Robot Design

• What Does a FIRST Robot Look Like?
• Common Tasks
• Strategic Design
• Functional Design
• Resources
FIRST Robotics Competition
Waterloo Regional

Ian Mackenzie

• 8 years FIRST experience
• Co-General Manager for Team 1114 in 2004, winning 8 FRC awards
• Lead designer for two revolutionary FIRST drive systems (Hexadrive 2002, SimSwerve 2004)
• Specific Areas of Mentorship
  – Mechanical Design, Competition Strategy
• 4th year Systems Design Engineering major at the U. of Waterloo
• Current member of the Waterloo Regional Planning Committee
Karthik Kanagasabapathy

- 8 Years FIRST experience
- Co-General Manager for Team 1114 in 2004, winning 8 FRC awards
- Specific Areas of Mentorship
  - Strategic Design, Competition Strategy, Field Coaching, Team Administration
- 5th year Math Major at the U. of Waterloo
- Current member of the Waterloo Regional Planning Committee
What Does a FIRST Robot Look Like?
Overview

- 3' long
- 30” wide
- 60” high
- 130 lbs.
- 1-2 functions mounted on a moving chassis
FIRST Games

- Score points by accomplishing certain tasks
- Usually too many tasks for one robot to do everything
- 2 minute matches, 2 vs. 2
- No deliberate damage or tipping, but some pushing and shoving
Controls

- Controller programmable in C
  - Designed for FIRST
  - Default code supplied
- Digital radio modem
- Very easy to use sensors
  - Potentiometers
  - Limit switches
  - Optical sensors
  - Gyroscopes, etc.
What does a FIRST robot look like?

Common Tasks

Strategic Design

Functional Design

Resources

Motors

- Usually 12-14 motors provided in the kit
- Not allowed to buy others
- Range of speeds and torques
- Car seat, door, window motors; Fisher-Price jeep motors; trailer lift motors, etc.
Pneumatics

- Compressor, air tank, cylinders, pressure sensor and valves supplied with kit
  - Can choose what size cylinders you want
- 120 PSI storage, 60 PSI in cylinders
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**Common Tasks**
Pick up Objects

- Usually balls, sometimes other objects
- Grabbers, rollers, scoops, suction cups
Move Objects Around

- Goals, ramps, mobile platforms
- Hooks, latches, clamps
Obstacles

- Climb over ramps and steps
- Limbo under bars
- Hang from bars
Move Autonomously

- Knock over objects
- Get into some position
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Strategic Design
Case Study – 2002: Zone Zeal

• Playing Field
  - 24’ x 48’ playing field
  - Divided widthwise into five approximately equal zones
  - Three 180 lb. movable goals located in the center zone
  - 20 soccer balls located on either long side of the field, 10 in each alliance station
Case Study – 2002: Zone Zeal

- Playing Field Diagram

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Resources
Case Study – 2002: Zone Zeal

• Scoring
  – Assume your alliance started in zone 1
  – Each goal in zone 4 is worth 10 points
  – Each ball in a goal in zones 4 & 5 is worth 1 point
  – Each robot in zone 1 is worth 10 points
Analyzing The Game

- Read the rules
- Examine every possible way to score points, no matter how obscure
- Examine every possible way to prevent your opponents from scoring
- Evaluate the likelihood of these scenarios
- Consider possible strategies
The Chokehold Strategy

- A strategy which, when executed, guarantees victory, independent of any action by your opponents
- FIRST tries to design games with no reasonable chokehold strategy
- If one exists, it will be very difficult to perform
  - Team 71, Beatty & Hammond, 2002
Effort vs. Rewards

- For each task you must compare the difficulty of accomplishment to the reward for doing so
- The best tasks to perform are those which are relatively easy, yet provide big points
- Remember denying your opponents 10 points is just as good as scoring 10 points
Simplicity

- **K.I.S.S.**
- **Golden Rule #1**: Always build within your team’s limits
  - Evaluate your abilities and resources honestly and realistically
  - Limits are defined by manpower, budget, experience
- **Avoid building unnecessarily complex functions**
  - “Is it really needed?” “Could we better use our resources elsewhere?”
- **Golden Rule #2**: If a team has 30 units of robot and functions have maximum of 10 units, I’d rather have 3 functions at 10/10 instead of 5 at 6/10
Prioritization

• Two separate lists
  – Robot qualities
    • Things like speed, power, agility
  – Tasks
    • The things you want your robot to be able to do
      – Grab goals, pickup balls

• At this point you can merge the two lists, and decide on a drive system and functionalities
Tradeoffs

• The key to deciding upon a design is to evaluate the tradeoffs

• With any FIRST robot, when you choose on function or ability, you usually have to give something

• Making the right choices based on your analysis will determine the fate of your season

• e.g. Speed vs. Power, Complexity vs. Durability, Goals vs. Balls

• Remember the Golden Rules – Teams who try to do more than they’re capable of, tend to fail
Other Points

- This strategic analysis is a MUST
  - There’s a tendency to skip this stage, and to head straight into design and implementation

- You must know what you want to do before you can figure out how to do it

- Remember, you have a partner. It’s okay do depend on them for certain tasks. (How much you leave to them should be decided by the Golden Rules)
  - Although, be careful not to leave too much in you partner’s hands.
Before You Finalize…

- By this point you should be able to identify the different types of robots that will exist.

