Using Taguchi's experiments part II: creating a computer for heavy games and image processing

Usando as experiências de Taguchi parte II: criando um computador para jogos pesados e processamento de imagem

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Abstract
This study aimed to identify and present applications of statistical methods in problems of agricultural and environmental nature. To achieve this objective, an applied research of exploratory and quantitative nature was carried out. Two case studies were adopted as method and technical procedures. As a contribution to this research, the use of statistical methods in problem solving and as a tool for decision making is pointed out.

Keywords: Statistical Methods. Environmental and Agricultural Problems. Decision Making Tools.

Resumo
Este estudo teve como objetivo identificar e apresentar aplicações de métodos estatísticos em problemas de natureza agrícola e ambiental. Para alcançar este objetivo, foi realizada uma pesquisa aplicada de natureza exploratória e quantitativa. Foram adotados dois estudos de caso

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Introduction

Statistics is the science that uses probabilistic theories to explain the frequency of occurrence of events, either in observational studies or in experiments to model randomness and uncertainty to estimate or make possible the prediction of future phenomena, as the case may be (Myers, R.H. and Montgomery, 1995).

Some statistical practices include, for example, the planning and interpretation of observations. Since the goal of statistics is to produce the best possible information from available data, some authors suggest that statistics is a branch of decision theory (Montgomery, 2017).

Currently, statistics have contributed significantly to the decision-making process because a large part of the production chain depends on quantitative methods, and statistics is one of these areas. In the age of information and data processing, statistics uses mathematics to support professionals in many different areas (Fonseca, D;Correa, M.P.O;Santos, R.R;Cardoso, R.P;Reis, J.S.M;Sampaio, 2023; Reis, Cardoso, et al., 2023).

Design of experiments are technique used by professionals in various fields to improve a process through experiments that indicate the effect of factors in the procedure, such as concentration, temperature, the speed of an industrial chemical process, the purity of a material, etc. It is a method of observing the results to act on the process, although at some point it is possible to include technical and scientific studies to help evaluate the influence of a factor (Cardoso, R.P ;Sampaio, N.A.S;Reis, J.S.M;Silva, D.E.W;Barros, 2023; Rezende et al., 2023).

A Taguchi design is a method for designing experiments that usually require only a fraction of the full factorial combinations. In the orthogonal matrix the design is balanced, so that factor levels are weighted equally. Therefore, each factor can be evaluated independently of all the others, so that the effect of one factor does not influence the estimate of another factor. There are two types of Taguchi experiments:
• Static experiments (without a signal factor);
• Dynamic experiments (with a signal factor);

The main objective of the Method is to improve the characteristics of the process or a product, by identifying and adjusting its controllable factors, which will minimize the variation of the final product about its objective (Correia & Cardoza, 2011; Lescura et al., 2023; Reis, Neto, et al., 2023).

The consumer has several options to decide on similar products and services. Most of the time the choice is made based on their general perception of quality or value. In general, consumers want the best possible return for their money. To stay competitive, companies need to identify what is important to increase the consumer's perception of the value or quality of a product or service (Fonseca, D; Correa, M.P.O; Santos, R.R; Cardoso, R.P; Reis, J.S.M; Sampaio, 2023; Reis, Espuny, Cardoso, Sampaio, de Barros, et al., 2022; Sales et al., 2022).

Given the above, the research question that guided this paper is: to visualize a practical application of the Taguchi Experiment for making computers for heavy gaming and image processing. The goal of this paper is to show these applications. Initially, the paper will discuss the concepts of statistical treatments. Next, the results and discussions of the proposed objectives will be presented, and an application performed with data from a book will be shown. Finally, the conclusion will be presented with suggestions for future studies.

Theoretical Referential

The development of a new product and/or process usually depends on a large number of variables. Conscientious planning of the experiments that must be performed to determine, and even quantify, the influence of the variables on the desired responses is fundamental to obtaining reliable results and performing consistent statistical analysis. These ideas are called production optimization and have been on the market for some time (Costa, 2011; Espuny et al., 2022; Sales et al., 2021).

