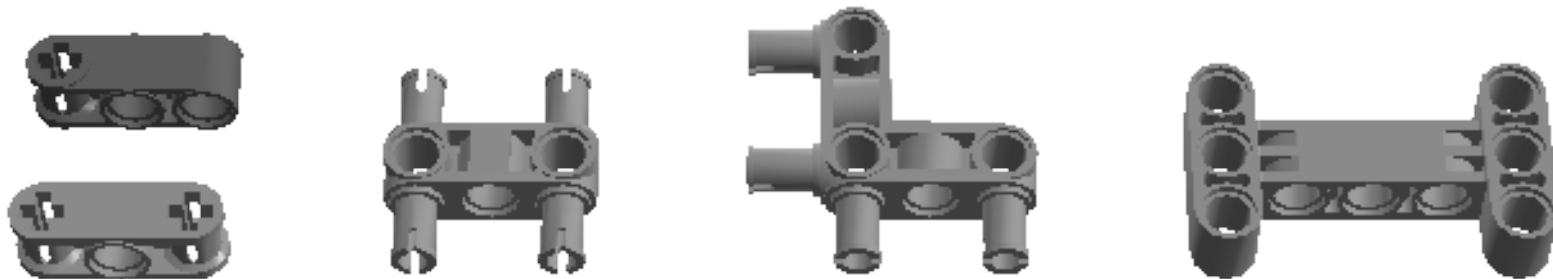
Useful LEGO pieces – cross blocks

These cross blocks have a wide variety of uses

- ◆ 32291: Cross block 2x1 ("Mickey")
- ◆ 41678: Cross block fork 2x2 ("Minnie")

Connect two parallel beams
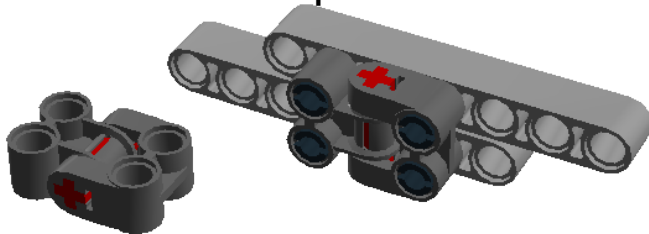
Create holes at right angles
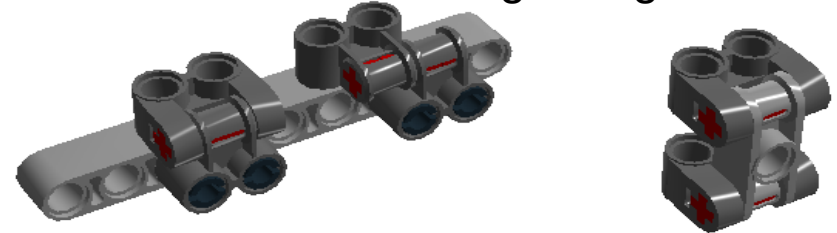
Mount axles in different directions
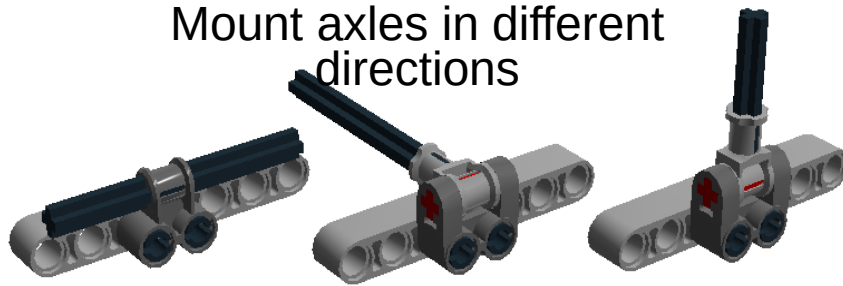
Create "beams" with even # of holes
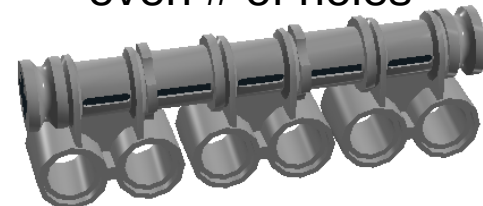
Useful LEGO pieces - misc

