Game-based Teaching Approach of Accuracy and Precision

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Abstract – Accuracy and precision are one of the bacis static characteristics of any instrument or sensor system. However, this terms are often interchangeable used and not well understood by the students, regardsles of their different meaning. This paper aims to fill this gap by proposing a game-based approach to teach students the nature of accuracy and precision. The game is realized in LabVIEW environment and supports two gaming scenarios: simulated controls, and realistic controls. The game idea and implementation is described and experimental results are given. It has ben shown that the teaching process and the quality of learning can be improved by involving such interesting and intuitive software and hardware tools.

Keywords – Accuracy, precision, game-based learning, virtual instrument

I. Introduction

Accuracy and precision are the two important factors when taking measurement data. Both accuracy and precision refer to how close a measurement is to an actual value, but accuracy means how close a measurement is to a known or accepted value, while precision denotes how reproducible measurements are, even if they are far from the accepted value.

The meaning of accuracy and precision can be defined in terms of hitting a bull's-eye. Accurately hitting the target means close to the center of the target, even if all the marks are on different sides of the center.

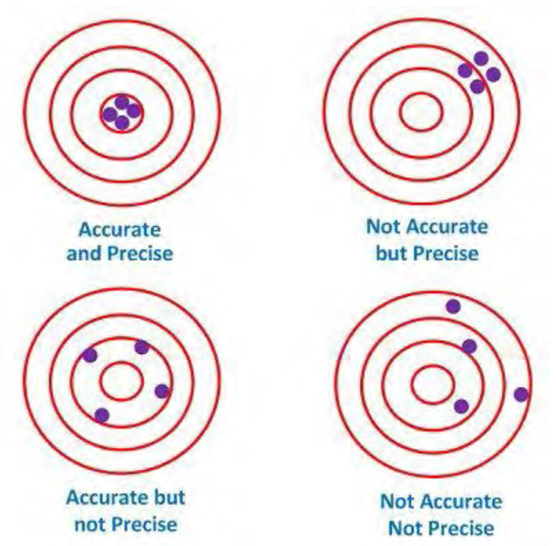

Fig. 1. Examples of accuracy and precision

Precisely hitting a target means all the hits are closely spaced, even if they are very far from the center of the target. Measurements that are both precise and accurate are repeatable and very near true values. The examples on Fig. 1 show four possible combinations of accuracy and precision. The target at the upper lefrt figure shows both accuracy and precision as the shots are clustered together (they are precise) in the target's center-most ring (they are accurate). The next example (right) shows results that are precise, but inaccurate because they are at the target's outer edge instead of its center. The third example is considered accurate because the four shots cluster around the target's center, but they are not precise because the individual shots are quite far apart from each other. The final example shows a dispersion of shots that is both inaccurate and imprecise. Note that the average for a set of measurements may be accurate even if the individual measurements deviate significantly from the desired or theoretical value.

In measurent technique the accuracy is the ability of the instrument to measure accurate value. Or according to the International Organization for Standardization (ISO) definition [1], accuracy is a level of measurement that yields true (no systemic errors) and consistent (no random errors) results.

The term precision means two or more values of the measurement are closed to each other. The value of precision differs because of the observational error. The precision is used for finding the consistency or reproducibility of the measurement. The conformity and the number of significant figures are the characteristics of the precision.

Game-based learning [5-7] aims at students to learn about a certain subject or to acquire certain skills by means of playing. This teaching approach must fulfill both recreational and didactic goals in order to succeed. This paper proposes a game-based learning approach intended to teach students the difference and the meaning of accuracy and precision.

II. Accuracy vs Precision

There are two common definitions of accuracy. The more common definition is that accuracy is a level of measurement with no inherent limitation (ie. free of

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systemic error, another form of observational error).

In science, engineering and math, accuracy refers to how close a measurement is to the true value [2].

The precision of a measurement system, related to reproducibility and repeatability, is the degree to which repeated measurements under unchanged conditions show the same results [2, 3].

The ISO standard applies a more rigid definition, where accuracy refers to a measurement with both true and consistent results.