In Taguchi Robust Parameter Experiments, you first choose the control factors and their levels and choose an appropriate orthogonal matrix for these control factors. The control factors make up the internal matrix. Simultaneously you determine a set of noise factors, with an experimental design for that set of factors. The noise factors make up the outer matrix. You run the experiment by performing the full set of noise factor settings on each combination of control factor settings. The response data from each noise factor run in the outer matrix is
lined up in a row next to the factor settings for that control factor run in the inner matrix (da Silva et al., 2021; Mazza et al., 2022; Paese et al., 2001; Stochero et al., 2020).

According to the amount of variation that appears as a response, control factors that contribute to quality variation reduction can be identified. The signal-to-noise ratio combines repetitions into a value that shows how much variation there is. Minimizing the loss of quality means maximizing the signal-to-noise ratio, i.e. the level that has the highest S/N will be considered the optimum level (Butola et al., 2019; Cui et al., 2017; Schneider et al., 2017).

The dominant idea in Taguchi design focuses on reducing variation in the quality function of a product, both in the laboratory and later in the process. This is not the case in the classical design of experiments theory. Here, the variation of the quality characteristic is assumed to remain constant for all levels of the model factors. This does not take into account the problem of variability reduction, which is a key issue when looking for quality improvement (Jumianto et al., 2019; Rajesh Ruban et al., 2020; Setiawan et al., 2020).

**Research Method**

This paper can be classified as an applied research, as it aims to provide improvements in the current literature, with normative empirical objectives, aiming at the development of policies and strategies to improve the current condition (Bertrand & Fransoo, 2002; Moura et al., 2023; Reis, Espuny, Cardoso, Sampaio, Barros, et al., 2022; Sampaio et al., 2010). The problem approach is quantitative, as is the modeling and simulation research method. The research steps were carried out following the sequence shown in Fig.1.

- **Step 1:** The Experimental data was selected from the book of (B et al., 2020). This choice was based on the fact that this book brings interesting data to be treated with the respective statistical analyses.
- **Step 2:** The data was adjusted to provide a statistical analysis, with the objective of showing an application of the Taguchi Experiments.
- **Step 3:** Statistical Analysis of the Taguchi Experiments was performed using Minitab Software.
- **Step 4:** The interpretation of the results was performed.
Step 5: Scientific writing of the Results and Discussion were performed
Step 6: The conclusions presented at the end of this paper are drawn from the results obtained in the previous steps.

3.1 Case Study

The problem presented by (B et al., 2020) served as motivation for the realization of this work, because it shows a practical application of the Taguchi Dynamic Method, so in the application of this work it is necessary to detect what is the best configuration of components for the computers in your company, based on the end user's experience. The goal is to combine several brands of components and measure in practice, which component configuration will provide the best end-user experience. But the end user may use the computer to play heavy games, and may also use it to create graphic animations and image processing. In this case, the user himself will inject into the system a variation that can affect the signal-to-noise ratio regardless of the ideal configuration specified by the manufacturer. Surely you have heard that Apple computers are better for imaging, due to their configuration, but not so good for gaming. The person responsible for configuring the high-end computers in his company decides to use the Taguchi method to perform the experiment with the following characteristics:

Control Factors:
- Processors: AMD or Intel
- RAM memories: Samsung or Kingston
- Graphics Card: Radeon or Nvidia
- Noise or Response Factors: Seconds for the complete execution of the tests
- Signal Factor:
  - Test Type for Benchmark (PCMark8 (1) for imaging jobs, and Catzilla (2) for gamers)

Using Minitab 19 Software, you create a Taguchi Experiment with 2 levels and 3 factors, and choose an L12 so that the experiment has at least one replicate for each combination, it is not known which Benchmark Test will be performed, so you add a sign factor for the dynamic characteristics. The response variable is Seconds (time required to complete the benchmark test). Table 1 shows an experimentation worksheet that combines all the factors and signals with the appropriate Response Variable.