- 2654: Slide shoe round 2x2
  (good for skids)
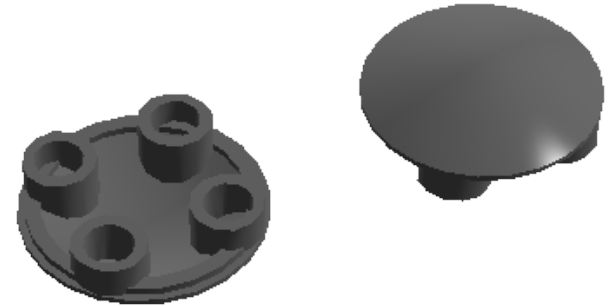
- 41531: Turbine 31.01 x 2
  (wheels that also slide)
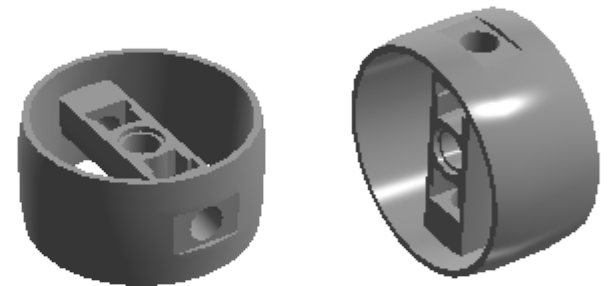
Places to find and buy LEGOs

http://bricklink.com/
   Website to connect buyers and sellers of LEGOs

Attachments

Attachments

Attachments are the things added to the chassis to solve missions and manipulate models

Good attachment design makes solving missions easy

Attachment design principles

Robot precision often limited to 1.5cm

If a target is small, try to make the attachment big

Use mission models and walls for precise alignment

Things that seem easy for humans can be hard for a robot

    Manually test attachments with eyes closed

Mounting attachments

The best attachments are those that never need to be added or removed from the robot

→ saves time during matches

If an attachment must be added or removed, make sure it can be done quickly

Avoid using pegs for removable attachments
Use axles and axle pegs
Use gravity

Removing is usually faster than adding

Rubber bands can be used to snap attachments into place

Attachment types

FLL missions usually involve

Pushing
Pulling
Lifting
Dropping / dumping
Placing / delivering
Releasing
Capturing / collecting
Shooting
Turning

Attachment building tips

Tend to use axles and plates when possible
   Axles are easy to adjust, resize, and relocate
   Plates and frames are better than walls of beams

Sources of energy for attachments
   (in order of our preference)
   1. Gravity
   2. Leverage
   3. Elastics
   4. Motors

Passive attachment: Pusher

One of the simplest (and useful) attachments is a bumper.

