ECE 100 - ITP

Lecture 6

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Questions?

- 5 PM tonight - Deadline for Presentation and Teamwork Evals
  - 18 students in danger of receiving a zero for their presentations
  - 19 students in danger of receiving a zero for their teamwork contribution
- Attendance required for entire lab session, but …
  - Flu viruses are serious. If you have flu symptoms, do NOT come to lab. Instead, see a medical professional immediately. Then, bring the documentation to me later.
- Lab Assignments due at 1:50 pm
  - Don't wait until the last minute to print your reports
- All written work must be your own! Zero credit for any report with any duplicated material anywhere. Referred to ECE Department.
- Executive Summary due Oct 15 in lecture

Pre-Lab 4 Proposal

- ❑ Keep it real. This is not a creative writing assignment.
- ❑ Your "tape-path following" robot is limited to two light sensors.
- ❑ Your Problem Statement should focus on preparing for Round 1.
- ❑ Research & Investigation is required, otherwise your proposal will be weak.
- ❑ For the first "light sensor" lab, you don't need alternative strategies, but you do need to describe and present some code.
- ❑ Your detailed plan will be evaluated very carefully. Be sure to include milestones for Labs 4, 5, and 6.
- ❑ Be careful what you promise! In practice, an accepted proposal becomes your contract.
- ❑ Bring electronic code and hard copy proposal to lab. Upload electronic proposal via Blackboard SafeAssignment.

Broken sensors? - Broken code?

```
/* main1.ic */
#include turtle.ic
void main()
{
    forward(); sleep(1.0);
    right(); sleep(0.4);
    while ( !digital(10) || !digital(11) )
    {
        forward();
    }
    while (1)
    {
        forward();
        if (digital(10) || digital(11))
        {
            backward(); sleep(0.6);
            …
        }
        …
    }
}
```

```
/* main2.ic */
#include turtle.ic
void main()
{
    forward(); sleep(1.0);
    right(); sleep(0.4);
    while (!( digital(10) || digital(11) ))
    {
        forward();
    }
    while (1)
    {
        forward();
        if (digital(10) || digital(11))
        {
            backward(); sleep(0.6);
            …
        }
        …
    }
}
```

Debugging Example - What's going on?

```
/* main1.ic - first while loop*/
/* condition: left to right, inside out */
    while ( !digital(10) || !digital(11) )
    {
        forward();
    }
```

```
/* main2.ic - first while loop */
/* condition: left to right, inside out */
    while (!( digital(10) || digital(11) ))
    {
        forward();
    }
```

dig(10)	dig(11)	!dig(10)	!dig(11)	!10 || !11
0	0	1	1	1
0	1	1	0	1
1	0	0	1	1
1	1	0	0	0

dig(10)	dig(11)	dig(10) || dig(11)	!(10 || 11)
0	0	0	1
0	1	1	0
1	0	1	0
1	1	1	0

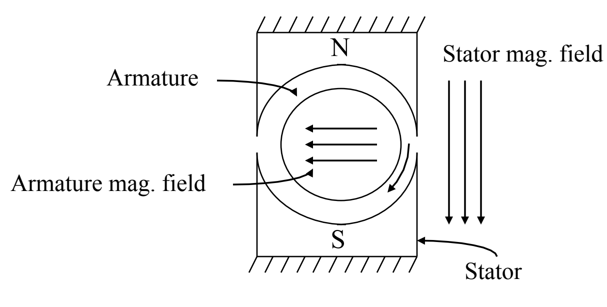
Motors, Gears, and Mechanism

- Prime Mover Methods
  - Pneumatics (air pressure, steam pressure)
    - Automotive garage air tools
  - Hydraulics (fluid pressure)
    - Construction equipment, stage lift
  - Electromagnetics (electric motors)
    - computer disk drives, power tools, diesel locomotives
  - Combustion (chemical reaction)
    - internal combustion engine, dry fuel booster rockets
- Growth Area: electromagnetics
  - More Electric Aircraft
  - More Electric Ships
  - More Electric Vehicles (hybrid, plug-in hybrid, pure electric, etc.)

DC Motor

- Energy conversion process: electrical to magnetic to mechanical.
  - The motor frame (stator) is built from a permanent magnet which creates its own **stationary** magnetic field.
  - Electrical current flows through a loop of wire (armature winding), which creates a magnetic field. The armature is located on a rotating shaft inside the motor frame.
  - In fact, the armature has many isolated windings which contact the armature brushes at different times as the shaft rotates (commutation). Note that exactly one armature loop contacts the brushes at any time.
  - The armature windings are positioned on the armature such that the magnetic field produced by the electrical current is perpendicular to the stator magnetic field. The two magnetic fields try to align, causing the shaft to rotate.
  - After a small rotation, the first armature loop slides off the brushes, and the second loop contacts the brushes. Once again, the armature magnetic field is perpendicular to the stator field.

