

Methods of the quality assurance applied at the remote laboratory selection

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Abstract—Quality assurance principles applied at the remote laboratory network there are similarly with the same principles applied at the production process, which has as a result products used by society. Remote experiment is a product used by learners, a part of our society, with the main reason to increase the quality of knowledge. Learners are the consumers (the clients) and teachers are the producers.

At limit, one student must to open all of the remote laboratories referred at the same experiment to be able to declare that his knowledge and image about this experiment there is complete. But, similarly with the classic production process, there are a various grades or levels of quality. These differences are the result of the *intentional* design of the experiment, determined by the level of the laboratories endowment, of the level of Internet connection, the type and complexity of the subjects approached in the remote way, the acceptance of national language or of the English ones. All of the above factors being *intentional*, the quality aspects are named **QUALITY of DESIGN**.

There are other factors which influenced the quality of the remote laboratory. They are: hardware and software utilized for the remote experiment, knowledge level of the producers (teachers) and of the consumers (students), type of quality assurance system in use inside of the schools, assessment and evaluation rules applied for the student knowledge, etc.. This group of factors will determine **QUALITY of CONFORMANCE**, indicating how well the laboratory works (as product) conforms to the specifications required by each training system who intend to use the remote experiment network.

There is a considerable necessity of the clarifications about quality in the field of the remote laboratory network, many times above notions being often used without a clear distinction. Being a global system, the remote experiment network includes an unavoidable conflict between *quality of design*, which represents a local decision and *quality of conformance*, which is a global requirement. As a result, in the paper the authors want to propose the application of some statistics methods, to do the above distinction and to start new approach regarding quality assessment in the remote experiment network.

Keywords-component; quality of design; quality of conformance; remote experiment; sampling; null hypothesis; OC curve; F ratio;

I. INTRODUCTION

If we agree the idea to consider all of laboratory works from the remote experiment network as a products and the students as a consumers, then quality is becoming the basic consumer decision. As every consumer from the market, student feels that the products of certain universities are substantially better in quality than the others. In this situation it is possible to apply in the laboratory work selection, the statistical methodology used in the quality control from manufacturing process? During the search of the laboratory works, the student has two alternatives: to accept the opened laboratory work or to reject it for some reasons. Because the student do not have time to do his acceptance after opening all of the similar laboratory works, it means that he made acceptance and rejection using only a sample from the entire *“lot”* of laboratory works. Up to now, the above operations seems to be similarly with acceptance sampling from statistical quality control. Three peculiarly aspects must to be mentioned:

1. Acceptance sampling, like above, do not estimate the *“lot”* quality; it simply accepts or reject laboratory works using some subjective criteria;
2. Acceptance sampling do not provide any direct form of the quality control;
3. The most effective use of the acceptance sampling is an audit tool which, ensure the customer that the output of a design *conforms* to its requirements.

There are some differences in the acceptance sampling applied to the laboratory works contained in the remote network:

1. Middleware, which ensure sampling of *“n”* laboratory work at one trial, selected at random from the *“lot”*, will not be able to characterize the entire *“lot”* quality, as in the manufacturing process;

2. The final acceptance number “c” of laboratory work used by the student after selection, does not represent the limit of the defective items in the sample, as in the manufacturing process. It has the significance that: “if “c” laboratory work fulfill student’s requirements, than will exist other with similar quality in the “lot” so that the next decision of the student-client will be to take a second sample”;
3. The second sample will not offer to the student the right to do a global decision regarding the quality of the laboratory works contained in the “lot”. It is due the fact of the huge diversity of evaluation of the laboratory work content, produced by the large diversity of the cultural heritages involved in the network;
4. In the case of the manufacturing process, the random numbers “n” is generated by a computer. In the case of the remote experiment network, the sampling is random because the middleware accessed diverse sites of the laboratory works in dependence with the situation of the momentary Internet connection.

II. SAMPLING ANALYSE

In the case of a single sampling plan, if the number of the similarly laboratory works are “N”, then the sample size is “n” and the acceptance number is “c”. If the nonconforming laboratory works observed is “d” and $d \leq c$, then the student has minimum two laboratory works of the good quality? It is the question, because the criteria accordingly with comparisons and selection are made, will be also random, in direct connection with the student prerequisite knowledge.