- Go through the different permutations of alliances:
  - e.g. How would we do paired with type ‘x’, against type ‘y’ and type ‘z’
  - What would we do if we had to play ourselves?
Functional Design
Brainstorming

- No bad ideas
- Think outside the box
  - Read the rules carefully
  - Cantilevering, “squish the fish”
- Mechanisms as well as overall designs
- Keep the ideas!
- Playing field model or mock-up very useful
Prototyping

- Proof of concept
- Size
- Motor / piston capability
- Shape
- Motion
- Try several ideas if possible
- Focus prototyping on unknown areas

What does a FIRST robot look like?

Common Tasks

Strategic Design

Functional Design

Resources
Final Design and Build

- Design and build final mechanisms
- Keep monitoring robot weight
- Make sure to buy or order necessary parts before you need them
- Check for interference between components
- Form sub-groups
- Miscellaneous tip: Don't get shavings in the speed controllers!
Testing and Practicing

- Test beyond what the robot will likely experience
- Test many times in different circumstances
- Reinforce weak areas
- Tweak components
- Build spare parts for suspect components
- Practice!
  - Different scenarios
  - Close to competition circumstances
FIRST Robotics Competition
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Principles

- Simplicity
  - Fewer things to fail
  - Easier and faster to build and repair
  - Lighter
  - More durable
  - More elegant

- Design for assembly and disassembly
  - Leave bolts exposed

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Strategic Design

Functional Design

Resources
Principles

• Durability
  - Simplest mechanisms often the most durable
  - Robot will likely go through much more stress than you expect
    • Different driving in a competition situation
    • Collisions with other robots
    • Unanticipated situations
  - Examples: twisted shaft, sheared pins, latch bracket, arm chain, steering mechanism
  - Careful with welding

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Resources
Principles

- **Weight distribution**
  - Keep as much weight as low as possible
  - Put weight over the drive wheels for most traction
  - Battery is a large component of the total weight (14 lbs) and can help move center of gravity
Principles

- **Vibration**
  - Robots go through a lot of vibration, especially at competitions
  - Bumpy wheels increase vibration
  - Use Pozi-Lok or other lock nuts to avoid nuts falling off
  - Check bolted connections and shaft collars frequently
  - Check the antenna!
Principles

• Multi-functionality
  – Cuts down on weight, complexity, building time etc.
  – Slight modification can often lead to a new, useful function
  – Be wary of conflicting requirements
  – Example: arm for ball manipulation and hanging

• Consolidation
  – Multi-motor gearboxes
  – Common shafts
Principles

• Theory

- Classroom theory really can be useful
- Eliminate infeasible ideas quickly
- Free-body diagrams
- Kinematics and dynamics
- Gear calculations (torque and speed)
- Electrical power consumption
- Vector geometry
- Trigonometry
Computer Aided Design (CAD)

- Very useful in certain situations
  - Components needing high accuracy
  - Complex shapes and assemblies
- Can be used for virtual prototyping
  - Useful for checking for interference
- Often too slow for simple components
Useful Components

- **Bronze bushings**
  - Cheaper, more rugged than bearings
  - More friction

- **Aluminum profile (e.g. Bosch)**
  - Very fast, versatile frame construction

- **Aluminum angle / L-channel**
  - Extremely versatile and useful

- **Delrin, HDPE, nylon, Lexan etc.**
  - Sliders, rollers, spacers
  - Lighter, but weaker and less rigid than aluminum
  - Easy to cut, but can be difficult to machine
Basic Materials

- Nuts (Pozi-Lok) and bolts
  - Standardize if possible
- Steel shafts of different sizes
- Shaft collars
- 1/4” aluminum plate
  - Be careful about weight
- Aluminum square tubing
- Surgical (latex) tubing
- PVC / ABS tubing
- Cable ties (no tape allowed!)
Resources
Sample Mechanisms

www.firstroboticscanada.org
(in 'Resources' section)

- Frames
- Grippers
- Drive trains
- Gearboxes
- Wheels
- Elevators
- Rotating joints
- Arms
Other Resources

- www.firstrobotics.net
- www.chiefdelphi.com/forums/papers.php
Questions?

- Ian Mackenzie (ian.e.mackenzie@gmail.com)
- Karthik Kanagasabapathy (kkanagas@hotmail.com)

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