A SOFTWARE APPLICATION FOR MANAGING AND OPTIMIZATION OF INDUSTRIAL PROCESSES THROUGH THE USE OF STATISTICAL PROCESS CONTROL

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Abstract

The main goal of most organizations, no matter of their nature, object or size, is to be competitive as possible on the market, a crucial factor in ensuring a long operating duration. Managing and providing a better view competitiveness can not be given unless we use some statistic models. This models' variables follow closely each step of the process. If in the past years the issue of the control managing of a process wasn't seriously taken into consideration, today more things like more pretentious customers or the growth of the competitiveness level on the products and logistics market, made almost all companies to hire people, especially for the control of the quality. They have to check not only the final products but also the intermediate stages of the process. The aim of this paper is to offer a very useful alternative to the quality control of some services and processes using a unitary software application meant to help many specialists in quality checking field.

Key words: statistical process control, control charts, warning zone, action zone, process indices

Nowadays most of the companies dropped the old and rudimentary methods of quality management process in favor of high finesse mathematical and statistical models, which give a more complete and deeper image about the level of their quality processes.

A process is the transformation of a set of inputs, which may include materials, actions, methods and operations in desired output results, results which take the form of products, information or services. In each area of an organization there may be many processes that take place. It's very important that any process to be analyzed by a careful examination of the inputs and outputs. This thing will determine the necessary actions for improve the quality of the process. Any error in the input or in the output leads irretrievably to a wrong control. The final result (or the output value or simply the output) of a process is "something" that is transferred to someone or something – the customer. Clearly, to produce an output that meet customer requirements, it is necessary to define, monitor and control the system inputs, process which in turn may have provided an output of the previous process.

The other basic notion is, as likely to see from what we wrote above, *the control*. All processes must be monitored and brought "under control" through the collection and use of data. This refers to the measure of system performance and the necessary feedback for corrective actions, when it's needed. Managers are in control only when they have created a climate where their subordinates can exercise control over their own processes (Bhote K.R., 1991).

After these introductive notions we can proceed to define the basic notion of this paper, namely *statistical process control*. One of the most important experts in the field, John S Oakland defines the statistical process control as a *set of tools for managing processes*, *and also for determining and monitoring the quality of final products within an organization* (Oakland J.S., 2003). *Also, the statistical process control can be viewed as a strategy for reducing variation in production processes*, *where the variation represents an unwanted thing for any company producing goods or providing services*. Another well known specialists D.C.Montgomerry (Montgomery D.C., Keats J.B., 1996) considered statistical process control *as a collection of very powerful techniques for solving the problems that are used to achieve the highest level of stability of the process and also in order to improve the process capability, by reducing the variability*.

During this paper it will be seen that a very important notion in statistical process control is represented by the *process control charts*, charts which establish if a process is in statistical control or not.

Statistical process control is not only a tool, but a whole strategy to reduce variability, the cause of most problems of achieving the quality standards. The variation can occur anytime and anywhere: in production, in delivery process, in people's attitude, in equipment and in it's use and in maintenance practices. The Total Quality Management (TQM), as well as the statistical process control require the process to be continuously improved by reducing variability (Ciobanu R.C., Schreiner C., 2002).

MATERIAL AND METHOD

Before presenting the data which referred to the process, it's important to present the two types of variations that may occur during the process stages. The first type of variations are *random variations*, so that the process does don't need to be revised. This type of variation represents the sum of effects of complex interactions of random or common causes. When the random variations are not accompanied by other types of variations is practically impossible to track their causes. E.g. the set of common causes that produces variations in processes quality may include random variations in processes inputs: atmospheric pressure or temperature changes, tracking traffic on the road or power fluctuations or moisture. When in a process are present only common causes, the process is considered to be "stable", "in statistic control" or simply "in control" (Chakraborty S., Tah D., 2005). Unfortunately, the random variations are not the only type of variations. Another class of variations are *the variations that are determined by the special causes*. When in a process are present special causes of variation, the variation is considered to be "in excess" and the process is classified as "unstable" or "outside the statistical control" or beyond the expected random variations. Special causes include a faulty handling or unjustified adjustment of the process, when it is stable. After the presentation of these two types of variations, we can move to the central part of this paragraph.

Data is the most important basis for the analysis, decisions and actions and the form and presentation differs from one process to another. Collecting and recording data must be done carefully and systematically, because otherwise they couldn't be used in process analysis. The amplitude of variations is very important because it offers a first insight of a possible variability of a process. Also, it allows conclusions concerning the errors, the process capability and the potential risks. Obviously, data provides the current state of the process, but on their basis it can make various predictions regarding on future state processes.

