$\bar{X}$-R Control Charts

Golf is a great game – at least some folks think so. Imagine that you are a pro golfer – getting to fly around to beautiful golf courses throughout the year and compete for million dollar purses in golf tournaments. Golf tournaments consist of four rounds of 18 holes of golf over four days. So, suppose you are a golf pro. You want to monitor whether your golf score is getting better. How could you do this? One method would be to track your average tournament score, i.e., the average of the four rounds. You would like to see this score get lower since lower scores improve your ability to earn money in the pros.

You would also probably be interested in your consistency, i.e., how close the four rounds in a tournament. You won't like a lot of variation your results – shooting a 72 one day and a 90 the next. So, you could also track the range in your golf scores for a tournament.

This module introduces a method of tracking an average over time as well as tracking the variation within individual results. This method is called the $\bar{X}$-R control chart.

Purpose

The purpose of this module is to introduce the $\bar{X}$-R control chart: what it is, when to use it, how to construct it, and how to interpret it. This chart is used with variables data – data that are taken from a continuum. It consists of two charts: the $\bar{X}$ chart that tracks the variation in subgroup averages and the R chart which tracks the variation within subgroups. The $\bar{X}$-R control chart has been the most used type of control chart over the years.

Understanding the $\bar{X}$-R Control Chart

Like all control charts, the $\bar{X}$-R control chart examines variation. Let's return to the golf example. To use an $\bar{X}$-R control chart, you need fairly frequent data because you form subgroups. There is frequent data for the golfing example: four rounds of golf for each tournament. You also need a method rationally subgrouping the data. This means that there needs to be a way of grouping the data that makes sense and allow you to see the variation you want to explore. It makes sense to group the golf data by tournament. The four rounds of golf can be used to form a subgroup.

Suppose the first tournament you play for the year has the following results for the rounds: 70, 76, 70, and 73. These four rounds form the first subgroup. You can calculate the subgroup average (the average of the four rounds of golf):

$$\bar{X}=\frac{\sum X_i}{n}=\frac{70+76+70+73}{4}=72.25$$

You can continue this for each tournament you are in and plot the results on an $\bar{X}$ chart. This chart then shows you have much variation there is in your average tournament score from tournament to tournament.

You can also calculate the range of this first tournament of the year (the first subgroup). The range is simply the highest score (76) minus the lowest score (70). So, the range for the first subgroup is:

$$\text{Range} = \text{Highest} - \text{Lowest} = 76 - 70 = 6$$

You can continue this for each tournament you are in and plot the results on the R chart. This chart shows you how much variation there is in your scores within a tournament from tournament to tournament.

One key to understanding $\overline{X}$-R control charts is to understand that the two charts are monitoring different sources of variation. The $\overline{X}$ chart is examining the variation in subgroup averages over time and will let you know if these subgroup averages are consistent (in control – only common causes of variation present) or if any subgroup averages fall outside the "normal" variation (out of control – special cause of variation present).

Figure 1 shows the $\overline{X}$-R control chart for the golf data. The top part of the chart is the $\overline{X}$ chart. There are three other key lines plotted on this chart. The overall average ($\overline{\overline{X}} = 70.32$) is the centerline on the chart. It is the average of the subgroup averages. The upper control limit (UCL) and the lower control limit (LCL) have also been plotted. Remember that the UCL represents the largest value we would expect from the process if there are only common causes of variation present. In this example, the UCL = 75.04. This means that the highest tournament average one would expect is 75 as long as only common causes of variation are present. The LCL represents the smallest value we would expect from the process if only common causes of variation are present. The LCL = 65.61. This means the smallest tournament average we would expect is about 65.6 as long as only common causes of variation are present.

As long as there are no points beyond the control limits and no patterns, the $\overline{X}$ chart is in statistical control. This is the case as seen in Figure 1. This means that the variation in the subgroup averages (tournament averages) is consistent over time. The process is consistent and predictable. It means that we can predict what will happen in the future. We don't know what the next tournament average will be, but we do know that it will be between 65. 61 and 75.04 with a long term average of 70.32 as long as the process stays the same. It also tells us that our golf score is not getting lower over time.

The bottom part of Figure 1 is the range control chart. Remember that this chart is monitoring the variation in the range of scores from a single tournament. The average range (6.47) is the centerline on the chart. The upper control limit (14.77) is also plotted. In this example, there is no lower control limit. Since there are no points beyond the control limits or patterns, the R chart is in statistical control. This means that we can predict what will happen in the future. We don't know the exact range of scores that will occur in the next tournament, but we do know that it will vary between 0 and 14 with a long term average of 6.47 as long as the process stays the same.

Once a process is in statistical control, the only way to improve it is to fundamentally change the process. If we want our average score to decrease or for there to be less variation in the range, we have to change the way we do things. This includes a different golf coach, a new swing, or new clubs.

$\bar{X}$–R Control Charts

We are here for an education.

-W. Edwards Deming

SPC FOR EXCEL

Introduction

- Golf
- 18 holes over four days
- Monitor your score
- What would you like to happen to your score?
  - Average
  - Consistency
- $\overline{X}-R$ Chart