The measure of the acceptance sampling plan is the operating characteristic (OC) curve. This curve plots the probability of the “lot” acceptance versus the lot fraction with nonconformities. The probability of observing “d” nonconforming laboratory works is:

$$P\{d\} = f(d) = \frac{n!}{d!(n-d)!} \cdot p^d \cdot (1-p)^{n-d} \quad (1)$$

The probability of acceptance is the same probability when $d \leq c$ or:

$$P_a = P\{d \leq c\} = \sum_{d=0}^c \frac{n!}{d!(n-d)!} \cdot p^d \cdot (1-p)^{n-d} \quad (2)$$

where: p is the fraction of the nonconforming laboratory works in the “lot”.

For example, from 500 laboratory works referring at Ohm law, suppositional existed in the remote network, the random sampling gives $n=50$ and the acceptance number $c=3$. Considering the variation of the lot fraction nonconformities “p” with the values given in the table 1:

TABLE I.

p								
0,01	0,02	0,03	0,04	0,05	0,06	0,07	0,08	0,09

the OC curve of the single sampling action there is in accordance with the Fig. 1:

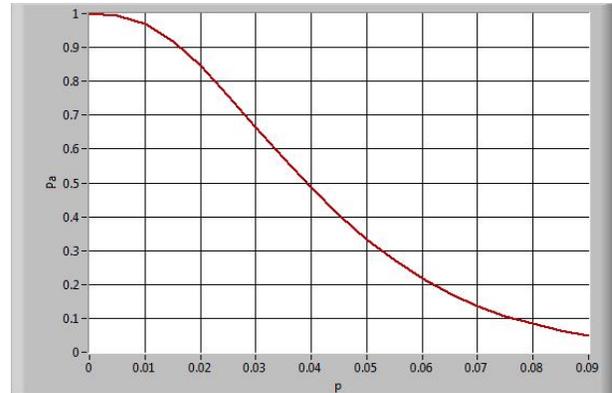


Figure 1. OC curve at single sampling action

As we have mentioned above, a warranty of the good selection impose a double sampling action. Obviously, a double sampling plan is defined by the four parameters:

- n_1, n_2 – sample size on the first sample respectively of the second sample;

- c_1, c_2 – acceptance number of the first respectively of the second sample with the condition $c_1 < c_2$;

The conditions which results from this action are:

- if $d_1 \leq c_1$ the lot is accepted on the first sample;

- if $d_1 \geq c_2$ the lot is rejected on the first sample;

- if $c_1 < d_1 \leq c_2$ a second random sample of size n_2 is drawn from the remote experiment network and the number of nonconformities d_2 are observed.

The combined number of observed nonconformities from both samples, $d_1 + d_2$, is used to determine the lot nonconformities:

- if $d_1 + d_2 \leq c_2$ the lot is accepted;

- if $d_1 + d_2 > c_2$ the lot is rejected.

The OC curve for a double sampling activity has two curves. One P_{a1} for the n_1, c_1 and the second P_{a2} for the n_2, c_2 . P_{a1} , denotes the probability of acceptance of the first sample and P_{a2} the probability of acceptance of the second sample. $P_a = P_{a1} + P_{a2}$ denotes the probability of

acceptance on the combined samples. The calculation manner is mentioned in the following. First is calculated the P_{a1} probability:

$$P_{a1} = \sum_{d=0}^{c1} \frac{n_1!}{d_1!(n_1 - d_1)!} \cdot p^{d_1} \cdot (1 - p)^{n_1 - d_1} \quad (3)$$

with the condition: $d \leq d_1 = c_1$

The second sample is drawn only if there is the condition: $c_1 < d_1 \leq c_2$. The lot is accepted in the following situations:

- a. $d_1 = c_1 + 1$ and $d_2 = 0$ or 1

That is, we find $c_1 + 1$ nonconformities on the first sample and zero or one on the second sample. The probability for this situation there is:

$$\begin{aligned} P\{d_1 = c_1 + 1, d_2 \leq 1\} &= P\{d_1 = c_1 + 1\} \cdot P\{d_2 \leq 1\} = \\ &= \frac{n_1!}{(c_1 + 1)! \cdot [n_1 - (c_1 + 1)]!} \cdot p^{c_1 + 1} \cdot (1 - p)^{n_1 - (c_1 + 1)} \cdot \\ &\cdot \sum_{d_2=0}^1 \frac{n_2!}{d_2!(n_2 - d_2)!} \cdot p^{d_2} \cdot (1 - p)^{n_2 - d_2} \end{aligned} \quad (4)$$