After the collection phase, data are analyzed and the useful information are extracted through the statistical methods. Data must be in a form that make analysis easy as possible. Highly important is the planning phase and also the construction of documents or systems for data collection. It's necessary to record not only the observation goal and it's characteristics, but the date, data selection plan, the tools used for measures, the method, the personnel that collects data and so on. The calculation of the totals, averages and amplitudes are often necessary and data recording format may be easier this operation.

The next stage is the representation of this data through histograms or charts. *The control charts* (Motorcu A.R., Gullu A., 2004) represents perhaps the most important element of statistical process control. A control chart can be viewed as a device to be used when the process is in progress by the people responsible with the process. The results are displayed in a graphical form and reflects the variation in the process. The three areas of importance from a control chart are:

- *the stable zone* (that meets the *central line*) where there are only common causes of variation, is the area when it should not take any measures, the process is in control;
- *the warning zone* (where there are *the upper warning limit* and *the lower warning limit*) where the process can show special causes of variation and the optimal solution is to examine in more detail the process and to get more information;
- *the action zone* (where there are *the upper action limit* and *the lower action limit*) where there are only the special causes of variation and the only solution is to investigate and adjustment the process.

The *figure 1* is very representative in terms of three areas of maximum importance of a process:

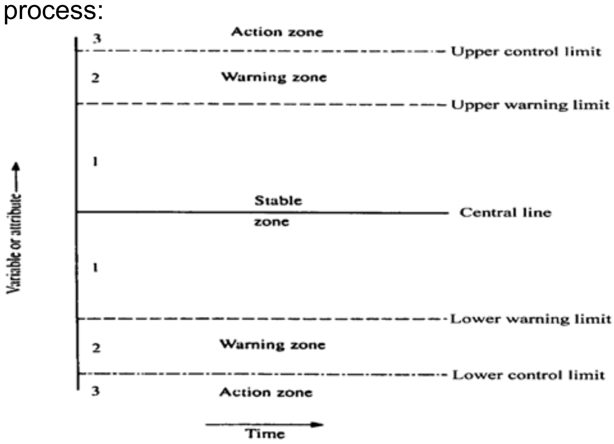


Figure 1 **Schematic control chart**

The most important two types of control charts of statistical process control are *mean chart* and *range chart*. The main contribution in control charts achievement belongs American statistician Walter Shewhart, which is also considered "the father" of statistical process control. He realized in 1920 the control charts for collected and recorded data, at Bell Telephone Laboratories, and from that moment these charts may also be called *Shewhart charts*. Clearly, besides mean and range charts, which may be used together, there are many other types of Shewhart charts.

The main statistic measure around which the mean chart is analyzed is the standard deviation. So, if a process is stable, then we expect that most of the individual results belong to the interval $[\overline{X}-3\sigma;\overline{X}+3\sigma]$ (or, $[\overline{X}\pm 3\sigma]$). The *figure 2* is suggestive in terms of proportion of expected output values in a normal distribution, between values $\mu\pm\sigma, \mu\pm 2\sigma$ and $\mu\pm 3\sigma$.

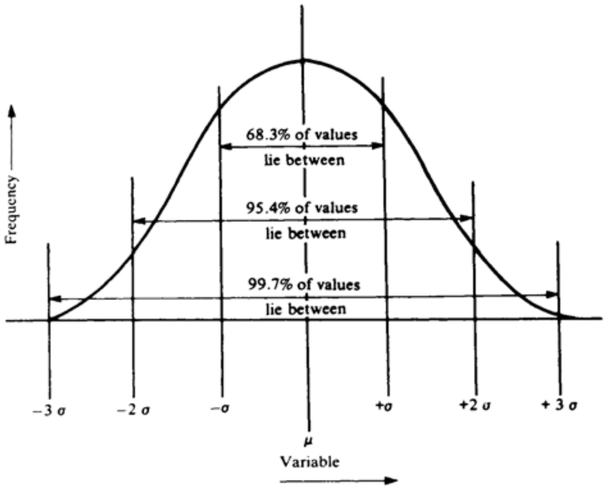


Figure 2 **The proportion of output expected values of a process from a normal distribution**

Returning to the mean chart, it is also very important to say that if the sampling take place in a stable process, then the most of the sample means belong to the interval $\overline{X}\pm 3SE$, where *SE* represents the *standard error* (Chakraborty S., Tah D., 2005). Don't make the confusion between the standard deviation and the standard error. The standard error is the standard deviation divided by the number of samples. If the process is running satisfactorily then more than 99% of the means of successive samples will lie in the range bounded by the lower action line and the upper action line. The distance between the centerline and one of the two lines of action is by three standard errors. The probability of a point falling outside of these lines is 1 to 1000, if the process does not suffer interference during sampling period. The distance between the warning lines and the centerline is two standard errors and the probability that a sample mean to be outside these limits is 1 to 40, if the process remained stable.