A measurement system can be accurate but not precise, precise but not accurate, neither, or both. For example, if an experiment contains a systematic error, then increasing the sample size generally increases precision but does not improve accuracy. The result would be a consistent yet inaccurate string of results from the flawed experiment. Eliminating the systematic error improves accuracy but does not change precision. A measurement system is considered valid if it is both accurate and precise.

In addition to accuracy and precision, measurements may also have a measurement resolution, which is the smallest change in the underlying physical quantity that produces a response in the measurement. In numerical analysis, accuracy is also the nearness of a calculation to the true value; while precision is the resolution of the representation, typically defined by the number of decimal or binary digits.

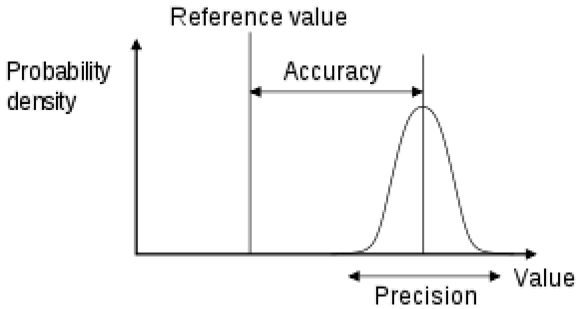

Fig. 2. Accuracy is the proximity of measurement results to the true value, precision, the repatibility or reproducibility of the measurement [4]

According to ISO 5725-1 [1] the general term "accuracy" is used to describe the closeness of a measurement to the true value and precision to repeatability or reproducibility of the measurement, as it is shown in Fig. 2.

When the term is applied to sets of measurements of the same measurand, it involves a component of random error and a component of systematic error. In this case trueness is the closeness of the mean of a set of measurement results to the actual (true) value and precision is the closeness of agreement among a set of results.

III. GAME IDEA AND REALIZATION

The game idea is bazed on the concept explained in Fig.1, i.e playing a shooting game where the player's performance metrics are described through accuracy and precision. The main goal is to provide a competitive scenario for the students where they can be ranked regarding the geometrical distance from the center of the board (accuracy) and regarding the dispersion of their results (precision). The game is realized in Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) platform. The front panel and the block-diagram of the virtual instrument are given in Fig.3 and Fig.4 respectively.

When playing the game, the player should try to shoot as close as possible, and as consistent as possible to the center of the board. The game realization is obtained by a red laser spot that can be moved with certain controls. The game supports two modes of playing: simulated or realistic controls. In the first mode, the controls for horizontal and vertical deflection of the laser spot are simulated in LabVIEW, whereas in the second mode the player uses a joystick to move the laser spot. The firing is realized through simulated or realistic digital switch in the simulated or realistic game mode respectively. In the "realistic" mode, the virtual instrument uses a Data Acquisition (DAQ) card to read the joystick and the digital switch status.

At the beginning of the game, the player must select the game mode (simulated or DAQ) and enter it's personal name. Moreover, the user adjusts the number of tries (shots) and the amount of noise (difficulty). Afterwards, the game starts by pressing the digital control "Start". The user now has a predified number of shots to finish the game. However, each time the player shoots, the amount of noise to the laser spot is automatically increased. Therefore, as the shooting progresses, the game becomes more difficult to play. When the predefined number of shots has been reached, the virtual instrument automatically calculates the standard deviation and the geometric mean. The standard deviation is then used as a diameter of a circle which is drawn around the geometrical center of the shots. At the end, the results for the particular player are presented numerically (in a table) and graphically by exporting the target screenshot in Microsoft Word format. The game continues by entering the personal details of the second player and repeating the described procedure all over again.

In order the game to fulfill the didactic goals, it is essential to have more players. The more players are involved, the probability to have more diverse results increases. As the number of results increase, one will eventually obtain samples where the better/worse player accuracy or precision is obvious.

The virtual instrument is realized by using a state-machine programming architecture. The program can be in one of the following five states: *initialize*, *start*, *play*, *end* and *presentation*. In the *initialize* state, the virtual instrument performs reinitializations of all controls and indicators to their default values and immediately enters the *start* state. Now the program wait for player scenario selection.