A bumper can easily push/deliver objects

It can also provide places for other attachments
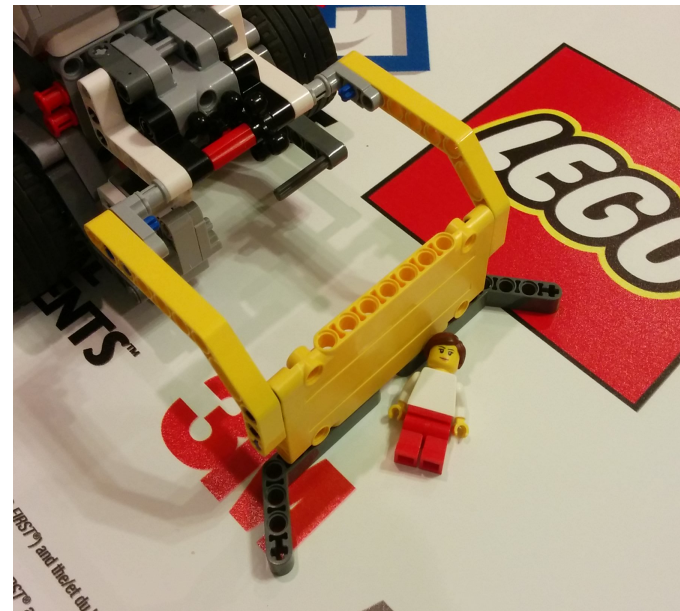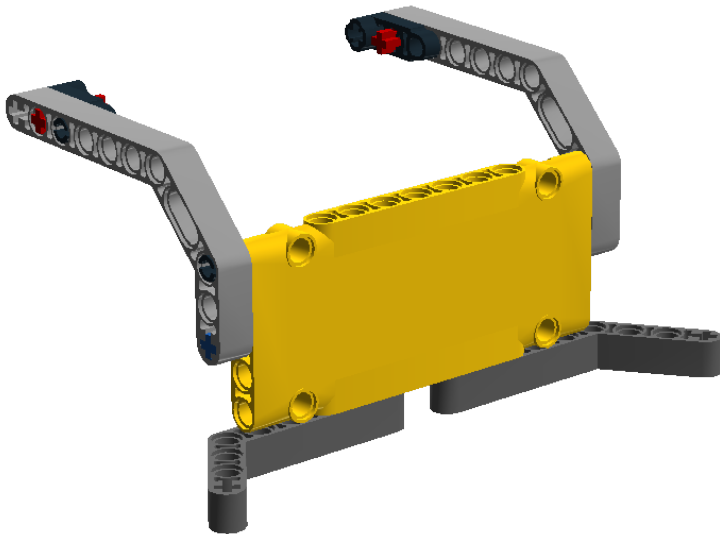
Passive attachment: Hook