<table>
<thead>
<tr>
<th>Processor</th>
<th>RAM</th>
<th>GPU</th>
<th>Benchmark</th>
<th>Seg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel</td>
<td>Kingston</td>
<td>Radeon</td>
<td>1</td>
<td>610</td>
</tr>
<tr>
<td>Intel</td>
<td>Kingston</td>
<td>Radeon</td>
<td>2</td>
<td>587</td>
</tr>
<tr>
<td>Intel</td>
<td>Kingston</td>
<td>Radeon</td>
<td>1</td>
<td>608</td>
</tr>
<tr>
<td>Intel</td>
<td>Kingston</td>
<td>Radeon</td>
<td>2</td>
<td>590</td>
</tr>
<tr>
<td>Intel</td>
<td>Kingston</td>
<td>Nvidia</td>
<td>1</td>
<td>623</td>
</tr>
<tr>
<td>Intel</td>
<td>Kingston</td>
<td>Nvidia</td>
<td>2</td>
<td>604</td>
</tr>
<tr>
<td>Intel</td>
<td>Samsung</td>
<td>Radeon</td>
<td>1</td>
<td>556</td>
</tr>
<tr>
<td>Intel</td>
<td>Samsung</td>
<td>Radeon</td>
<td>2</td>
<td>527</td>
</tr>
<tr>
<td>Intel</td>
<td>Samsung</td>
<td>Nvidia</td>
<td>1</td>
<td>578</td>
</tr>
<tr>
<td>Intel</td>
<td>Samsung</td>
<td>Nvidia</td>
<td>2</td>
<td>564</td>
</tr>
<tr>
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<td>Samsung</td>
<td>Nvidia</td>
<td>1</td>
<td>574</td>
</tr>
<tr>
<td>Intel</td>
<td>Samsung</td>
<td>Nvidia</td>
<td>2</td>
<td>563</td>
</tr>
<tr>
<td>AMD</td>
<td>Kingston</td>
<td>Nvidia</td>
<td>1</td>
<td>697</td>
</tr>
<tr>
<td>AMD</td>
<td>Kingston</td>
<td>Nvidia</td>
<td>2</td>
<td>684</td>
</tr>
<tr>
<td>AMD</td>
<td>Kingston</td>
<td>Nvidia</td>
<td>1</td>
<td>699</td>
</tr>
<tr>
<td>AMD</td>
<td>Kingston</td>
<td>Nvidia</td>
<td>2</td>
<td>689</td>
</tr>
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<td>Radeon</td>
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<td>661</td>
</tr>
<tr>
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<td>Kingston</td>
<td>Radeon</td>
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<td>649</td>
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<tr>
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<td>Samsung</td>
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<td>541</td>
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<tr>
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<td>Samsung</td>
<td>Nvidia</td>
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<td>538</td>
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<td>Samsung</td>
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<td>512</td>
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<td>Radeon</td>
<td>2</td>
<td>549</td>
</tr>
<tr>
<td>AMD</td>
<td>Samsung</td>
<td>Radeon</td>
<td>1</td>
<td>515</td>
</tr>
<tr>
<td>AMD</td>
<td>Samsung</td>
<td>Radeon</td>
<td>2</td>
<td>541</td>
</tr>
</tbody>
</table>

Table 1. Data Experimentation Worksheet
Source: Authors (2023).
Results and Discussions

4.1 Case Study

Analyzing the data in Table 1 using Minitab 19 software first yields Table 2 of response for signal-to-noise ratio.

<table>
<thead>
<tr>
<th>Level</th>
<th>Processor</th>
<th>RAM</th>
<th>GPU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2,937</td>
<td>3,077</td>
<td>3,283</td>
</tr>
<tr>
<td>2</td>
<td>3,512</td>
<td>3,372</td>
<td>3,165</td>
</tr>
<tr>
<td>Delta</td>
<td>0,576</td>
<td>0,295</td>
<td>0,118</td>
</tr>
<tr>
<td>Posto</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 2. Response Table for Signal-to-Noise Ratios
Source: Authors (2023).

