AC 2009-195: TEACHING STATISTICS TO ENGINEERING TECHNOLOGY STUDENTS

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Teaching Statistics to Electronics Engineering Technology Students

Abstract

Statistics is an important tool for robustness analysis, measurement system error analysis, test data analysis, probabilistic risk assessing, and many other fields in the engineering world. However, traditionally statistics is not covered extensively in undergraduate engineering technology programs. Usually the students take a statistics course from the Statistics Department as a prerequisite for other engineering courses and seldom use the knowledge they learned in the course again, until they graduate from school and are faced with real-world statistics based engineering tasks. By then they have forgotten most of what they learned in the statistics course, or it was not relevant to the engineering applications encountered in the real-world.

Based on the results from existing literatures in the area of statistics education, a unique learning-by-using approach is proposed for the Electronics Engineering Technology program at Texas A&M University. Simple statistical concepts such as standard deviation of measurements, signal to noise ratio, and Six Sigma are introduced to students in different courses. Design of experiments (DOE), regression, and Monte Carlo method are illustrated with practical examples before the application of these tools to specific problems the students face in their engineering projects. Software is used to conduct statistical analysis.

Introduction

During the past two decades there has been a trend in industries to use management philosophies with emphasis in the systematic use of statistical methods. The Japanese manufacturing industry has made a tremendous improvement in quality because of the wide use of statistical methods such as Total Quality Management. Other statistical tools such as Statistical Process Control (SPC) [38] and Six Sigma[11,33] have also been proven effective in improving processes, product quality, and the corporate bottom lines. For example, Motorola credited the Six Sigma initiative for saving $940 million over three years and AlliedSignal reported a $1.5 billion savings in 1997[38]. Other companies responded to the quality competition by adopting these statistical methods. For industries such as pharmaceutical and manufacturing industries, tools such as Six Sigma have become required knowledge for a successful engineer.

While there is no doubt that today's industry needs engineers with experience and knowledge of statistics[3], most engineering students think that probability and statistics courses are useless, boring, and difficult. These course are too theoretical and appear to be unrelated to the engineering subject they study. As pointed out by Godfrey[10]: "We too often teach what appears to the students a collection of unrelated methods illustrated by examples taken from coin-tossing, card-playing and dice-rolling. And then we expect the students to be able to translate this wide variety of methods with simple gambling examples to complex industrial problems involving the application of a large number of methods". Many educators have realized that the current situation needs to be changed[12,32]. The needs from industry have led to a continuing effort to enhance the education on statistics[9, 10,13, 22,26,37]. Many statistics courses now use real-world examples, real data, and simulation to help students learn more effectively. Most of these educational research works were conducted by the Mathematics or Statistics Department.

Even though intensive statistical courses are included in most engineering curricula, traditionally statistics is not covered extensively in undergraduate engineering technology programs. Usually the students take a statistics course from the Statistics Department as a prerequisite for other engineering courses and seldom use the knowledge they learned in the follow on courses until they graduate from school and are faced with real-world statistics-based engineering tasks. By then they have forgotten most of what they learned in the statistics course, or they do not know how to relate the statistical knowledge to the engineering applications encountered in the real-world. Similar situations in other engineering programs have led to increasing curricula development efforts by engineering departments such as chemical engineering[15,25], biomedical engineering[29], civil engineering[24,30], industrial engineering[1,28], mechanical engineering[17], and electrical and computer engineering[36]. However, educational research in statistics by electronics engineering technology programs is few and far between. Part of the reason for this is that engineering technology students typically focus on the hands-on experience and do not like too much theoretical analysis. Statistics, however, can be used as a very practical tool, especially in the area of measurement and testing, which is a main topic in many electronics engineering technology programs. Although some results in statistics education found in the literature can be applied directly to electronics engineering technology, the uniqueness of the students and the program requires special effort to make it work.

This paper discusses the challenge of incorporating statistics in the curriculum of electronics engineering technology program at Texas A&M University.

