AUTOMATIC NORTH-FACING ROBOT WITH COMPASS MODULE AND CLOSED-LOOP CONTROL

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Abstract: A digital compass module is added to Parallax Boe-Bot, an educational robot. A proportional closed-loop control system is implemented on the BASIC Stamp microcontroller. By comparing the compass sensor output with the set point (north), the controller will control the speed of two servo motors. The two servo motors will turn clockwise or counter clockwise. The robot will turn and face north automatically. Different proportional gains are tested and the results are discussed. Lower gain will cause slower corrective action and larger steady state error (SSE). If the gain is too high, the servo motor will over correct the direction of robot, and cause the robot to oscillate around the set point (north). This is a great hand-on education tool to teaching micro-controller, robot, and process control technologies.

Key words: digital compass, robot, micro-controller, proportional gain, closed-loop control.

1. Introduction:

Teaching is better with real hands-on experiments. This paper is an investigation of a very versatile robotic system. The simple design helps the instructor explain the theory in a simple, interesting and direct way. It covers a wide area of subject like microcontroller, robotic system, smart sensors, and process control. Automatic north-facing robot can be easily reprogrammed for more complicated automatic navigation.

2. The North-facing Robotic System Hardware:

Parallel Boe-Bot, shown as Picture 1, is a popular educational robot. It is controlled by a BASIC Stamp microcontroller. The robot is programmed through a personal computer. Then the control program is downloaded to the microcontroller. The robot can be stand alone, disconnected from PC, and powered by its own battery. Different types of sensors can be added to the robot, for more advanced navigations. Commonly used sensors are IR sensor, light sensor, ultrasonic sensor. The Hitachi HM55B compass module measures direction. By adding compass module to the robot, the robot will sense the direction which can be used for more sophisticated navigations. The robot used in this experiment also has a LCD display panel. The LCD displays the robot's angle from north clockwise, which ranges from 0 to 359 degree. (Picture 2)

3. Proportional Feedback Control Software:

A proportional feedback control system is used for control the robot to face north automatically. The control software is written in BASIC. When the robot is facing north, the angle should equal to zero degree.

Here is the program for the proportional feedback control. The angle variable is the current position of the robot.

```
IF (angle>3) AND (angle<180) THEN
  set_point=0
ELSEIF (angle>=180) AND (angle<357) THEN
  set_point=360                          ; two different set_point based on the current position.
ENDIF
speed=750+((set_point - angle)*GAIN)     ; set the PWM signal
PULSOUT 12, speed                        ;PWM signal to serve that drives the left wheel
PULSOUT 13, speed                        ;PWM signal to serve that  drives the right wheel
PAUSE 20
```

The accuracy of this control system is +/- 3 degree. This is necessary because the compass module output is not very accurate and stable. Lowering the tolerance will cause the robot to oscillate continuously. The proportional gain can be adjusted by changing the GAIN variable in the program.

4. Results:

Three different proportional gains were tested. The GAIN variable was set to 0.5, 1, and 2. When the robot is manually turned away from north, compass module will sense the direction, and then the microcontroller will actuate the two servo motors to rotate the robot toward north. Figure 1 shows the dynamic responses of the robot with proportional gain set to 0.5, 1, and 2. Lower gain will cause slower corrective action, and larger SSE. If the gain is too high, the servo motor will over correct the direction of robot, and cause the robot to oscillate around the set point (north).

5. Conclusion:

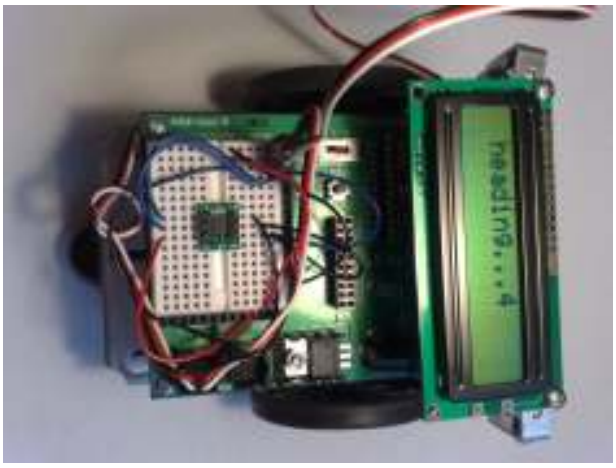
Based on the results of this experiment, the proper proportional gain for this robot should be set at 1. The noise and error from the compass sensor module prevent more accurate control, and a tolerance o of +/- 3 degree is needed to prevent oscillation. This is a great hand-on education tool to teach micro-controller, robotic systems, and process control technologies.

6. References:

Andy Lindsay, *Smart Sensors and Applications*, Parallax Inc., 2006.
Andy Lindsay, *Robotics with the Boe-Bot*, Parallax Inc., 2004.
Terry Bartelt, *Industrial Control Electronics: Devices, Systems & Applications, 3nd Edition,* Thomson, 2006.

7. Pictures and Figures:

Picture 1 Boe_Bot Educational Robot.



Picture 2 HM55B Compass Module and LCD display.

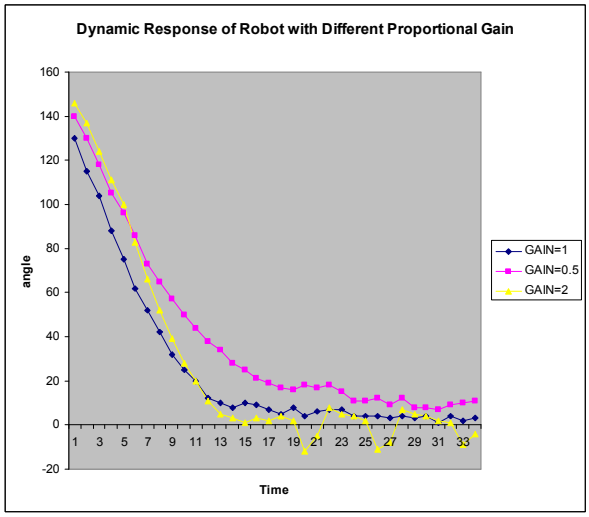


Figure 1 Dynamic Response of the North-facing Robot.