Chapter 7

Conclusions

In this thesis we have presented and studied the main univariate and multivariate control charts. Our scope was to deal with specific problems in the context of control charts. The first problem under consideration was the estimation effect on the control charts performance. This issue was investigated in the case of the univariate Shewhart charts for dispersion for both subgrouped and individual data. Specific recommendations are given for the number of samples or the number of observations needed to estimate accurately the parameters in order for the control chart to behave as in the theoretical case of known parameters. A second problem is nonnormality and how it affects the performance of a control chart. It was investigated on the EWMA charts for the dispersion when we have individual observations. A new EWMA type chart for the process dispersion is given that is proved to be robust up to nonnormality when we are in-control.

The identification of the out-of-control variable when a multivariate control chart signals is another problem examined. A new method is presented that computes probability limits that indicate with the desired probability the out-of-control variable or variables. This method has proven to be a competitive alternative to the existing procedures. Finally, the effect of measurement error on the performance of control charts was considered. A model with covariates for the EWMA chart is presented. This model is examined in some cases and it is proved that the presence of measurement error seriously

affects the ability of a control chart to identify the out-of-control situation.

Some thoughts for further research are given in the following discussion. The estimation effect is one of the issues that practitioners have to face. Although until recently the guidelines in the design of a control chart were talking about a number of subgroups needed, recent research proved that this recommendation is deceiving. Generally, a larger number of samples is needed. Although in today's industry there are usually large data sets, there are still processes that the recommendation for e.g. 100 samples for the estimation of the process parameters is a very large number and usually impossible to obtain because of the time needed for these observations or because of the money we have to spend. Therefore, the control limits have to be adjusted in a way that they will take into account the estimation effect. Nedumaran and Pignatiello (2001) have given such a solution for the $\overline{X}$ control chart and Jones (2002) proposes a way to design the EWMA chart for this case. Additional work on the other control charts has to be done.

Most of the control charting methodology has been implemented under the normality assumption. However, most of the times this assumption is not valid. All the charts are affected in the case of nonnormality but to a different extent. The EWMA chart for the mean has proved to be less affected when properly designed. The EWMA chart for the dispersion proposed in Maravelakis et al. (2003) is less disturbed by the nonnormality issue when we are in-control. Nevertheless, an EWMA chart for dispersion that can be robust in terms of nonnormality for both in and out-of-control is needed.

In the multivariate case, the nonnormality problem is even more challenging. But if normality is cumbersome in the univariate case, then in a multivariate environment the situation is even more dramatic. Recently, Stoumbos and Sullivan (2002) and Testik et. al. (2003) proved the robustness of the multivariate EWMA chart for the vector of means. However, there is a lot more work that has to be done in the field. A general technique able to detect efficiently, under any distribution, the out-of-control situation is needed. Moreover, since a process might involve both continuous and discrete characteristics another problem is to find a control charting methodology that will consider both of

them.

A very important problem in the multivariate control charts is to identify the out-of-control variable or variables when a multivariate control chart signals. This problem has generated many different opinions in the last decade. Although this problem is thoroughly investigated under the multinormality assumption most of the proposed solutions are mathematically complicated or time consuming. Consequently, new procedures that will overcome these disadvantages are needed. Graphical techniques are such techniques.

Measurement error is a factor that can affect seriously the performance of a control chart. The literature up to now investigates this problem under the assumptions of normality, independence, known parameters and predefined additive relationship of the true and measured variables. All of these assumptions have to be reconsidered. Moreover, the estimation effect in other types of control charts is an open problem.