Incorporating statistics into electronics engineering technology curriculum

Statistics is an important tool for robustness analysis, measurement system error analysis, test data analysis, probabilistic risk assessing, and many other fields in the engineering world. The key to the success of teaching and learning statistics for engineering students is to make it relevant to the engineering problems they face[26]. Using real-world data[5, 15] and real-world problems[10,37] is an important approach practiced by many educators. The Particular General Particular (PGP) strategy used by Mosteller[22] and Romero[26] can be very effective. Active participation by the students during the teaching and learning of statistics[9] is a good method to use. Using simulation[2,8,20,27] instead of theoretical derivation also works better for engineering technology students. Using Excel to perform basic statistical analysis is a very attractive option[6,14]. Project-based learning[16, 23,30] is another method used widely in engineering technology programs, since laboratory[4,17, 18,24] is one of the main learning tools for ET students. Early exposure and repetition is an effective approach of learning whether it is statistics[25] or other knowledge[42]. The critical ingredients found in the published educational research on teaching and learning of statistics that can be potentially adopted by electronics engineering technology programs are summarized as follows:

- Using real-world data and problems
- Active learning of students
- Using software and simulation
- Using statistics in laboratories and projects
- Early and frequent exposure to statistics.

Based on these approaches that can work effectively for electronics engineering technology program in the education of statistics, a learning-by-using method is used in several courses in the electronics engineering technology program at Texas A&M University. Instead of a stand-alone statistics course within the program, statistical analysis methods and tools are introduced to the students to solve engineering problems whenever appropriate. The learning of statistical tools and concepts is based on real-world data and examples. After presenting the examples, the students are asked to use the statistics tools to solve problems they face in laboratories and projects. Software packages, such as Excel and Minitab[19], that are easy to use were selected to conduct the statistical analysis. The learning of statistics is not limited to one course, so that the students first get exposure to the tools in a sophomore level circuit analysis course and then in several other courses in the following semesters. The goal is to have students understand that statistics is not just a course that they must take and then can forget about it; instead it is a useful tool that they need to learn in order to do a better job in engineering.

Parameter uncertainty and part-to-part variation

The concept of parameter uncertainty due to part-to-part variation is introduced to the students early in a sophomore level class when electronic circuits are designed and analyzed. The determination of tolerance bands for electronic parts is discussed using statistical terms such as normal distribution, mean, and variation. Students are asked to take the variations in the parameters into consideration when they conduct experiments in the laboratories. Discussion in their laboratory reports must include discussion on the variations in their test data and how they are related to the parameter uncertainty. The Monte Carlo analysis[7] tool in MultiSIM was introduced in the circuit analysis course. Students were asked to conduct Monte Carlo analysis for a circuit and compare to the actual test data.

Mean and standard deviation

Mean and standard deviation are two statistical concepts that are very important and easy to understand. They are discussed in several courses using real-world examples. The calculation of the mean and standard deviation can be easily done using Excel or other software. A particular example that helps students understand how these can be used in engineering applications is illustrated with test data from a faculty research project involving wireless communication[40]. In this example, six different tests were conducted under four different test conditions (using different wireless cards and at different locations). The mean and standard deviation from each test are used to calculate the signal-to-noise ratio (SNR) for bandwidth of the wireless communication using the following formula

$$SNR = \frac{mean}{StDev} \qquad (1)$$

Table 1. SNR for bandwidth

Test No.	Condition1	Condition2	Condition3	Condition4
1	4.0	2.0	16.7	14.3
2	3.3	2.2	25.0	14.3
3	2.5	2.5	20.0	12.5
4	1.9	2.3	20.0	12.5
5	2.3	2.0	14.3	12.5
6	3.1	1.9	25.0	12.5

It is clear that test condition 3 has the best signal-to-noise ratio among the four test conditions. Students in electronics engineering technology face similar scenarios in their projects. This example provides a simple application of statistical tools in solving engineering problems.

Six Sigma

A short presentation on Six Sigma and its application in real-world problems was prepared for students in a junior level instrumentation course and senior design teams[41]. The concept of reducing the variation in processes to improve the quality of a product is illustrated in Fig. 1. The DMAIC process of Six Sigma is briefly introduced in the presentation. Practical statistical analysis tools such as Design of Experiments[21], Monte Carlo analysis, Gauge R&R[38], ANOVA, probability test, and regression are introduced to the students in the context of Six Sigma. Four Six Sigma projects were successfully completed in the instrumentation course.

