http://tinyurl.com/zkoy5cr

Building a Better Robot

Tips and Techniques for a great robot design
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What are the most important aspects of a successful robot?

- Robust Structure
- Accuracy - getting from Point A to Point B
- Precision - repeatability, regardless of conditions
- Efficiency - on the field, in design, and in transition
- Awesome attachments!
Achieving Strong Structure

• Balance weight near center
• Weight vs. strength consideration
• Shape vs. mobility
• Consider attachments
Power Transmission

• If we drive a large gear with a small gear, we increase the torque but decrease the speed (that is called gearing down)
• Gear Ratio is defined as: 
  # of follower’s teeth : # of driver’s teeth
• Worm Gear very useful to gain lots of torque
Power Transmission (cont.)

- Worm Gear On Rack useful for forklifts, changing rotation into linear motion).
- Bevel and Crown gears useful for changing angle of rotation 90 degrees.
Using LEGO rubber bands

• Use LEGO rubber bands to:
  – Keep wires out of the way
  – Like springs - to hold touch sensor levers in place
  – To trigger a trap
  – Make rubber band motors
Accuracy - How do we get from A to B?

- Using encoders
  - Dia * Pi = Circumference, Circum * Rotations = distance?
- Brick encoders measure wheel rotations, not robot movement
- How to ensure accuracy of distance?
  - Using lines
  - Using (south) wall
  - Using models
  - Double touch rule
Designing for Repeatability

• The best robot (and program) designs make for robust robot performance given variation that happens in a real world environment
  – Every Competition Table has different texture (waves, bumps, dust, adhesion), alignment, lighting, pitch, color, models, etc.
  – Robot behaves different as motors and parts age, battery level changes, etc.
• Reduce variation wherever possible
  – Consider the wheel friction to the mat
  – Consider different lighting conditions
  – Consider variation of location of models and walls
Designing for Repeatability (cont.)

• Consider Battery Discharge Curve
Designing for Repeatability (cont.)

- Consider using the walls for locating robot
Designing for Repeatability (cont.)

• Make attachments that can handle as much error as possible

Example of using a comb to get loops.

Even the robot shifts, one of the comb will stick the loop.
Designing for Repeatability (cont.)

• Matching Motors
  – Better repeatability and easier to program
  – Website link in References
Alignment Guides

• Alignment guides can be used in base, and used outside of base as well, if carried by the robot

• Useful to align onto models to perform a task

• Useful to line up robot in base to reduce variation in leaving base
Variation Testing

• The best way to make sure that the robot is robust is to test with variations:
  – Slightly different starting positions
  – Different mat conditions – “dusty”, just cleaned
  – Different mat and model placements
  – Different table tilts
  – Different lighting conditions
  – Different wall textures – paint vs. wax paper etc.
Efficiency

• Robot needs to go as fast as possible without losing accuracy and precision
  – Have robot accomplish some tasks while moving
• Make transitions as seamless as possible and practice!!!
• Prototype designs before going down a long road of failure. Test blind.
• Group missions by proximity and attachments needed
Robot Attachments

- Consider handling variation!
- Consider doing tasks WITHOUT using the third motor
- Consider EASY TO ATTACH attachments
  - Use long black friction pins that won’t pull out when attachment is removed
Robot Attachment Design Techniques

• Think of examples in construction:
Robot Attachments

- Two basic categories of attachments:
  - **Passive (no motor)**
    - Pushing type
    - Hooking type
    - Dumping type
    - Collecting type
    - Spring or rubber-band loaded type
  - **Active (motor)**
    - Grabbing/Collecting type
    - Lifting type
    - Hooking type
    - Dumping type
Attachments

• Passive Pushing Robot Attachment
  Great for pushing mission models a
• Passive Hooking Robot Attachment
  Great for gathering objects
• Spring (Rubber Band) Loaded Design
Attachments

• Passive Dumping Robot Attachment
  A way to move mission objects from base to some location on the field.
  Doesn’t require a motor to activate; robot just “bumps” the trigger into something.