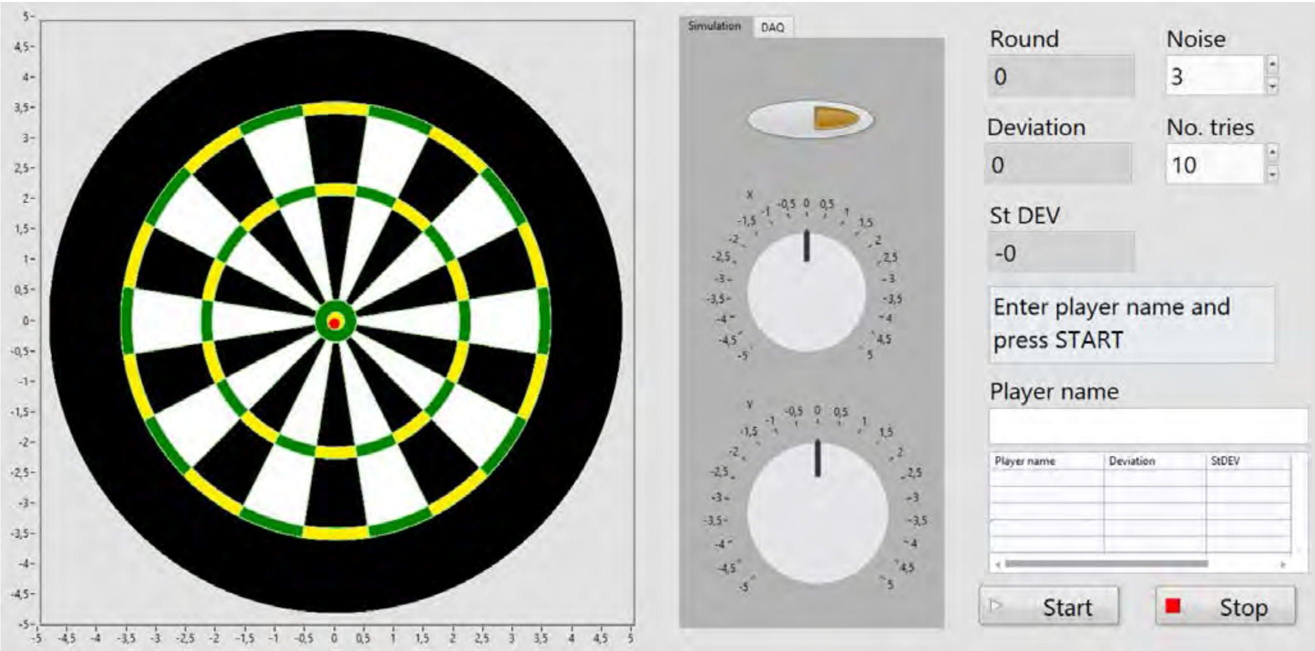

Fig. 3. Front panel of the virtual instrument used for implementing a game-based scenario for accuracy vs precision

