FLL Workshop – Day 3 Chassis and Attachments

Patrick R. Michaud pmichaud@pobox.com

University of Texas at Dallas June 2017

### LEGO basics

- Chassis design
- Attachments



#### 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

2M
3M
5M
5M
6
7M
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
6
<

Can be "thin" or "thick"

### 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



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



#### 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



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

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



Used to hold axles on beams

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

- 32123 Half-bushing
- 6590 Bushing









# Other elements can also be used as bushings or spacers



Axles can be joined using a wide variety of connectors



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





#### Strong



Strong



Strong



Angled bracing is very strong

Use 3:4:5 spacing to ensure right angles and proper alignment





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

![](_page_16_Picture_6.jpeg)

### 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

![](_page_17_Picture_7.jpeg)

### 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

![](_page_18_Picture_5.jpeg)

#### Create holes at right angles

![](_page_18_Picture_7.jpeg)

![](_page_18_Picture_8.jpeg)

Create "beams" with even # of holes

![](_page_18_Picture_10.jpeg)

![](_page_18_Picture_11.jpeg)

### Useful LEGO pieces - misc

 2654: Slide shoe round 2x2 (good for skids)

![](_page_19_Picture_2.jpeg)

 41531: Turbine 31.01 x 2 (wheels that also slide)

![](_page_19_Picture_4.jpeg)

Robot design and strategy

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

# Great robot + poor strategy $\rightarrow$ inconsistent scores

## Fair robot + good strategy $\rightarrow$ consistent scores

The robot must always start from Base

Base is the only place where changes can be made

#### Matches are 2:30

When the Robot is in Base, it's not scoring  $\rightarrow$  minimize time spent in Base

#### Travel on the field takes time

- $\rightarrow$  minimize time spent moving from place to place
- $\rightarrow$  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"

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

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

# Whenever the robot or humans make a mistake in scoring,

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

### From the Robot Design judging rubrics:

		Beginning	Developing	Accomplished	Exemplary
	Durability Evid		lence of structural integrity; ability to withstand rigors of competition		
ign	N D	quite fragile; breaks a lot	frequent or significant faults/repairs	rare faults/repairs	sound construction; no repairs
I Des	Mechanical Efficiency Economic use of parts and time; easy to repair and modify				
anica	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
Jech	MechanizationAbility of robot mechanisms to move or act with appropriate speed, strength and accuracy for intended tasks (propulsion and execution)				
2	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

#### 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

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  $\rightarrow$  time to solve more missions Slower robot  $\rightarrow$  more consistent and accurate 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

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

![](_page_34_Picture_2.jpeg)

![](_page_34_Picture_3.jpeg)

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

![](_page_34_Picture_5.jpeg)

![](_page_34_Picture_6.jpeg)

2 wheels and skid(s) Works great, may have difficulty with ramps/obstacles

![](_page_35_Picture_2.jpeg)

- 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

![](_page_35_Picture_6.jpeg)

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

Treads

Good for obstacles, hard to predict turns

Exotics

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

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

![](_page_39_Picture_6.jpeg)

To save match time, always start from same spot

Attachments

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

Good attachment design makes solving missions easy

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

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

 $\rightarrow$  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

#### FLL missions usually involve

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

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 preference)

- 1. Gravity
- 2. Leverage
- 3. Elastics
- 4. Motors

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

![](_page_46_Picture_4.jpeg)

![](_page_46_Picture_5.jpeg)

#### A hook can be used to capture objects

#### Axles allow quick attach / removal

![](_page_47_Picture_3.jpeg)

![](_page_47_Picture_4.jpeg)

#### A fork has multiple prongs for capturing objects

#### This helps make a wider target

![](_page_48_Figure_3.jpeg)

![](_page_48_Picture_4.jpeg)

# Dumpers use gravity and simple pegs to release contents

![](_page_49_Picture_2.jpeg)

![](_page_49_Picture_3.jpeg)

#### **Powered attachment: Vertical lifts**

#### Forklift will raise or lower as worm gear turns

![](_page_50_Picture_2.jpeg)

#### Powered attachment: Four-bar linkage

# Raise/lower bar without rotating it

![](_page_51_Picture_2.jpeg)

Turn this gear to raise/lower lift

Fork moves up and down without rotating