This article is part of the IEEE Reliability Society 2009 Annual Technology Report.

NXT Battery Voltage Experiment

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Introduction

The *FIRST* organization was founded by Dean Kamen in 1989 with a specific mission—to inspire young people to become leaders in science, engineering, and technology. *FIRST* sponsors several different programs for different age groups, such as Junior *FIRST* LEGO® League (Jr FLL), *FIRST* LEGO® League (FLL), *FIRST* Tech Challenge (FTC), and *FIRST* Robotics Competition (FRC). *FIRST* is an acronym meaning For Inspiration and Recognition of Science and Technology. The authors participated in FLL local and regional competitions in 2008 (as team #3413 *Random Robotics*) and in 2009 (as #5249 *Random Robotics* and #4526 *SCS Turduckens*). The 2009 FLL season involved over 14,700 teams from 56 different countries.

FLL involves building an autonomous robot using LEGO® structural elements, a LEGO® NXT Intelligent Brick, LEGO® Mindstorms® Motors and Sensors, and LEGO® NXT Software (powered by LabVIEW from National Instruments). The robot must complete multiple topic-based objectives on a playing field within a time limit. Precise navigation on the playing field is vital to successful completion of the objectives.

Problem

In 2008, we observed that changes in battery voltage caused the robot to take a different path than what was originally programmed. At that time, to correct this problem, we measured the voltage during programming and at the start of each competition match to make sure the voltage was within +/- 0.2 V of the “programmed” voltage. This year, we decided to conduct an experiment to see if we could compensate for changes in battery voltage (to make our robot more consistent).

Experimental Factors

The experiment involved two factors: *battery voltage* and *type of turn*. Two levels of battery *voltage* and three categories of *turn type* were evaluated. The high level for *voltage* was 9.4 V and the low level was 7.6 V. The three *turn types* were:

1. Both wheels moving, but one moving slower than the other (S = 20),
2. One and only one wheel moving (S = 40), and
3. Both wheels moving with equal power in opposite directions (S = 100).

Experimental Setup

For this experiment we attached a dry-erase marker to the robot and placed it on a white board on the floor. We marked a starting place on the white board so we could start the robot in the same place every time. For the experiment, our robot had a 5:1 gear ratio. We used the NXT Software’s **MOVE** block for all turns and we set motor power to 100% for all runs. We programmed three different ninety-degree *turn types* by adjusting the number of wheel revolutions for each so that the robot would precisely turn ninety degrees at the low *voltage* level (R = 11.3 for S = 20; R = 5.5 for S = 40; R = 2.87 for S = 100). We ran each of the three programs four times (two at low *voltage*, two at high *voltage*) for a total of twelve runs, using the white board and dry-erase marker to track each run. In other words, we ran each *turn type* two times at high *voltage* and two times at low *voltage*. We then measured the deviation from ninety degrees for each run.

Results

At both *voltage* levels and for all three *turn types*, repeat runs were close to one another (i.e. good repeatability). At the low *voltage* level, all runs for all three *turn types* were close to ninety degrees, which we expected because we programmed each turn to be "ninety degrees" at the low *voltage* level. We expected all high *voltage* runs to vary from ninety degrees for all three *turn types*. However, only the first two *turn types* deviated considerably from ninety degrees at high *voltage*. **With the third *turn type* (both wheels moving with equal power in opposite directions) the turn angles at low and high *voltage* were extremely close to ninety degrees, which was a complete surprise.**

In summary, with the first and second *turn types*, the angle of travel differed greatly with changes in battery *voltage*. But, with the third *turn type* there was little change in the angle of travel with differing battery *voltages*. The experimental results are shown in Figure 1. The red lines show the path taken by the robot for each high *voltage* run. The green lines show the path for each low *voltage* run. The top set of runs (S = 20) corresponds to the first *turn type*, the middle set (S = 40) corresponds to the second *turn type*, and the bottom (S = 100) the third *turn type*.