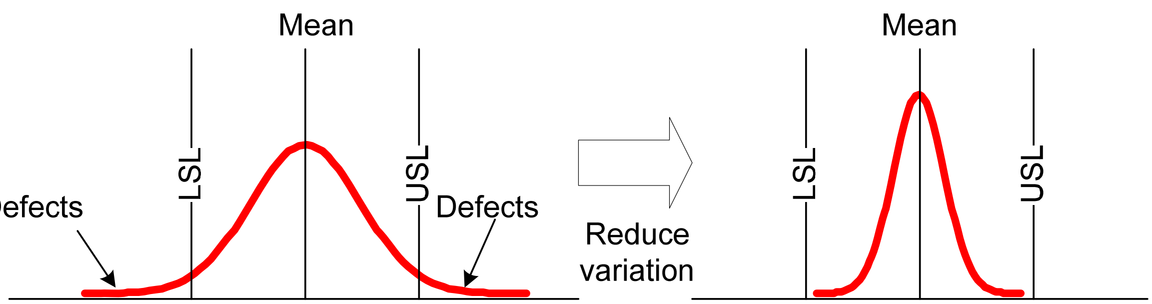

Figure 1. Improvement of the quality of a product by reducing the variation

Design of Experiments

The Design of Experiments (DOE) technique is usually not discussed in an undergraduate statistics course. However, the tool is very important for test engineers. With the help of software such as Minitab, the design and analysis aspects of DOE become fairly straightforward.

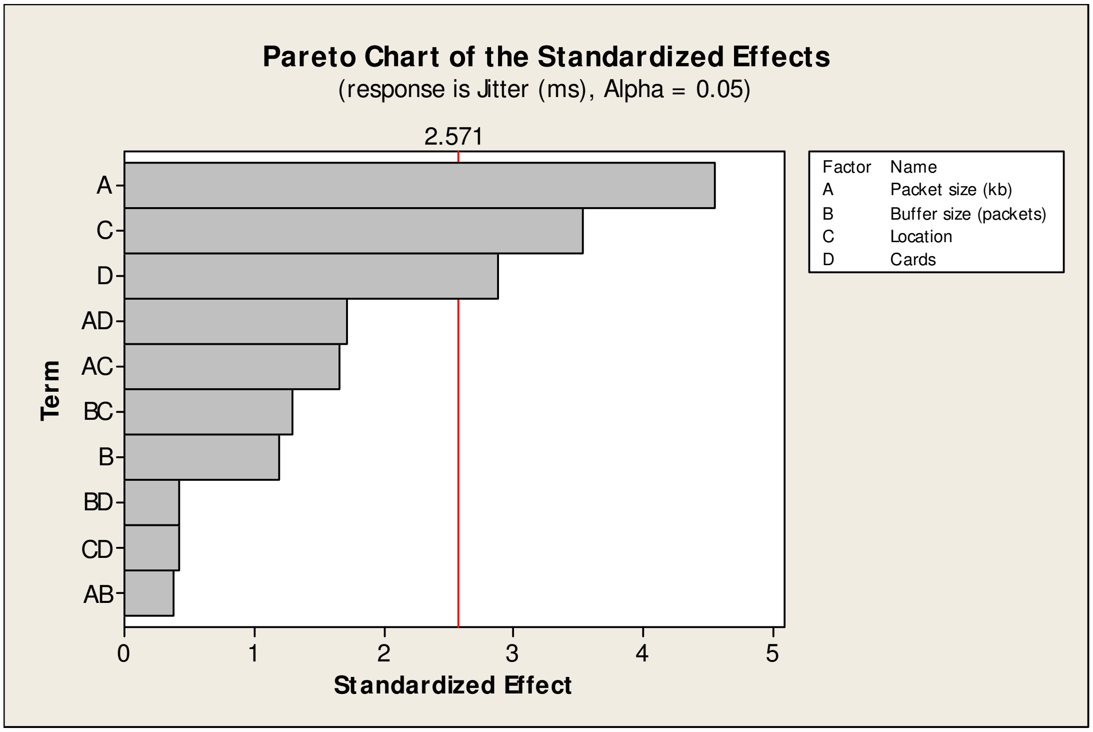

Figure 2. Pareto Chart for wireless communication jitter

First, the student defines the problem. Second, factors and levels are chosen. Third, the response variables to be measured are selected. Fourth, a test matrix is created using Minitab. Fifth, the experiments are conducted. Finally, Minitab is used to perform statistical analysis. This process is illustrated with an example from the wireless research project discussed earlier. The result of the DOE analysis for jitter in wireless communication is plotted in Fig. 2. Based on Fig. 2, three major contributors to the jitter are identified as: packet size, location, and wireless card.

