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System to adjust student response time measured with touch devices

Sistema para ajustar la medición del tiempo de respuesta de los alumnos medido con dispositivos táctiles

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Abstract

In the increasingly common situation of learner assessment using computerized systems, especially online, the learning process can be analyzed using more data than just the learner's answers. The time taken to answer each question is a clear example of this extra information, but whenever it is measured there are always errors that cause the measured value to differ from the real value. We present a prototype that allows the measurement of these differences and some results of its use.

En la cada vez más habitual situación de la evaluación usando sistemas computerizados, sobre todo online, se puede analizar el proceso de aprendizaje utilizando más datos que la simple contestación del alumno. El tiempo asociado a responder cada pregunta es un claro ejemplo de esa información extra, pero siempre que se mide existen errores que hacen diferir el valor medido del real. Presentamos un prototipo que permite la medición de esas diferencias, y algunos resultados de su utilización.

Keywords: Response time, Online evaluation, Learning analytics, ExGaussian distribution.
Palabras clave: Tiempo de respuesta, Evaluación online, Analítica del Aprendizaje, Distribución Gaussiana modificada exponencialmente

1. Introduction and Objectives

Every living being reacts to the physical stimuli it perceives, human beings are no exception. The time elapsed between the appearance of the physical stimulus and the reaction is called response time (Indeed 2021). Response times depend on many factors such as the individual, the environment, and the physical stimulus. The study of this variability and its possible causes is an important field of research (Navarro 2013, Yan 2010).

An example of a stimulus that provokes a reaction is, without a doubt, an exam question. In a paper-and-pencil-based assessment, it is very difficult to measure these response times. However, as automated and online assessment systems become more widespread, it is increasingly easier to obtain these times, which could provide relevant information on different elements of the student's learning process (Rushkin 2019).

Although it may seem trivial, measuring these times accurately has always been a problem in the field where its study was born, psychology, and has been maintained even with powerful computers (Plant 2016). In fact, in psychology, where the desired accuracy is in the order of milliseconds, special hardware and software systems have been developed to achieve the target accuracy (Peirce 2019, Toda 2017). An example of the reason why accurate response times are needed is the early detection of attention deficit disorder (ADD) problems, in which applications based on "serious games" can be used. If this time is altered due to the device (computer, tablet, or mobile) used in the tests, false positives can be generated in the diagnoses. In addition, great care must be taken, if different types of devices are used when diagnosing a large number of children, the results cannot be grouped without pre-processing the data obtained. Another example is the detection of symptoms of cognitive problems in the elderly (Lemus 2015).

By measuring the response times of a user, a list of values is obtained with the times observed between the appearance of the stimulus (e.g. a question appears on the screen) and the start of the response (e.g. the student selects an answer). A common way of using these results is to obtain a series of parameters that define the type of user response, in a way that facilitates its interpretation. One way to perform this parameterization is to assume that the response times follow a certain statistical distribution, and it is the parameters of that distribution that will be used in the rest of the process. In this way, it is possible to make comparisons between users or different situations for the same user.

One of the statistical distributions used (Lacouture 2016, Moret 2014, Palmer 2011) is the exponentially modified Gaussian distribution (also known as exGaussian or EGM). This distribution is the convolution of a Gaussian and an exponential distribution, so it has three parameters: two of the Gaussian: mean (μ) and variance (σ), and the third is the lambda parameter (λ) of the exponential part. As a result of a response time experiment, values (μ', σ', λ') of these parameters will be obtained from the measurements made in the experiment. These parameters may differ from those that would define the user (μ, σ, λ) if the measurements and/or the system used to calculate the parameters are not exact.

The main objective of this article is to present the development of a system that allows, assuming an exGaussian distribution of the response time, to know how far the estimated parameters are from the response time measurements in a touch device (e.g., a Tablet or a mobile phone) of those that define that response time.

For this, it was built an automated system that performs the "press" action on the touch device, which is the action that is carried out after the appearance of a "stimulus". Its operation, unlike a human, will not be influenced by parameters such as the time of the test, mood, or weather conditions. In order to interact with this hardware, an Android application has been developed that generates the stimuli and measures the response times. The objective of this system is to simulate a "human" that has a known response time and is stored in a file. For each element of that file, the "stimulus-response" time is measured, starting when the system generates the stimulus until the time when the reaction is detected in the same system, which is expected to be different from the real one.