A hook can be used to capture objects

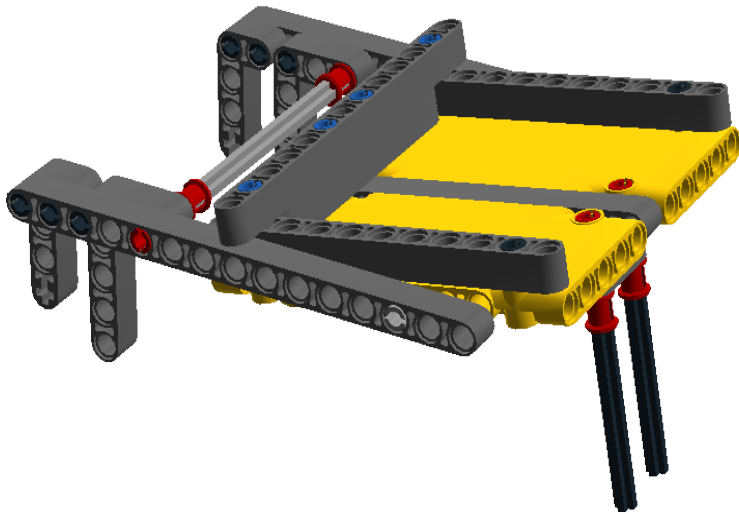Axles allow quick attach / removal
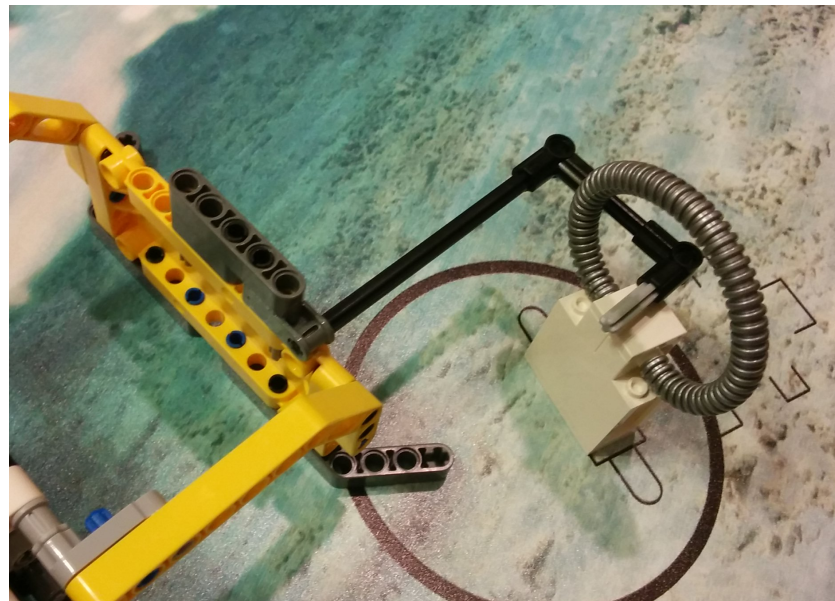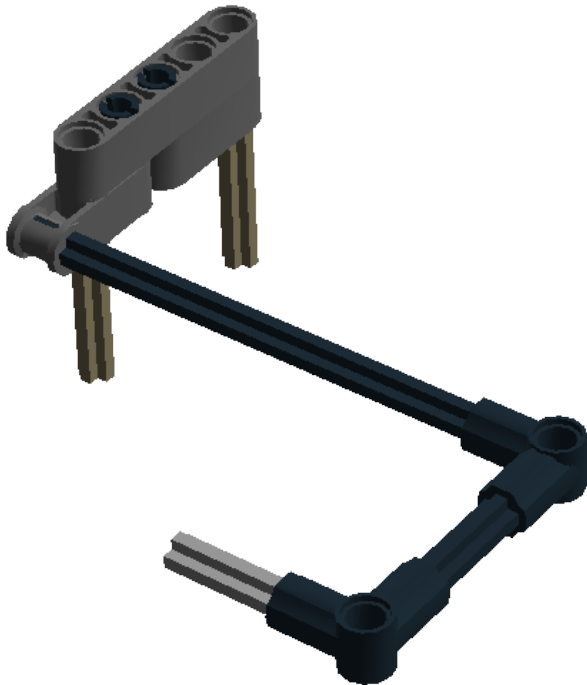
Passive attachment: Fork

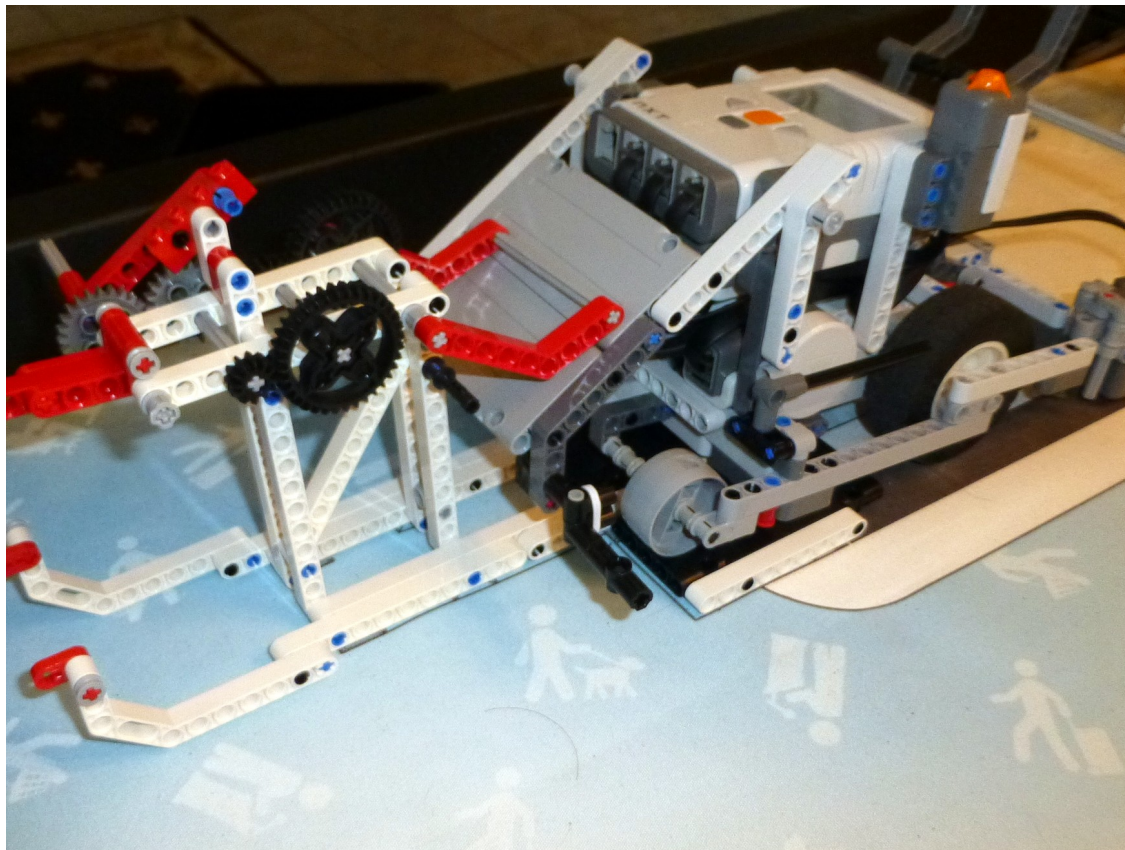A fork has multiple prongs for capturing objects