• Passive Collecting Robot Attachment
  Great for bringing mission objects back to base
  One way trapdoor
Attachments

- Active Hooking Attachment
  Lots of missions need some way to hook objects
- Active Lifting Attachment
  Forklift attachment uses worm gears for strength in lifting
- Active Grabber Attachment
  Great for collecting objects in multiple places on the field
References

• Brick Link: Buying LEGO parts
  – http://www.bricklink.com/

• Matching Motors: Better robot handling

• NXT Battery Voltage Experiment: Turn repeatability experiment

• LEGO Gearing Tutorial
References (Continued)

• Designing for FLL and LEGO Hints and Tips presentation
  – http://www.syraweb.org/resources.htm
• Winning Design! LEGO Mindstorms NXT, David J. Trobough
• FLL Robot Design Workshop, Tool Design and Mechanism presentation, Dr. C. H. Lin
  – www.neohstem.org/assets/pdf/FLL%20Robot%20Design%20Workshop
End!!!
Weight and Balance

• Too much weight on non-drive wheel(s)
  – Hard to make turns
    • Need more force to overcome more friction
    • Turns can be less accurate
  – Drive wheels may lose traction, skid, “burning rubber”
  – Rotation sensors measure wheel rotation not robot travel!
Weight and Balance (cont.)

• Not Enough Weight on non-drive wheel(s)
  – Robot can pop a wheelie when starting or stopping
  – Steering becomes inaccurate, directional stability is lost
  – Wheelie effect can be reduced
    • Accelerate slowly
    • Brake slowly
Weight and Balance (cont.)

- Too much weight on one side of robot
- Robot leans to one side, tends to steer in that direction
- Wheel on light side can slip
Weight and Balance (cont.)

• Heavy Robot
  – Tires can flatten, separate from rims
  – Takes lots of force to start, stop, and turn
  – Batteries run down faster
  – Axles can become permanently bent
    • Especially if robot sits on its wheels for several days
Weight and Balance (cont.)

• Long Robot (dragster)
  – Takes more force to turn, even if not front-heavy
  – Center of mass is natural pivot point
  – Dragster: center of mass is further forward

• Weight and Balance will change when robot lifts, carries and drops objects
Strong vs. Heavy

• Sometimes the robot needs to be heavy
  – “raise the house!”
• Usually, strong and light is better
  – Especially on robot arms and attachments
    – Consider axle beams vs. bricks
    – Consider how bridges are built
• Just strong enough
  – Don’t add unneeded weight or bulk
    – Needs to be reliable
Gearing (cont.)

• Gear Ratio is defined as:
  # of follower’s teeth : # of driver’s teeth

• So for a gear down of 24 teeth to 8 teeth we have a gear ratio of 24:8, which can be reduced to 3:1. This means that it takes 3 revolutions of the driver gear to turn the follower gear one revolution.
Gearing (cont.)

• Great Gear Tutorial link in References
Tires and Squishiness

• What are the best wheels and tires?
• Fat tires vs. skinny tires
  – Fat tires offer good traction
  – Fat tires can squash under weight, change diameter
  – Fat tires have a large footprint – inaccurate turning

• Big wheels vs. small wheels
  – Big wheels mean higher speeds
  – Big wheels may slip less than small wheels

• Dual wheels
  – 2 large skinny wheels on each side (like a truck)
  – Good traction, supports weight, fairly accurate turns
Wheel Size

• “I want the robot to go 12 inches, how many rotations is that?”

\[
\text{Diameter} \times \pi = \text{Distance Per One Rotation}
\]

(about 3.14)

If wheel diameter is 2.5 inches, one rotation is about 8 inches of travel.
Designing for Repeatability (cont.)

• Reduce variation wherever possible
  – Consider the battery power and motor loads

These curves show the speed of a motor vs. its load and battery voltage under several conditions. Note that as voltage changes and robot design changes, so will robot performance.
Designing for Repeatability (cont.)

• Attachments can change robot behavior dramatically to improve repeatability

Example of an attachment to make robot go perfectly straight.

**cartridge**

The base robot mated with the cartridge