This type of system would allow the use of mobile devices to improve the quality of education (Goal 4) by allowing the collection of relevant information on the students' learning process. In addition, the possibility of creating a database of the characteristics of different devices would allow the reduction of inequalities currently generated by the impossibility of accessing special devices for robust measurement of response times (Goal 10).

In order to achieve the main objective, a secondary objective is established, which is to establish a mechanism that allows knowing the distance between the measured model and the real one, that is, if we assume a time model with exGaussian distribution, the distance between the estimated parameters $(\mu', \sigma', \lambda')$ and the reals (μ, σ, λ).

2. Development and Methodology

In this article, we present the results obtained with a system prototype that allows us to know how accurate the measurement of response time is in touch devices, as well as a first test carried out on a Tablet with the Android operating system. This prototype has specific hardware and software to simulate, respectively, the hand of a user that interacts with the device and the software that in the device generates the stimuli and measures the response times. The prototype is based on a one-degree of freedom robotic actuator (Actuator 2021) driven by a servo motor controlled by a Pololu Micromaestro board (Pololu 2021) which is responsible for generating the delays, compensating them with the movement time of the servomotor (time that is considered fixed).

With the hundreds of thousands of measurements obtained (each measurement measures the time between a stimulus and the possible response of a user), the measured response time parameters have been compared with the exact "generated" delays. With this experiment, we intend to verify if the devices with touch interaction modify the characteristics of the response times.

In addition to the software and hardware application of the simulator, a Matlab© library (Lacouture 2016) has been used to generate data from an exGaussian distribution with typical parameters of a normal human interaction extracted from (Moret 2014). The parameters used have been a mean of 625 ms, a variance of 55 ms and an exponential parameter of 180 ms and 4000 values have been generated. Before experimenting, itself, it has been verified that the numbers generated as the known response time of a human follow the desired distribution.

These values have been introduced in the prototype on a Samsung Galaxy Tablet (model SM-T530 and with Android version 5.0.2). In the experiments carried out, the device has been put in "Airplane" mode to reduce the possible secondary effects that the CPU consumption necessary to access the network could have on the response time. An example of its use can be seen in Figure 1, in which you can see the developed application and the "hand" in which a pointer for capacitive screens has been mounted.

3. Results

During the tests, a response time measurement is obtained for each of the times included in the file generated in the previous point. The times obtained are, as expected, different and

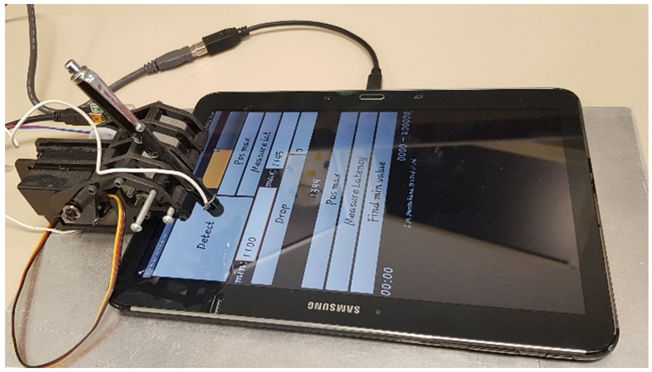

Figure 1: The prototype during an experiment.

greater than the original ones, as can be seen in Figure 2. In that same figure, the distribution of the difference between both times can be observed.