This helps make a wider target
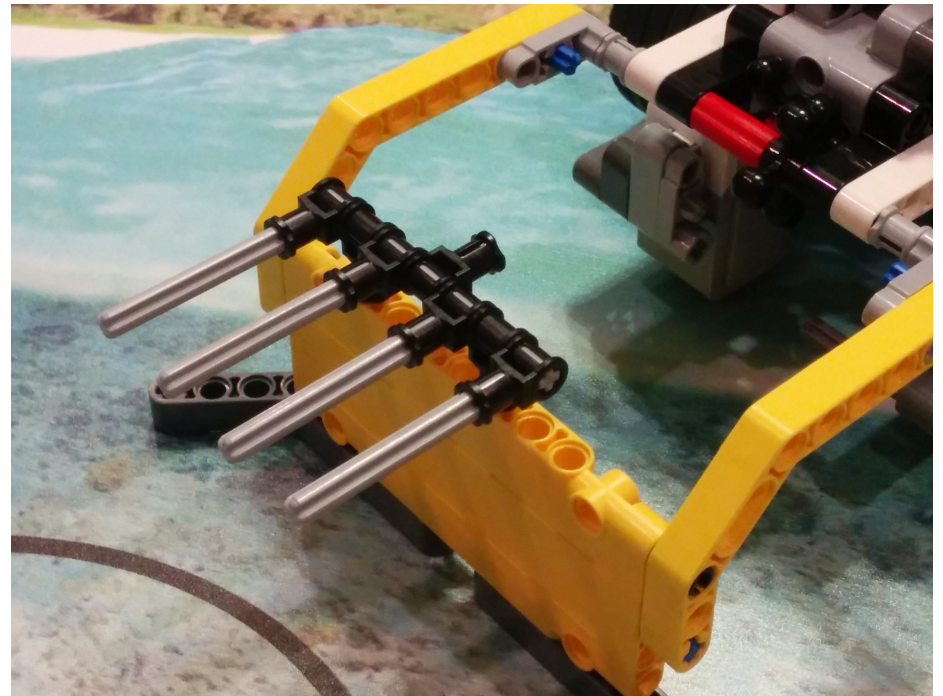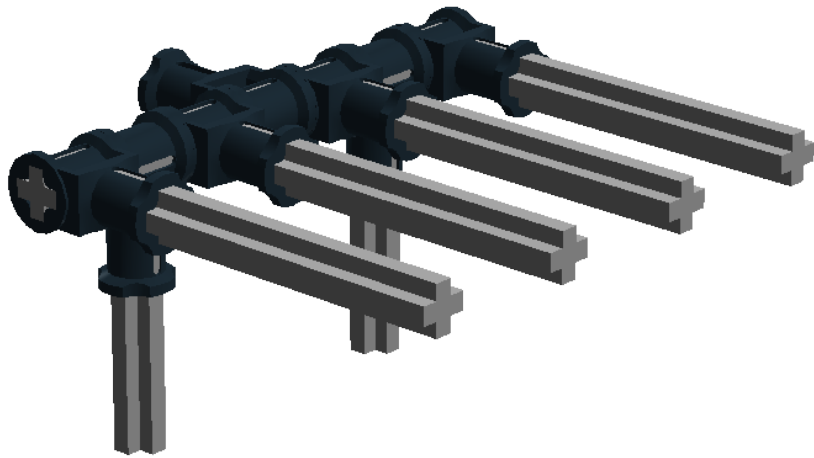
Passive attachment: Dumper