- b. $d_1 = c_2$ and $d_2 = 0$

That is, we find c_2 nonconformities on the first sample and zero nonconformities on the second sample. The probability of this is:

$$\begin{aligned} P\{d_1 = c_2, d_2 = 0\} &= P\{d_1 = c_2\} \cdot P\{d_2 = 0\} = \\ &= \frac{n_1!}{c_2!(n_1 - c_2)!} \cdot p^{c_2} \cdot (1 - p)^{n_1 - c_2} \cdot \\ &\cdot \frac{n_2!}{0!(n_2 - 0)!} \cdot p^0 \cdot (1 - p)^{n_2 - 0} \end{aligned} \quad (5)$$

Thus, the probability of acceptance on the second sample is:

$$P_{a2} = P\{d_1 = c_1 + 1, d_2 \leq 1\} + P\{d_1 = c_2, d_2 = 0\} \quad (6)$$

For the entire lot, the probability of acceptance is therefore:

$$P_a = P_{a1} + P_{a2} \quad (7)$$

The OC curve for the double sampling activity is shown in the Fig. 2.

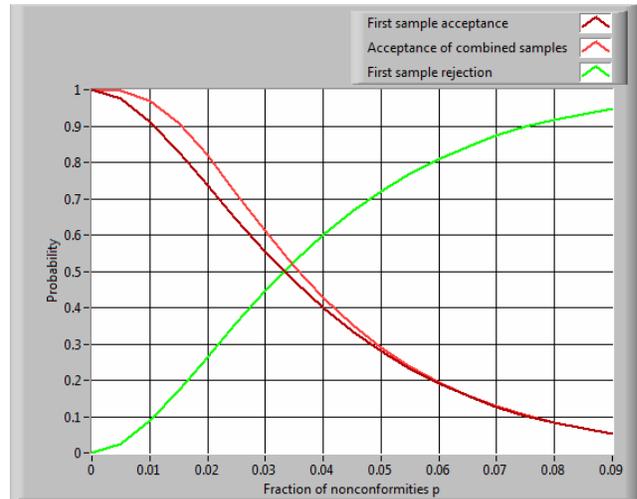


Figure 2. OC curves for the double sampling

Comments:

It is the first step of the quality analyze with statistic methods. It is referred at the quality of conformance because is a tool which indicates the manner in which the students accept or reject the laboratory works from the remote experiment network.

But, this action depends in a great measure by the some factors proper of the Internet environment:

- The number of the connections requested in the same time and the capacity of the remote site to accept one or more;
- The capacity of the middleware to do connections in conformance with the student solicitations;
- The speed of the Internet connection, used by the students;
- The student ability in the English language which determine the connection duration;

As a result, the quality analyze might be distorted. We have mentioned above that only sampling analyze will not give too much information about the laboratory works quality. It only gives us some indications about the quality of conformance. And the levels of the conformance there is distributed and diverse between users. We must introduce in the quality system of the remote network, in completion of the above tool, other analyze regarding quality of design [8].

III. KEPPEL METHOD

In our point of view, the good analyze of the quality of design applied at laboratory works is the method of null hypothesis applied by Keppel* in the behavioral sciences. We need a tool which allows us to state if the laboratory works opened by the students will produce effects on the student knowledge. The null hypothesis method evaluation gives us this certainty.

In short, for remembering the statistic assumptions regarding the null hypothesis, we have:

$H_0 : \mu_1 = \mu_2 = \mu_3 \dots \mu_i$ – The null hypothesis;

$H_1 : \mu \neq \mu_1$ – The alternative hypothesis;

The null hypothesis mentioned that we have the same values of the mean to the different populations analyzed. If H_0 is true, our treatments (learning from the remote network) do not give effects on the population.

The alternative hypothesis states that the values of the means are not equal. If H_1 is true, we expect to find some treatments effect with influence on the students knowledge.