DC Motor Diagram



DC Motor Characteristics

- Operating voltage: depends on design & construction.
- Operating current: given constant voltage, the motor draws current proportional to the rotational force, called torque.
  - If no mechanical resistance, then motor draws very little current.
  - Under extreme load, the motor stalls and draws maximum current (stall current).
- Stall torque: amount of torque produced by stall current.
- Maximum mechanical power at rated speed: torque x rotational velocity
  - Under no load, velocity is at a maximum, but torque is "zero", so mechanical power is zero.
  - Under extreme load, motor stalls, torque is at a maximum, but velocity is zero, so mechanical power is zero.

DC Motor Characteristics (continued)

- Symmetry
  - Some motors are designed to operate more efficiently in one direction than the other.
  - How could you test?
- Direction of rotation
  - If you change the direction of the armature current, then you change the orientation of the armature magnetic field by 180^{o}.
  - To change the direction of the armature current, simply switch the polarity of the DC voltage across the motor terminals.

Gearing

- DC motors are inherently high speed, low torque devices.
- Robotic applications require more torque than speed, so we need to trade off speed for torque.
- Rotational force (torque) at center of a gear is product of tangential force at edge of gear times radius: $T = F\,r$
- Work is product of torque times angular rotation: $W = T\,\theta$
- Explanation of "gear reduction" (circumference $C = 2\pi r$)
  - $W1 = T1\,\theta1$ and $W2 = T2\,\theta2$
  - Conservation of work implies $T1\,\theta1 = T2\,\theta2$ and $T1/T2 = \theta2/\theta1$
  - "Linear distance" traveled by gear: $d = C\,\theta/360$
  - Linear distance traveled is same for both gear edges.
  - $d1 = d2$, so $\theta1\,C1 = \theta2\,C2$ and $\theta2/\theta1 = C1/C2 = r1/r2$
  - Therefore, $T1/T2 = r1/r2$

Gearing (continued)

- Suppose input gear has radius r1 and output gear has radius r2, with r2 > r1. Then, T2 > T1.
  - When small gear drives larger one, output torque increases and output speed decreases relative to input.
- Worm gear has an "n:1" gear reduction, which means an output gear with "n" teeth has a reduced speed of a factor of "n" with respect to the rotational speed of the worm gear.
- What is the effective gear ratio of the HandyBug's drive train?

Motor Drivers

- ❑ H-Bridge Motor Driver Circuit
  - ➢ Popular configuration, widely used.
  - ➢ Due to large volume of applications, the entire circuit has been implemented on a single chip by various manufacturers.
  - ➢ HandyBoard uses the ST-Microelectronics L293D which can handle a 600 mA load.
- ❑ Pulse Width Modulation
  - ➢ PWM is widely used in many applications.
  - ➢ Key: duty cycle = (on time) / (cycle time).
    - ❖ 50% duty cycle means the signal is on during 50% of the cycle.
    - ❖ 25% duty cycle means the signal is on during 25% of the cycle.

LEGO Design

- ❑ Read Section 4.5 in <u>Robotic Explorations</u> by Fred G. Martin.
- ❑ Key to structural integrity is "cross-bracing".
- ❑ Gearing
  - ➢ Excessive speed can end in disaster
  - ➢ Which is better?
    - ❖ Smaller gear reduction and smaller motor power
    - ❖ Larger gear reduction and larger motor power

Post-Lab 4 Milestone Report (due week of Oct 1)

- Similar to the Post-Lab Report template, but you need to persuade your reader that you will be successful (see email).
  - Perspective: http://archive.darpa.mil/grandchallenge/gallery.asp
- Additional questions for A&T (put questions in bold, followed by answers in non-bold font)
  - Four questions on pp. 81-82.
  - First three questions on p. 85 (under "Normalizing Exercises").
  - How many "normalize" functions do you need for two light sensors? Can you use the "normalize" function in the book for both sensors? Justify your answers.
- Post-Lab 4 Milestone report should describe your robot's "tape path following" performance and your project plan adjustments.
  - Given your experience, how has your solution strategy changed?
  - Provide revised detailed plan: identify completed tasks, revised tasks, new tasks (incr advantages, decr disadvantages)