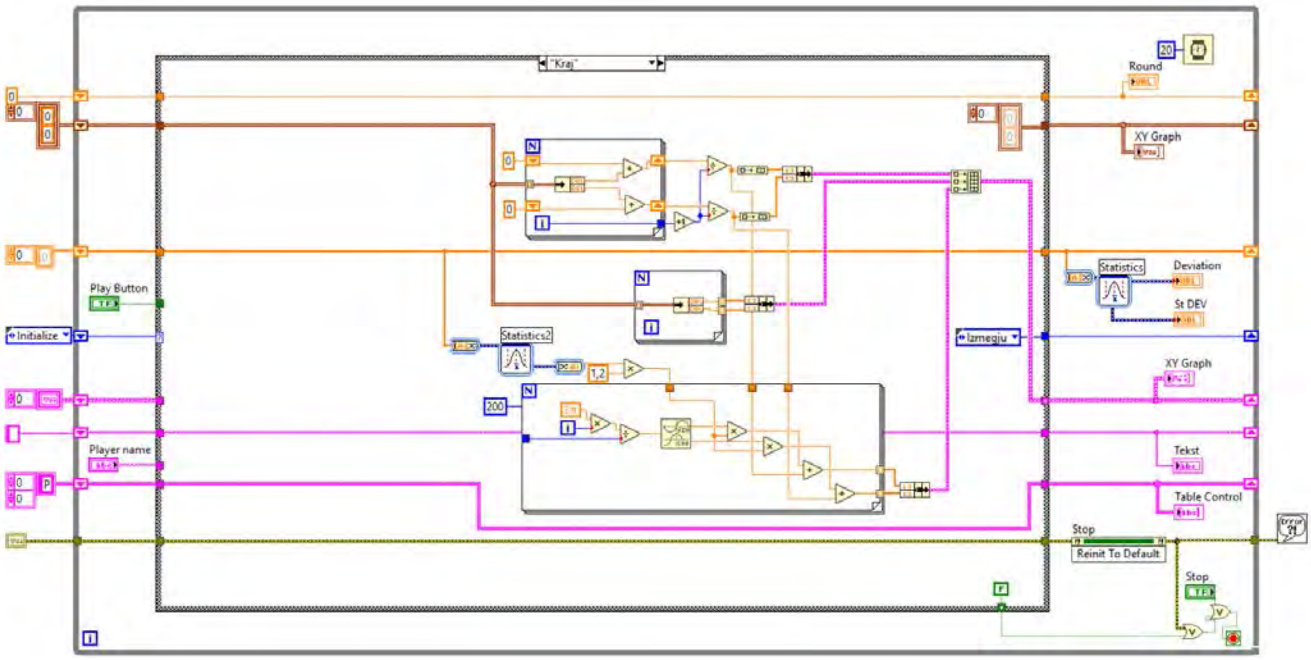

Fig. 4. Block diagram of the virtual instrument (End state)

The user must define the following parameters: game mode (simulation or DAQ), number of tries, noise amplitude and enter personal name. When all data has being defined, the program enters the “Play” state by pressing the *Start* button. Now the virtual instrument initializes the DAQ card channels (in case of DAQ mode) and continually reads the horizontal and vertical controls. In the meantime, the program stores and counts each player shot until the predefined number of tries has being reached. Then, the program enters the *End* state given in Fig. 4. In the *end* state, the program calculates the mean and the standard deviation of the shots and plots all results on the target. Besides each particular shot, the program draws circle whose center is defined by the geometrical mean of the samples, whereas the diameter is defined by the samples standard deviation. The results are simultaneously represented graphically and numerically. Moreover, the target is automatically exported in Word format in the *presentataion* state. Finally, the program is restarted to the *initialize* state and all steps are repeated with the next player. Each player can stop the program at any time by pressing the *Stop* button.

