Robot Control

• Introduction
  – There is a nice review of the issues in robot control in the 6270 Manual
  – Robots get stuck against obstacles, walls and other robots.

Why? Is it mechanical or electronic or sensor failure?
Answer: Sometimes! More often than not it is because of POOR SOFTWARE design. The robot is not mechanically stuck, it is mentally stuck! The program did not account for this situation and did not provide a “way out” of the dilemma.
Robot Control

• Example
  – Bump sensors (switches) do not always trigger!
  – A robot wall follows for a while and then for no apparent reason bumps the wall.
  – A robot approaches a corner and “trembles” (that is, gets trapped!)

• How long does it take to write robot software?
  
  *One or two days like in other courses?*

Two factors to consider:

You are running in *real-time* and you are *multitasking*
Robot Control

*You cannot predict every situation, further, there are always situations you never thought about when designing the software*

- How often do we deal with time-varying data in our engineering curriculums?
- Can you write contest/demo day software at the same time you are modifying your platform?
- What happens if your code has “values” the were obtained by calibration (e.g., servos) and you now have to replace your servos?
Arroyo’s Rules of Thumb

• Successful robots are those that have their platform completed 2 weeks before demo day.
• Successful robots demo at the 90-95% level on pre-demo week.
• Successful robots have software that modularly and systematically test subsystems independently.
• Successful robots have software that was developed deliberately, using sound software engineering design principles and follow established conventions and hints given in class.
Robot Control Strategies

• Negative Feedback - it is called negative feedback because corrections decrease the error.
  – You compute an error signal
  – You make a change that is proportional to the error
  – Consider a wall-following example
    • Sense the values
    • Determine if too close or too far
    • Turn either toward the wall or away from the wall accordingly
Int Wall_dist(sensor_value Int)
    {If Sensor_value < Too_far_threshold Return Too_far
    If Sensor_value > Too_close_threshold Return Too_close
    Return Ok}
Void Follow_wall ( )
    {While (1) {
        Int Sense = Analog(ir_sensor);
        Int State = Wall_dist(Sense);
        If (State==Too_close) Turn_away( );
        else If (State==Too_far) Turn_toward( );
        else Go_straight;
    }}
Robot Control Strategies

- Negative Feedback - Point
  - How sharply we turn the motors affect performance
  - The IR sensors need calibration
  - The threshold values need to be EXPERIMENTALLY determined
  - How fast we go around the loop determines performance
  - Can we change the motors smoothly?
Robot Control Strategies

• Open Loop Control - Figure *a priori* how long or how well you perform an action and program the robot to perform the action w/o measuring the results (i.e., no feedback).
  
  – Example: Use a shaft encoder to generate pulses and figure the relationship between pulses and distance
  
  – Requires a high degree of accuracy & predictability
  
  – Requires careful tuning
  
  – Errors accumulate (like compound interest)
  
  – Has not historically worked well in IMDL robots
Robot Control Strategies

• Feedforward Control - Attempts to predict (via measurement) parameters that affect open loop programs (like dynamically figuring \textit{a priori} how the pulses in shaft encoders change as a function of battery voltage level and correcting “a priori” the pulse ticks vs distance measurements.)

• Another way of thinking about this is that it is like “compensating” open loop programs via “a priori” measurements.
Sensor Calibration

• The threshold values for the sensor levels, as measured by the A/D system (0-255) are correlated to physical units before values are coded into your software.

• As a minimum these should be `#define` constants.

• The better IMDL robots have included self-calibration or dynamically adjusted calibration routines to automatically adjust the sensors.
  
  • Example: Jose Diaz’s robot when first turned on, would approach a wall and dynamically adjust the Too_close / Too_far sensor thresholds.
Sensor Calibration

• Tae Choi’s PhD work at MIL - the robot learns its own threshold values (uses machine learning).

• Light Sensors (CDS cells)
  – Affected by room lightning levels
  – Should be physically shielded
  – You must control the source of the light if the “degree of light” is important
  – You should measure the “ambient light level” is possible
Sensor Calibration

• Motor/Servo Sensing
  – Depend heavily on battery level, which can be sensed using a voltage divider circuit
  – You can sense battery charge by using a thermistor
  – You should measure “free”, “geared” and “stall” currents

• You should use “persistent global variables” for all your calibration values
Failures

• Mechanical Failures: careful design exploiting modularity and with counter-measures

• Electrical Failures: loose connections, cold solder joints, shorted leads, etc. Use good techniques and plenty of hot glue and preventive measures

• Unreliable Sensors: sensors provide “noisy” samples (the value changes given the same physical conditions) or fails to register (e.g., a bump sensor that does not trigger).
Sensor Failures

• Spurious Sensor Data - (can software filtering be used?) Fix via averaging or taking differences

• Missed data - electrically or because of software design you may miss reading a sample (the change may have been too fast/slow for the software to detect it)

• Corruption - battery level or a change of environment change the sensor readings

• Since filtering is equivalent to averaging it is possible to filter and detect anomalies and fix
Problems in Task-Oriented Control

- Robot runs into a wall, object or other robot
  Respond to bump/switch sensor
- Robot runs into a wall, object or other robot
  The bump/switch sensor did not trigger
- Robot wanders and never “sees” anything
  How long do you wander and not see (spin in place)
- Robot slams into a wall, object or other robot
  Respond forcefully to a bump/switch sensor (oscillate)
Problems in Task-Oriented Control

- Sensor, bump mechanism fall off or disconnects
  Detect anomalous readings and stop(?)
- The board fails
- The board resets
- Electrical noise
- Multiple battery packs
To Handle Possible Problems in Task-Oriented Control

- **Exit Conditions**
  - If a robot does not sooner or later run into an obstacle, then something is wrong
  - Instead of while(1) use while (!stuck()) and return either Normal_exit or Error_exit values

- **Timeout** -- add a timer-based exit condition or count the number of actions. If too many, then do something random
To Handle Possible Problems in Task-Oriented Control

- **Monitor Transitions**
  - Correct sequences are determined a priori, and if you get a wrong sequence something is wrong or do something random (e.g., you cannot be following a wall if all you get is Turn_left commands…)

- **To multi-task or not to multi-task**
  - Task sequence (use a loop to execute tasks)
  - Allow concurrent tasks that do not compete
  - Use priority or other tricks to resolve task conflicts