The range chart is the other chart of great importance that control the stability of a process. Basically is a very similar chart with the mean chart, except that there it considers the difference between maximum and minimum values of samples taken into account. The range chart is not so sensitive like the mean chart.

The application we proposed in this paper was made in Matlab programming. Although apparently Matlab is not for classical software applications (Stoleriu I.,2009), but more mathematical and statistical analysis and processing of various signals, we use Matlab because the most of the functions used here are already implemented, so that the programmer's work is more easy. In a classical objected oriented programming language, like the .NET platforms (Visual Studio.NET or C#), C++ or Java the interface is extremely easy to achieve. This thing is not available in Matlab, but in these languages the statistical functions must be implemented, a very hard work. In the rows below takes place the presentation of the application, without focusing on a various Matlab language properties, the aim of this paper not being this.

The application has four windows (forms): test.fig (the main form of the application), stat.fig (where we calculated the statistical values), defesantion.fig (here take place the sampling) and time.fig (here the selection times are set). In the lines below we realized a presentation of this forms, by highlighting the most important aspects. It should be noted that any form is accompanied by the files that have a .m extension, that represent the Matlab code for respective form (as in any object-oriented programming language). Also, it should be noted from the beginning that the Matlab interfaces are not so "spectacular" like the interfaces in other programming and we not show in this paper the code, a CD with the whole application can be found at authors of this paper.

The test.fig form is presented below and show relatively simple:

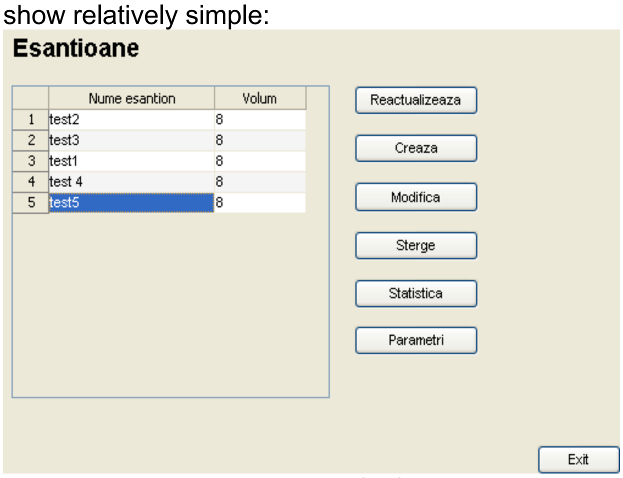


Figure 3 **The test.fig form**

In this *figure* we consider 5 samples with the volume 8. "Volum" represents the number of values that may contain a sample, because in a statistical control is not necessarily that the number of values of samples to be equal. Still, in most of the research regarding the stability of a process, it is considered samples cu equal volumes. The button "Creeaza" make the relationship with the form defesantion.fig. Here take places the operations referred to the defining and creating the samples. This *figure* show like this:

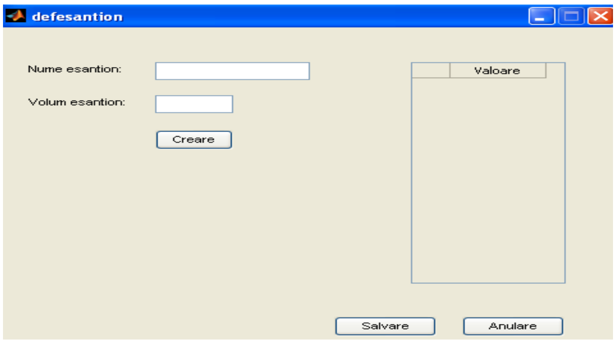


Figure 4 **The creation of the samples**

When we chose a sample, the window look like this:

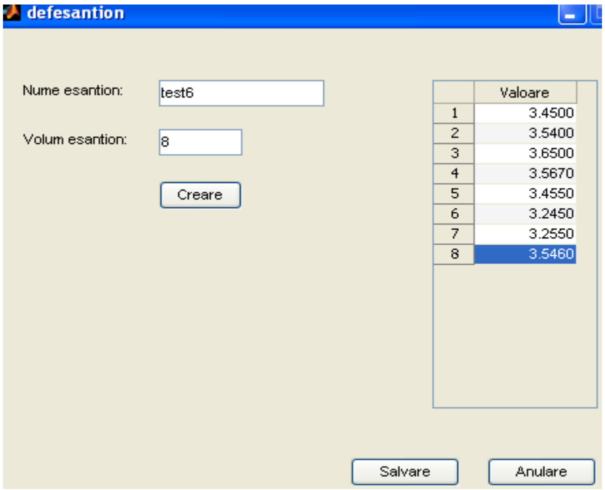


Figure 5 **The load of a sample**

So, we created a new sample, "test6" with the values in the right, under "Valoare". We used a number of 4 decimal places just to increase accuracy. After click the button "Salvare" the data are recorded in test.fig form, where are stored all samples chosen. If we want the update of the form we click the button "Reactualizeaza". If we want the change of a sample, we click on the desired sample and we may change the name or the volume of the sample. If we want the delete of a sample, we click on the button "Sterge". Returning to the "test.fig" form, we created another button, "Parametri". Clicking on this button it will be open another form, time.*fig*:

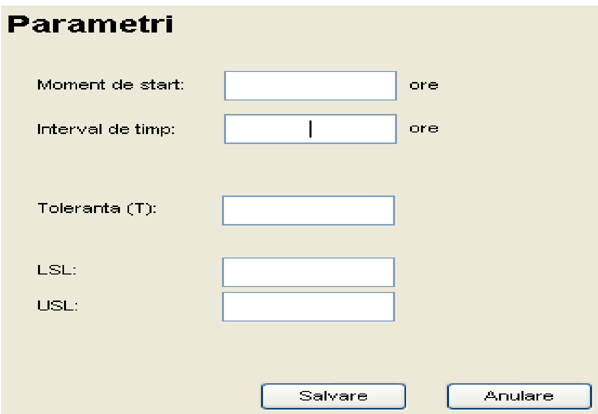


Figure 6 **The window with times and tolerance parameters**

So, in this form we have the starting moment of the process analysis, the time interval and the values of tolerances (T) and lower and upper specification, respectively (LSL, USL).

The button "Statistica" make the relationship with stat.fig form, the window where there are almost the most important elements of our application, the statistical measurements and the charts. Practically, this form is the essential part of this application. This form will be open easily, but we cannot made various operations until setting the time. This thing happen when we click the button "Calcul":

Figure 7 **A warning referred to the time setting**

After setting the starting moment and the time interval, we expect, by clicking again the button "Calcul", to appear the expected results. But again appears another warning information:

Figure 8 **A warning referred to the tolerance setting**

So, we must now to setting the tolerance of the products that will be analyzed. Don't confuse the central line of a process with the tolerance! The tolerance is setting by the manufacturers and should always be known at the beginning of the process analysis.

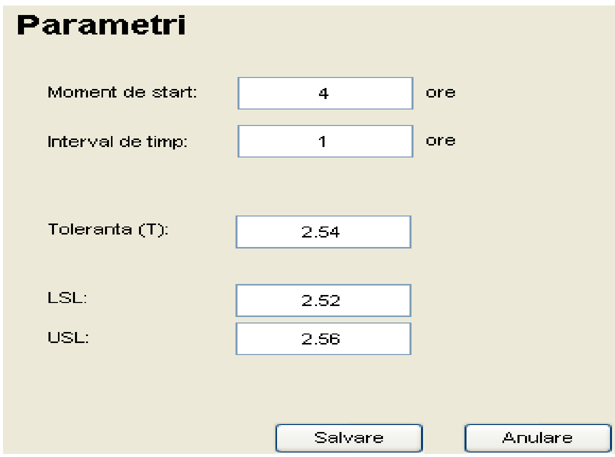
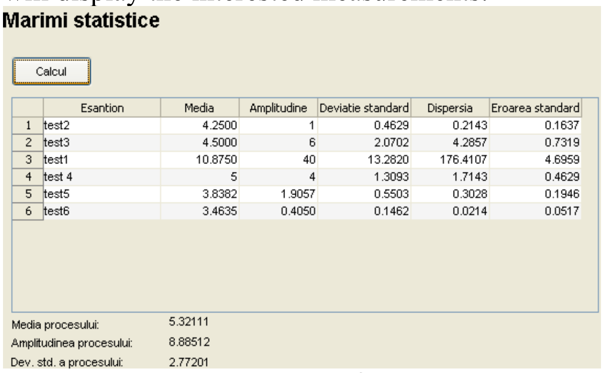