The evaluation of the above situations is made through F distribution. Simply and direct, F ratio is defined as:

$$F = \frac{\text{BETWEEN GROUPS VARIANCE}}{\text{WITHIN GROUP VARIANCE}} \quad (8)$$

Between groups differences are the result of the combined effect of the experimental treatment and of the experimental errors. Within group differences represent the influence of experimental error alone.

F is a numerical index which is “sensitive” to the presence of treatments effects in the population. Only the value $F > 1$ indicate the existence of the treatment effect (see above definitions of the numerator and denominator of the F ratio).

We will present now the way and the motivations which will conduct us towards F ratio calculation and interpretation.

If we have an independent variable as factor A, with three levels of variation: a_1, a_2, a_3 , applied at “s” subjects down form one population, the frequency distribution of the three sets of scores are presented in Fig. 3:

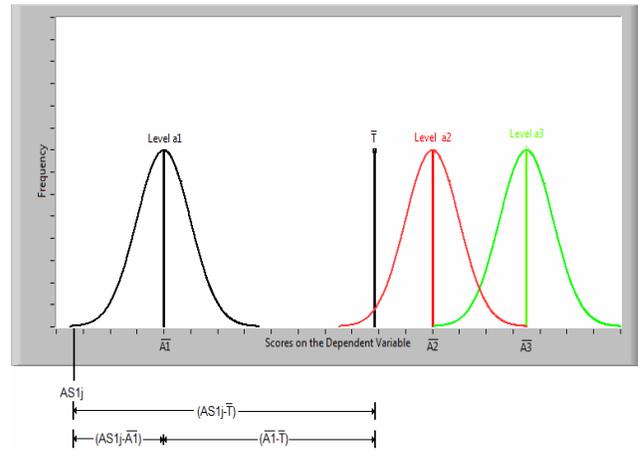


Figure 3. The components of deviation scores* [1]

According with the Fig. 3, AS_{1j} represents the scores at level factor “1” having “j” values, and the correlations showed are:

$$AS_{1j} - \bar{T} = (\bar{A}_1 - \bar{T}) + (AS_{1j} - \bar{A}_1) \quad (9)$$

where: $AS_{1j} - \bar{T}$ - is total deviation;

$(\bar{A}_1 - \bar{T})$ - is between groups deviation;

$(AS_{1j} - \bar{A}_1)$ - is within group deviation

In the [1] this relation is written accordingly with the Hays [2] and Winer [3]:

$$SS_A = \sum_i^a s \cdot (\bar{A}_i - \bar{T})^2 \text{ – Between groups sum of squares;} \quad (10)$$

$$SS_{S/A} = \sum_{j=1}^s (AS_{ij} - \bar{A}_i)^2 \text{ – Within group sum of squares;} \quad (11)$$

with the obvious correlation:

$$SS_T = SS_A + SS_{S/A} \quad (12)$$

Starting from these notions, we will calculate the F ratio. For this we need to have the “degree of freedom” df , which represents the number of scores with independent information which enter into the calculation of the sum of squares. Accordingly with the Keppel definition:

$$df = \left(\begin{array}{c} \text{number of} \\ \text{independent} \\ \text{observations} \end{array} \right) - \left(\begin{array}{c} \text{number of} \\ \text{population} \\ \text{estimates} \end{array} \right); \quad (13)$$

* we will use the same notations as Keppel

For SS_A , $df_A = a - 1$ and for $SS_{S/A}$, $df_{S/A} = a \cdot (s - 1)$

As a result:

$$df_T = df_A + df_{S/A} = a - 1 + a \cdot (s - 1) = as - 1; \quad (14)$$

The next step of calculations is the mean of squares:

$$MS_A = \frac{SS_A}{df_A} \quad \text{and} \quad MS_{S/A} = \frac{SS_{S/A}}{df_{S/A}} \quad (15)$$

Where: MS_A estimates the combined presence of treatment effects plus error variance and $MS_{S/A}$ independently by MS_A estimates error variance.

