FLL Coaches Clinic
Chassis and Attachments

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September 24, 2016
Presentation Outline

LEGO basics

Chassis design

Attachments
LEGO basics
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.”
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
Pegs

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
Pegs

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
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

Mount axles in different directions

Create holes at right angles

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)
Robot design and 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.
Great robot + poor strategy → inconsistent scores

Fair robot + good strategy → consistent scores
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

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 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.
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:

<table>
<thead>
<tr>
<th></th>
<th>Beginning</th>
<th>Developing</th>
<th>Accomplished</th>
<th>Exemplary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Durability</strong></td>
<td>Evidence of structural integrity; ability to withstand rigors of competition</td>
<td></td>
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<tr>
<td>N</td>
<td>quite fragile; breaks a lot</td>
<td>frequent or significant faults/repairs</td>
<td>rare faults/repairs</td>
<td>sound construction; no repairs</td>
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<td>D</td>
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<tr>
<td><strong>Mechanical Design</strong></td>
<td>Economic use of parts and time; easy to repair and modify</td>
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<tr>
<td>N</td>
<td>excessive parts or time to repair/modify</td>
<td>inefficient parts or time to repair/modify</td>
<td>appropriate use of parts and time to repair/modify</td>
<td>streamlined use of parts and time to repair/modify</td>
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<tr>
<td><strong>Mechanization</strong></td>
<td>Ability of robot mechanisms to move or act with appropriate speed, strength and accuracy for intended tasks (propulsion and execution)</td>
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</tr>
<tr>
<td>N</td>
<td>imbalance of speed, strength and accuracy on most tasks</td>
<td>imbalance of speed, strength and accuracy on some tasks</td>
<td>appropriate balance of speed, strength and accuracy on most tasks</td>
<td>appropriate balance of speed, strength and accuracy on every task</td>
</tr>
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<td>D</td>
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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
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 $\rightarrow$ time to solve more missions
- Slower robot $\rightarrow$ 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

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

The 8t gear doesn't turn.

Turn this gear to raise/lower lift.
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