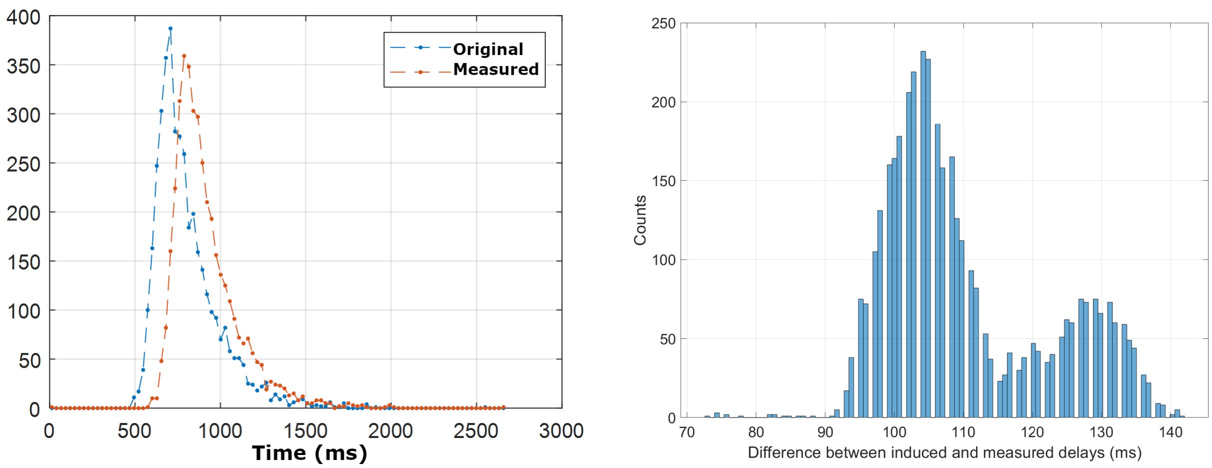

Figure 2: (Left) Comparative PDF of the original measurements and times. (Right) Histogram of the differences between both times.

The parameters of an exGaussian identified on the two data series, the generated and the measured, are presented in Table 3. In this table, it is shown even for the generated data series that the numerical methods always present a certain margin of error. The difference to the theoretical values used to generate the series. To check if the measured data follow the same distribution as the input data, a Kolgomorov-Smirnoff Z test has been performed (Marsaglia 2003). In this test, the hypothesis that the two samples have the same distribution is discarded when the returned statistic exceeds the significance value. Since the test returns a value of 0.35, there are statistically significant differences between the distributions of these samples.

Series	Average (μ)	Variance (σ)	Exponential (λ)
Theoric value	625	55	180
Generated value	623.11	55.21	181.40
Measured value	733.52	55.97	187.22

Table 1: Comparison of the desired and calculated parameters.

Looking in more detail at the data obtained, we can see that, of the three parameters that define an exGaussian distribution, the parameters σ and λ are very similar in all three cases, but the mean (μ) differs quite a bit in the measured data. It looks as if a constant (or close) was added to the measured data when experimenting.

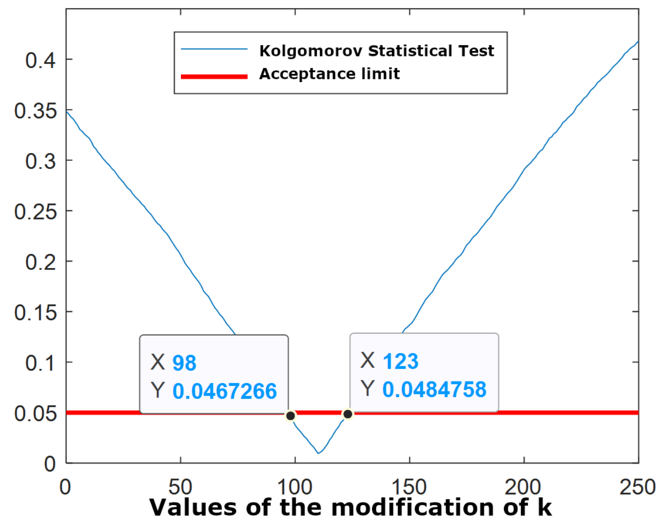

Figure 3: Statistics of the comparison between the original data and the modified measured data.

To test this hypothesis, a set of Kolgomorov-Smirnoff Z tests were performed in which the distribution of the “Generated” data was compared with a series calculated from the “Measured” data minus a value (k) that has been varied. between 0 (original series) and 250 (more than 2 times the observed difference between the mean of the original data series). The statistics obtained with each one can be seen in Figure 3.

4. Conclusions

In this article, we have started with an automated system design that simulates a user performing a large number of actions on a touch screen. The advantage of this approach is that the results do not depend on the ‘tiredness’ of the subject under study and, therefore, on the number of measurements to be made. This automated system has allowed us to perform hundreds of thousands of measurements on each of the devices under study.

The experiment consisted in generating events with known delays between them, using Android© devices the time between events has been measured. The difference between the known time and the measured time is significant and consistent with that measured in other similar studies.

In addition to comparing the difference in the measurements, the distributions of both data sets have been analyzed. The process of fitting the measures to an ExGaussian distribution has given very similar results in two of the three parameters that define that distribution. When performing a Kolmogorov-Smirnov Z test between the input data and those obtained from the measurements minus one value (k), it has been determined that the distributions of both sets are not always different. This fact means that the values of the measurements, knowing the value of k, could be preprocessed to normalize them appropriately and be used to carry out valid studies on the response time.

Since the adjustment value remains constant for the same device over time, it would be necessary to determine if this value is the same for different devices of the same model. If this

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fact were fulfilled, it would be feasible to build a database of models and adjustment values to adjust measurements made in this type of device.

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