Dumpers use gravity and simple pegs to release contents
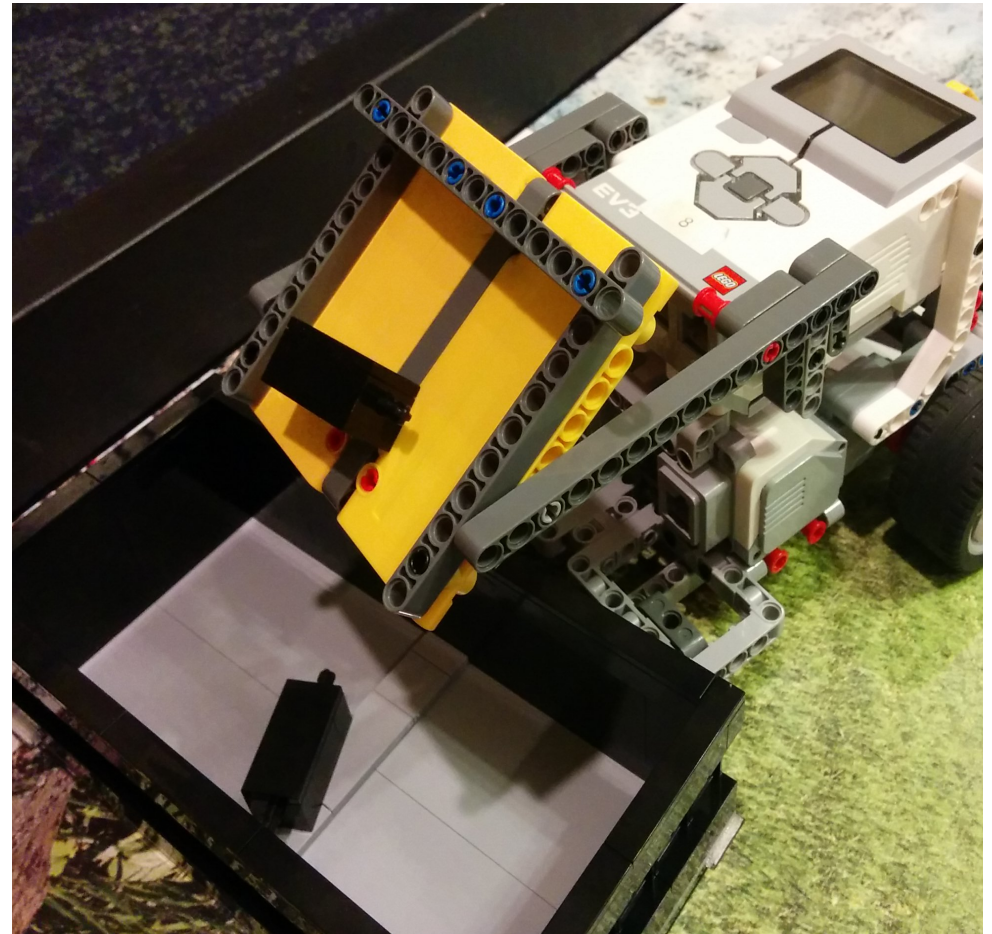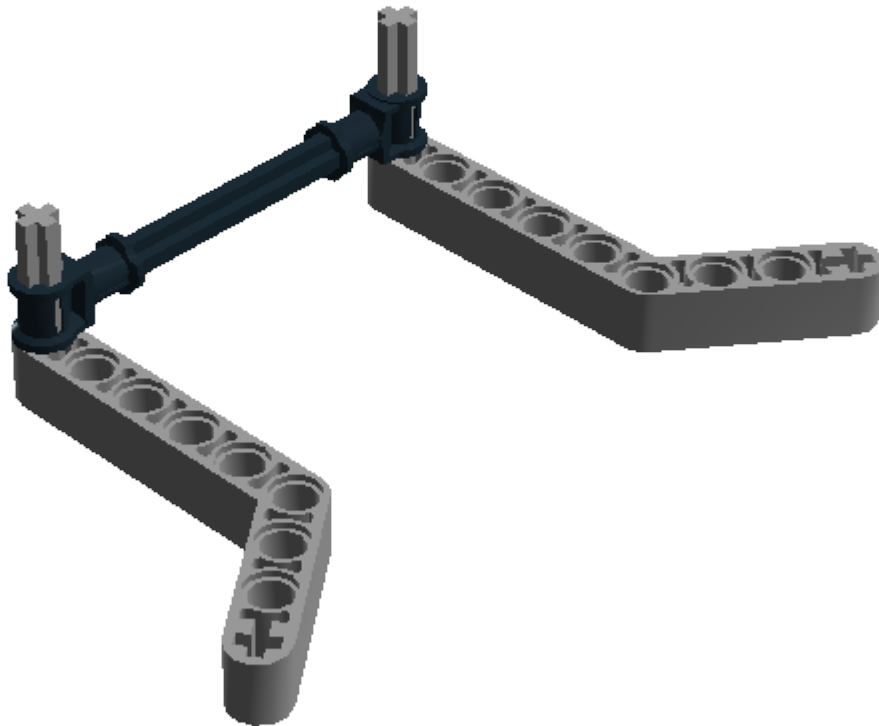
Passive attachment: Wedge