Regression

Regression is a useful tool for engineers. It can help the engineer to identify the relationship between variables based on test data. Students in a junior level instrumentation course and senior design teams were asked to characterize temperature sensors using test data. An example from a motor speed control research project[39] was used to illustrate how to use regression to derive a function relating two variables. Fig. 3 is the simulated data, which is used to derive equation (2) using least square regression method.

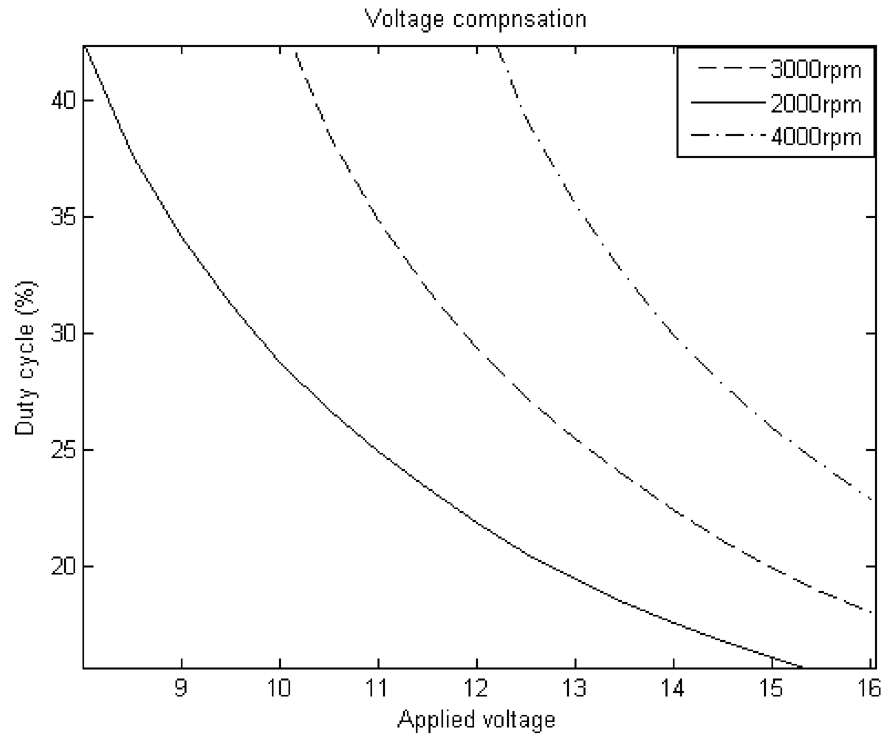

Figure 3. Simulated relationship between duty cycle and voltage

$$DC = 0.0267V^4 - 1.4984V^3 + 31.734V^2 - 303.28V + 1134.6 \qquad (2)$$

Monte Carlo Analysis

Monte Carlo analysis is first introduced in a sophomore circuit analysis course, where students use MultiSIM to conduct their analysis. The effects of the resistance and capacitance distributions on a low pass filter cut-off frequency were studied using Monte Carlo analysis. In a junior level instrumentation course, results from the motor speed control research project[39] were used to illustrate the use of the analysis method. First, a MATLAB model was built for simulation. One thousand sets of motor parameters were randomly generated in a MATLAB script file. These parameters were then used to simulate the average speed error during PWM control. Using the simulation data, statistical analysis for the average speed error was conducted. Mean, standard deviation, confidence intervals, and other statistical values were calculated, as shown in Fig. 4.