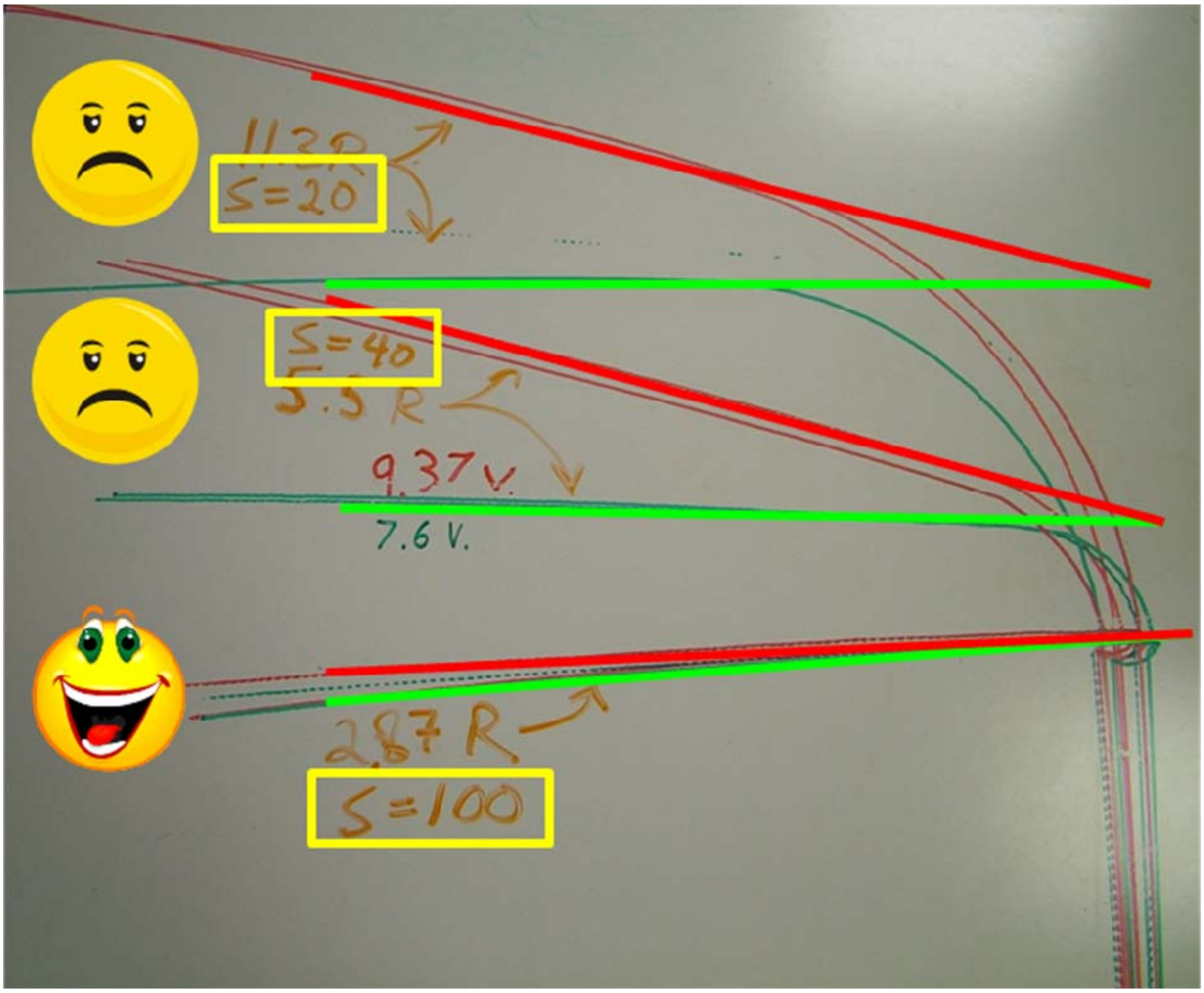

Figure 1 – Deviation by *Turn Type* (S = 20, 40, 100) and Battery *Voltage* (Red = 9.4 V, Green = 7.6 V)

Conclusion

Based on the results, we concluded that whenever the two wheels are set to use EQUAL power, the robot maneuvers *consistently* even with voltage changes. But, whenever the two wheels DO NOT use EQUAL power, the robot maneuvers *inconsistently* with voltage changes. In other words, the robot will maneuver consistently regardless of battery voltage as long as you ONLY go straight forward, straight reverse, or use the third *turn type*.

Recommendations

Based on this battery-voltage experiment, we came up with the following recommendation for FLL teams when using NXT Software to program their LEGO® NXT robots:

- Whenever you use the **MOVE** block to control your robot, ensure both drive motors maintain the same power level (e.g. only use "steering" values of -100, 0, or +100).

On November 21, 2009, we presented the results of our experiment to the FLL teams competing at the FLL 2009 OKC Scrimmage Tournament in Oklahoma City. On December 12, 2009, we competed in the FLL 2009 Oklahoma Championship Tournament, where one of our teams (#5249 *Random Robotics*) took home the Championship trophy and will advance to the FLL 2009 World Festival to be held April 14-17, 2010 at the Georgia Dome in Atlanta, GA. At the World Festival, *Random Robotics* will compete as one of the world's top 84 teams from 35 different countries.