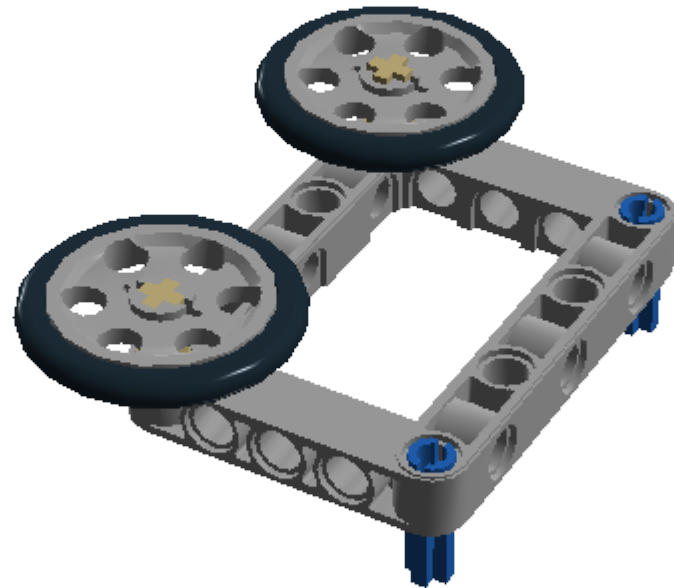A "wedge" can be used to push things up or down