Finally, the F ratio becomes:

$$F = \frac{MS_A}{MS_{S/A}} = \frac{\frac{SS_A}{df_A}}{\frac{SS_{S/A}}{df_{S/A}}} = \frac{SS_A}{SS_{S/A}} \cdot \frac{df_{S/A}}{df_A} \quad (16)$$

Numerical example

Suppose that we were interested in the effect in the comprehension of three different instructions referring at one laboratory work. One group are verified if they succeed to memorize the basic law settled at the laboratory work, a second similar group is asked to concentrate upon measurement units, and their influence upon experiment, and the third group will work free, without recommendations. All of groups will receive finally a test regarding the comprehension of the laboratory work as a whole. In the hypothetical example there are $s=5$ subjects who were randomly assigned to each of $a=3$ treatments conditions. It means that, the subjects connections with the remote network was randomly, so that they will encounter one of the above instructions. Using the Keppel notations, the AS_{ij} matrix applied at the above experiment has the aspect (tab.2):

TABLE II.

AS_{ij}	a_1	a_2	a_3
1	13	7	8
2	17	9	10
3	11	8	6
4	10	6	7
5	14	7	8
6	15	10	9
7	9	6	8
8	11	7	5
9	13	5	9
10	17	5	10

$\sum A_i$	130	70	80
\bar{A}_i	13	7	8
$\sum_j^s (AS_{ij})^2$	1760	531	664

With these data we may compute, following the above scheme, successively:

$$SS_A = \sum_i^a s \cdot (\bar{A}_i - \bar{T})^2 = \frac{\sum (A_i)^2}{s} - \frac{(\bar{T})^2}{a \cdot s} = 206,7$$

$$SS_{S/A} = \sum (AS_{ij})^2 - \frac{\sum (A_i)^2}{s} = 135$$

$$df_A = a - 1 = 2$$

$$df_{S/A} = a \cdot (s - 1) = 27$$

$$MS_A = \frac{SS_A}{df_A} = \frac{206,7}{2} = 103,35$$

$$MS_{S/A} = \frac{SS_{S/A}}{df_{S/A}} = \frac{135,35}{27} = 5$$

$$F = \frac{MS_A}{MS_{S/A}} = \frac{103,35}{5} = 20,67$$

Because $F > 1$ we put into discussion the correctness of the null hypothesis.

Comments

Remote experiment network there is similar with a large population from which teachers drew at random three sets of 10 scores for each level of factor A, with the final goal to assess the quality of the content (design) [6], [7].

Assuming that this operation there is made by a large number of teachers, from different places, each operation consisting of three groups of 10 scores with the final goal to compute the value of the F ratio (standard method imposed by the remote network administrator), it is possible to be constructed a graph relating F and frequency of occurrence. We are in two situations:

- Curve of sampling distribution of F , when the null hypothesis is true;
- Curve of sampling distribution of F' , when the null hypothesis is false;

All of teachers involved in this assessment expect to find some treatment effects, as a result of the described experiment.

The problem is to decide if, calculated value of ratio F , came from the F distribution or from F' distribution.

In the Fig. 4 is shown the empirical (F) and theoretical (F') sampling distribution of $F(2, 27)$ the F ratio computed in the above numerical example. The empirical $F(2, 27)$ distribution was obtained supposing that $\overline{A_1} = \overline{A_2} = \dots = \overline{A_i} = 7$ ($H_0 = \text{true}$). The theoretical distribution was obtaining supposing that $A_1 = 7, A_2 = 8, A_3 = 13$. In the both distribution, $SS_A = 206,7$.

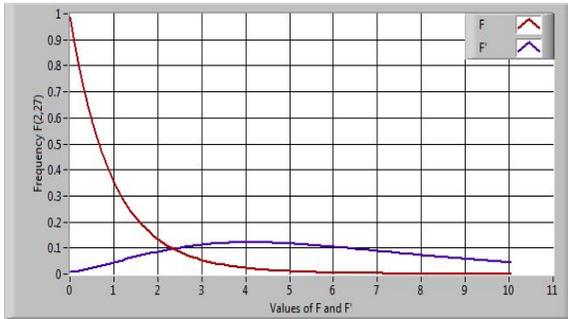


Figure 4 Sampling distribution of F and F'

The decision to reject of not the null hypothesis will be made by comparing the observed (computed) value of F with the value $F' = F$ located at the critical point of transition. The values of the critical F have been tabulated and, as we observed in the table 3, it is specified by three factors: df_A ($df_{numerator}$), $df_{S/A}$ ($df_{denominator}$) and α , which is refers at the portion of the area to the right of an ordinate drawn at F_α .