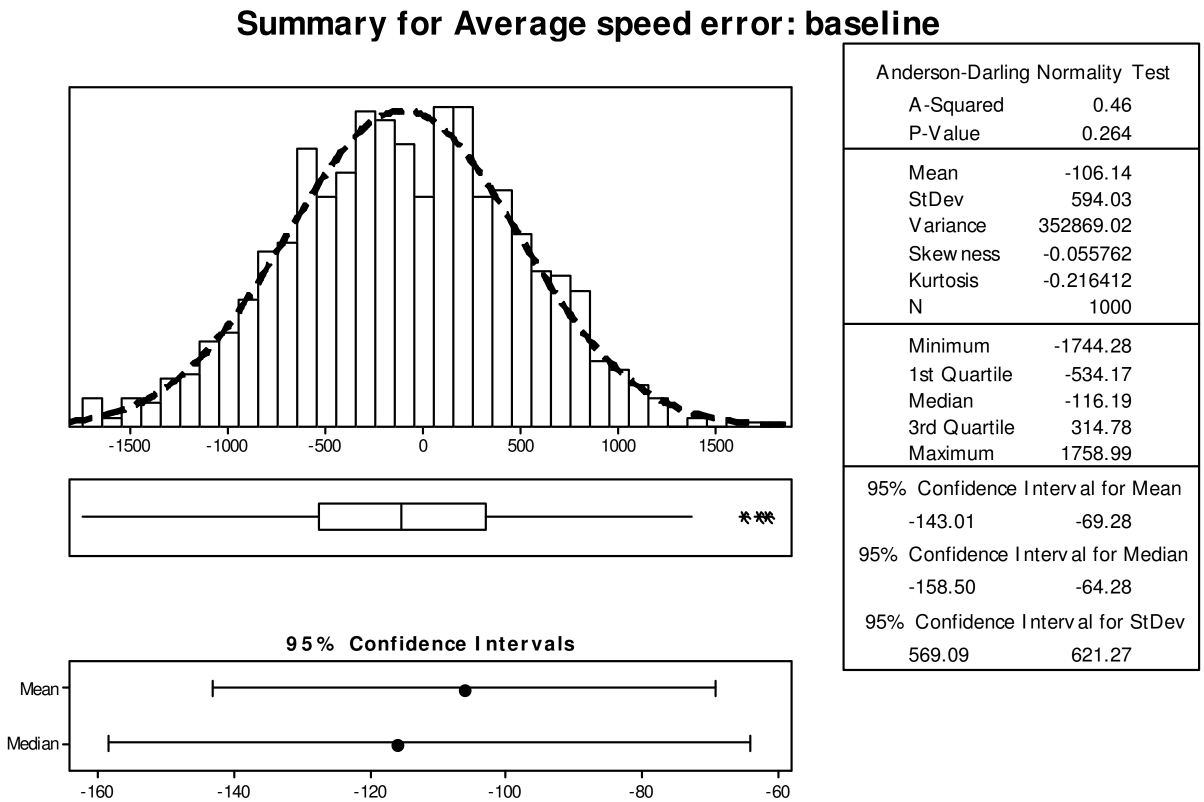

Figure 4. Monte Carlo analysis for motor speed control

Conclusions

In this paper, the initial effort to increase the learning and use of statistical tools in the Electronics Engineering Technology program at Texas A&M University is discussed. Taking advantage of the extensive educational research in teaching statistics, a unique approach of learning-by-teaching is adopted.

Statistical concepts such as mean, standard deviation, probability distribution, and variation in system parameters are introduced to students. Tools and methods such as Six Sigma, Design of Experiments, Monte Carlo analysis, and regression, are illustrated with real-world examples. Students at different levels, from sophomore to senior, learned these concepts and tools in different courses. Students used professional software extensively for statistical analysis.

The desired outcome is to make students comfortable using software to conduct statistical analysis in solving engineering problems. The approach of learning-by-using is efficient and effective for engineering technology students. It is also more flexible than a single statistics course since the materials can be taught whenever appropriate in individual courses. The frequent use of statistical tools reinforces the student learning. The relevance of the statistical analysis to the engineering problem faced by the students also increases students' motivation for learning and using statistical tools.

As an effort to continually improve our education program, the effectiveness of the proposed statistics teaching method will be quantitatively and qualitatively monitored through student and faculty surveys, feedback from former students and industry, and results of examinations. These results will be published when available.

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