Passive attachment: guides

Guides can be used to align things with mission models
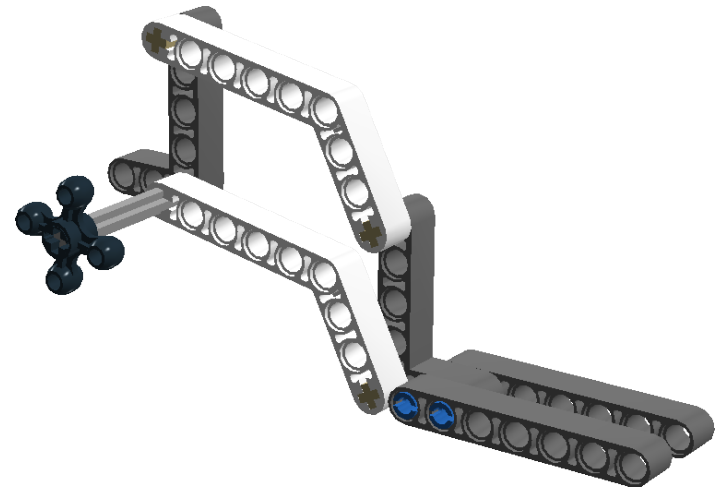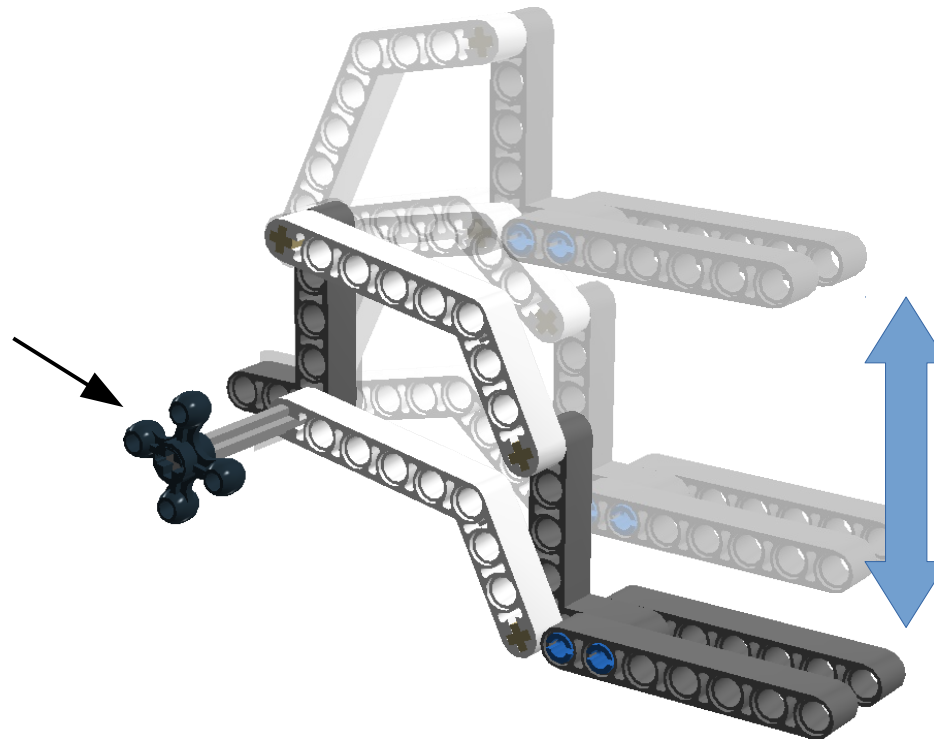
Around a model
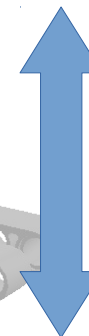
Along a wall

Powered attachment: Four-bar linkage

Raise/lower bar
without rotating it

Turn this gear
to raise/lower lift

Fork moves up
and down without
rotating

Forklift will raise or lower as worm gear turns

The 8t gear
doesn't turn

Turn this gear
to raise/lower lift