Taguchi's experiments show which factors have the most influence on the Response Variable, this table shows that the one with the largest Delta is the Processor, indicating that of all the factors the one with the greatest influence on the Final Response when switching from one to another is it, followed by RAM and lastly the Graphics Processing Unit (GPU).

In Table 4 (Response Table for Slopes) it is observed that the highest slope is for RAM followed by Processor and then GPU.

<table>
<thead>
<tr>
<th>Level</th>
<th>Processor</th>
<th>RAM</th>
<th>GPU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>346,5</td>
<td>382,3</td>
<td>347,9</td>
</tr>
<tr>
<td>2</td>
<td>362,5</td>
<td>326,7</td>
<td>361,1</td>
</tr>
<tr>
<td>Delta</td>
<td>16,0</td>
<td>55,7</td>
<td>13,2</td>
</tr>
<tr>
<td>Posto</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 3. Response Table for Signal-to-Noise Ratios
Source: Authors (2023).

The information obtained in Table 3 can also be obtained from Figure 1 (Main Effects Plots for Slopes).
In Figure 2 (Interaction Chart between Curves) it shows that there is no interaction between Processor and GPU, however the time is less for Intel than for AMD on Processor and it is also less for Radeon than Nvidia for GPU.

Observing Figure 3 (Main Effects Plots for Signal to Noise Ratio) it can be seen that the Intel processor has the lowest Signal to Noise Ratio, but in RAM there was an inversion in relation to Figure 2 because Kingston had the lowest Signal to Noise Ratio and in relation to the GPU there was also an inversion because Radeon has the highest Signal to Noise Ratio, this may indicate interaction, which will be easily observed in Figure 4.
In Figure 4 (Interaction Plot for S/N Ratios) it can be seen that if I am using an Intel Processor the Radeon card gives a better result than the Nvidia, but if I am using an AMD Processor the Nvidia gives a better result than the Radeon, i.e. there is an Interaction, i.e. depending on the Processor or on the Graphics Card I can have different results.

One can also perform Prediction of Results using Minitab 19 Software, for example in Table 4 the Configurations: Processor (AMD), RAM Memory (Sansung) and Graphics Processing Unit - GPU (Nvidia) have:
Table 4. Prediction
Source: Authors (2023)

<table>
<thead>
<tr>
<th>Razão S/N</th>
<th>Inclinação</th>
<th>DesvPad</th>
<th>Ln(DesvPad)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.42127</td>
<td>340.962</td>
<td>228.534</td>
<td>5.43074</td>
</tr>
</tbody>
</table>

Intel processors seem to be faster than AMD, and Kingston memory also performed better. The Radeon card shows better performance than the Nvidia. But with looking at the Interactions between the control factors it is easy to see that for the signal-to-noise ratio between processor and GPU, the lines cross, indicating strong evidence of interaction. It might be interesting to do a more detailed study to validate if really the combination of same GPU and Processor manufacturers (AMD + AMD and Intel + Intel) really plays an important role in the performance.

Conclusion

This study aimed to show the importance of Taguchi Experiments to help decision making in experiments related to industrial processes, more specifically when related to the choice of parts to optimize a compute for games and image processing. To achieve this goal, a statistical analysis was performed on a single case study. As a contribution of this research, opportunities to use these tools in situations related to industrial areas are pointed out. The second objective is to show the importance of quantitative statistical treatment in research, because this kind of treatment, especially Taguchi Experiments, provides to give the process a certain dose of robustness.

References


Cardoso, R.P;Sampaio, N.A.S;Reis, J.S.M;Silva, D.E.W;Barros, J. G. . (2023). How to perform a simultaneous optimization with several response variables Como realizar uma otimização simultânea com várias variáveis de resposta. Revista de Gestão e
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