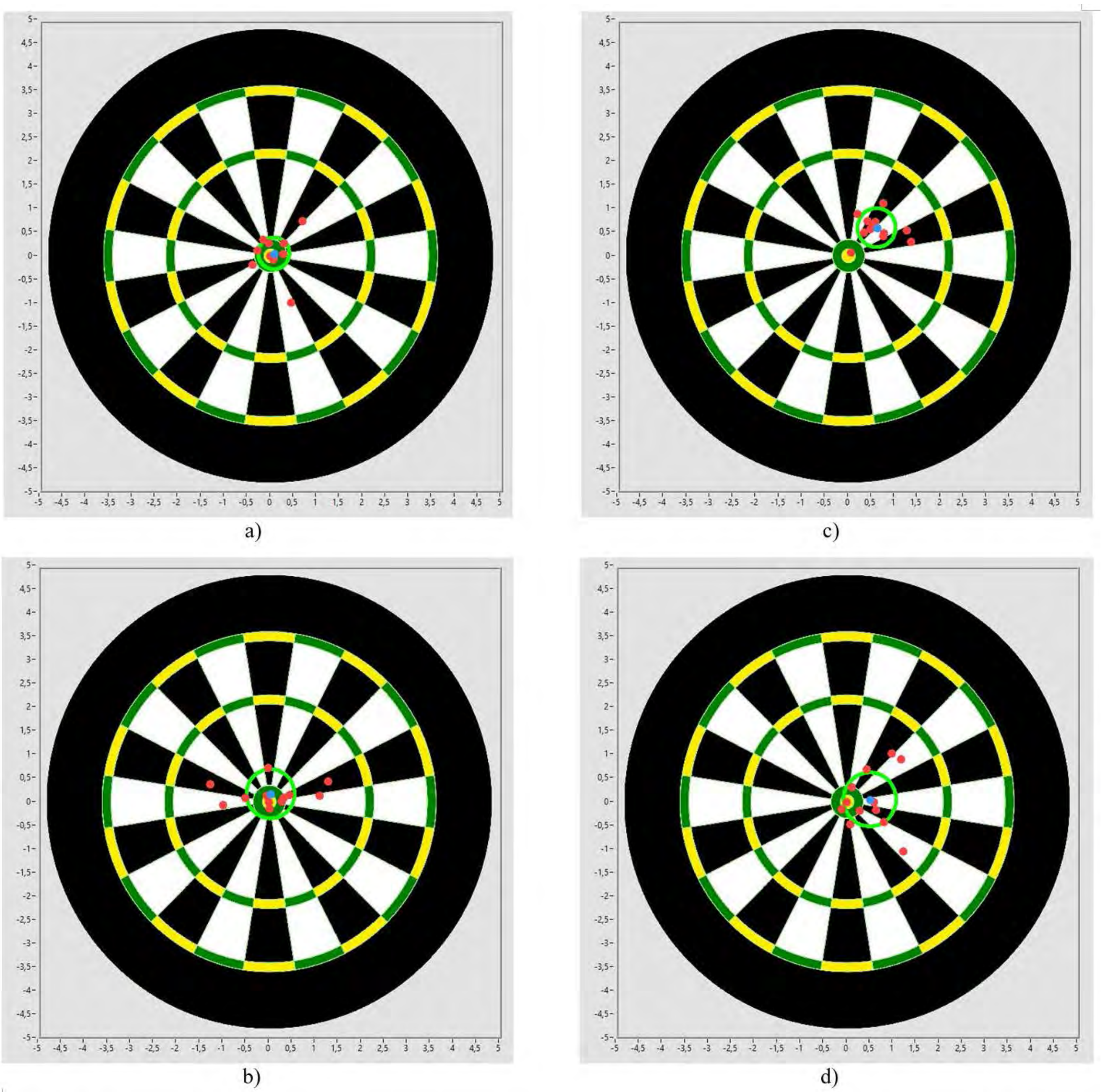

Fig. 5. Experimental results a) Good accuracy and precision, b) Good accuracy bad precision, c) Good precision bad accuracy, d) Bad accuracy and bad precision

IV. EXPERIMENTAL RESULTS AND DISCUSSION

The game-based approach proposed in this paper was implemented in the regular teaching activities of the course Electrical Measurements at the Faculty of Electrical Engineering and Information Technologies in Skopje. Ten students took part in the game experiment and interpretation of the results. Four of the results, given in Fig.5, that best explain the accuracy and precision concept were selected. The Table I summarizes the calculated standard deviation and absolute error of the selected games. The higher is the absolute error, the worse the accuracy is. Similarly, higher standard deviation suggests worsen precision.

TABLE I
EXPERIMENTAL RESULTS REGARDING ACCURACY AND PRECISION

Player name	Absolute error	Standard deviation
Player a)	0,281	0,326
Player b)	0,294	0,433
Player c)	0,868	0,344
Player d)	0,659	0,474

The analyses of the results reported in Fig.5 and in Table I suggests that players a) and b) were more accurate comparing to the players c) and d). This can be confirmed in two ways: graphically (from observing the results given in Fig.5), and numerically from Table I. It can be clearly seen that the geometrical mean (blue dot) for players a) and b) is closer to the target center. Consequently, the absolute errors of the shots for the players a) and b) are lower than those of the players c) and d). On the other hand, it is obvious that the diameter of the circles and the standard deviations for the players a) and c) is lower comparing to the players b) and d). This suggests that players a) and c) have better precision.

V. Conclusion

The goal of this paper is to describe a game-based method for teaching the difference between accuracy and precision. The game was realized in LabVIEW and was implemented in the regular teaching process of the course Electrical Measurements. The initial experience shows that the students gladly accept such teaching approach which in turn positively affects the quality of learning. Ten students took part in the game experiment and selected results were presented. It was shown that the accuracy is reffered to the distance of the mean from the center of the target, i.e the absolute error. On the other hand, the precision is reffered to the dispersion of the samples, i.e the standard deviation.

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