The shortest explanation of α significance there is shown in the Fig. 5. As we observe, α define the region of incompatibility of the F distribution. It is in fact a probability called “significance level” and the investigator may pick any probability he wants. In the table 3 it is present a fragment of tabulated values for F at different α probabilities.

The decision to reject of not the null hypothesis is made by comparing the observed (calculated) values of F ratio with the value of F' ratio drawn from the above table consider: $df_{nom}; df_{denom}; \alpha$.

TABLE III. (FRAGMENT)

df_{denom}	df_{nom}							
	α	1	2	3	4	5	6	7
3	0,25	2.02	2.28	2.36	2.39	2.41	2.42	2.43
	0,10	5.54	5.46	5.39	5.34	5.31	5.28	5.27
	0,50	10.1	9.55	9.28	9.12	9.01	8.94	8.89
	0,025	17.4	16.0	15.4	15.1	14.9	14.7	14.6
	0,010	34.1	30.8	29.5	28.7	28.2	27.9	27.7

	0,001	167	148	141	137	135	133	132
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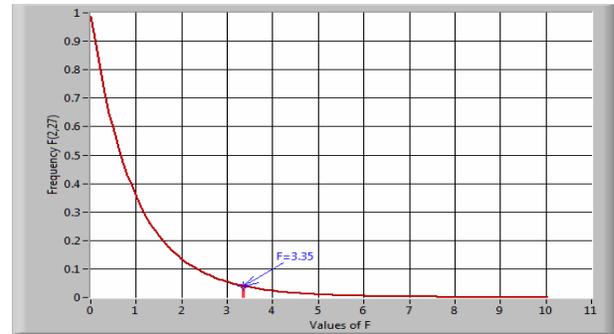


Figure 5 Sampling distribution of $F(2,27)$

With above clarifications we have the possibility to write the rule of decision:

- when $F_{calculated} \geq F_\alpha(d_{nom}, d_{denom})$ -reject null hypothesis H_0 . Otherwise do not reject H_0

In other words:

- If the value F - computed from experiment – falls within the region of incompatibility, the null hypothesis is rejected and alternative hypothesis is accepted;
- If the F value falls within region of compatibility, the null hypothesis is not rejected.

In our numerical example, $df_{nom} = 2$ and $df_{denom} = 27$. If we set $\alpha = 0.05$ the critical value of F (the value which share the F' distribution in incompatible and compatible regions) is 3.35 (from tables similarly with the table 3).

Because:

$$F_{observed} = 20,67 > F_{critical} = 3.35$$

we reject the null hypothesis H_0 , and we should conclude that treatment effects were present in this experiment. It means that, learning materials have some influence on the student knowledge. This conclusion means that the design of the laboratory work fulfill the quality requirements in some measure.

IV. CONCLUSIONS

It is possible to analyze the quality of the laboratory works existed in the remote experiment network with two methods:

- Quality of conformance with double sampling method;
- Quality of design with Keppel method;

The first method is useful in the case of the assessment of the laboratory work selection by the “clients” (i.e. students). Taking into account the number of the selections and the number of the rejections, it is possible to discuss about the

quality of conformance. It isn't an absolute criterion regarding quality because of the fact that there are some outside limits which influenced the selection (Internet connection, Internet speed, language, middleware possibilities, etc.) with not direct dependence with the student opinion about the laboratory work utility.

In the second method, it is necessary to do some questionnaires, with real evaluation of the content, applied to a sampling from the entire population of the remote laboratory works having the same topics. The students will answer at these questionnaires, and using the proposed way, will be possibly to state if these laboratory works have some treatments effects on the student knowledge.

Because the problem of the quality in this environment is quite new, the present paper reflects the first preoccupations of the designers, both of the network and of the content, regarding quality assessment [5]. Sure, the development of this environment will increase these preoccupations and other quality evaluation method will be proposed. The most important thing is the fact that this problem of the quality is raise from the beginning of the development of this remote network [9], [10].

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