Figure 9 **The setting of the time and the tolerances**

RESULTS AND DISCUSSIONS

So, after setting the times and the tolerances, we can finally click on the button "Calcul" that will display the interested measurements:


Marimi statistice

Calcul

	Esantion	Media	Amplitudine	Deviatie standard	Dispersia	Eroarea standard
1	test2	4.2500	1	0.4629	0.2143	0.1637
2	test3	4.5000	6	2.0702	4.2857	0.7319
3	test1	10.8750	40	13.2820	176.4107	4.6959
4	test 4	5	4	1.3093	1.7143	0.4629
5	test5	3.8382	1.9057	0.5503	0.3028	0.1946
6	test6	3.4635	0.4050	0.1462	0.0214	0.0517

Media procesului: 5.32111
Amplitudinea procesului: 8.88512
Dev. std. a procesului: 2.77201

Figure 10 **The statistic values of the process samples**

So, in this figure we have the mean, the amplitude, the standard deviation, the variance and the standard error of the samples considered. Below, we have the process mean, the process amplitude and the process standard deviation. But, this is only a half part of the "stat.fig" form. On the other side of the figure we have the mean chart of the process and also the indices that show the capability of the process. The equations of the capability indices of the process are presented in the *Equations* section. We concentrated here to the implementation of these values in the "stat.fig" form. For an easy implementation of these indices, we calculated the standard deviation using the *Hartley constant*. So, we implemented two functions: a function of the Hartley constant for the mean, "hartleymean.m" and a function of the Hartley constant for the amplitude, "hartleyamplit.m". All of the functions that we implemented here represent a helping tool for a good realization of the application. Then, we used these functions in the calculation of the standard deviation and finally in the implementation of these three process capability indices. Their equations and also their mechanism are presented in the Equations part of this paper. The mean chart of the values calculated above in the "stat.fig" form look like this:

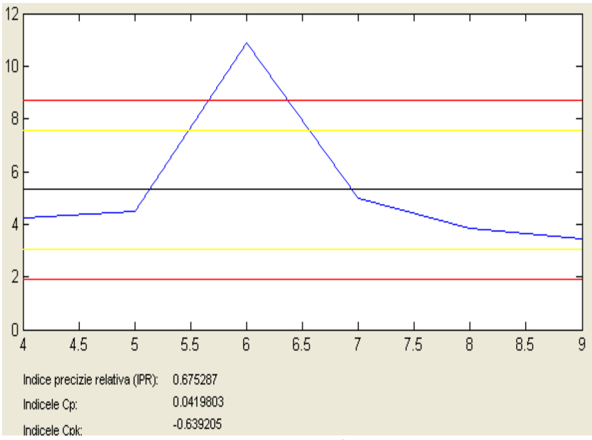


Figure 11 **The mean chart of the process and the process capability indices**

The black line represent the process mean, the yellow lines represent the warning lines, the red lines represent the red lines and finally with the blue color are represented the means of the process samples. Below there are the indices of the process capability. To mention that these three indices of the process capability are not in relationship with the process values (mean and warning and action lines). Clearly, these three indices are statistical values and must be treated in the same figure. Also, it can also provide a chart for these indices, but this will be done in other work. Still, the indices values are edifying for the capability of a process. In the next lines we present the values of the Cpk index that represent the given level of confidence in the process capability (Oakland J.S., 2003):

- Cpk < 1: a situation in which the producer is not capable and there will inevitably be non-conforming output from the process (fig.12.a);
- Cpk = 1: a situation in which the producer is not really capable, bacause any change within the process will result in some undetected non-conforming output (fig.12.b);
- Cpk = 1.33: an acceptable situation because non-conformance is not likely to be detected by the process control charts;
- Cpk = 1.5: this result is not yet satisfactory because non-conforming output will occur and the chances of detecting it are still not good enough;
- Cpk = 1.67: a promising result, non-conforming output will occur but there is a verry good chance that it will be detected;
- Cpk = 2: high level of confidence in the producer (fig.12.c)

CONCLUSIONS

In this paper we developed an application that will help the specialists from quality control in industrial processes by using the concepts of statistical process control. Also, we have implemented the capability indices of the process, because it is not sufficient that an industrial process to be only in statistical control. For an industrial process to have an increased capability is necessary firstly to be in statistical control, and then it can make an analysis on its capability. The implementation of an expert system based on this application, a system based on fuzzy inference rules, is an important issue on which we will focus on the future.

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