Application of Fuzzy Logic for Creating a GameFlow Quantification Model

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***Abstract*—Digital games move a huge market today, motivated by an audience with new forms of entertainment and fun. Multiplayer games receive even more prominence, since they promote not only competitiveness, but also interaction between players. Games that provide a profitable and fun experience, make the players enter a state of immersion that is explained by the theory of Flow. This work had as main objective, the development of a model of quantification of Flow, in the scenario of digital games, through the vision of a player, using the GameFlow model as a base. The results showed that, in general games, considered fun have GameFlow values above 50, while not-fun games have values less than 50, on a scale from 0 to 100. They still present patterns when analyzing several matches of the same player, making a direct relation with the Flow diagram.**

Keywords—Flow Theory, GameFlow, Fuzzy Logic

I. INTRODUCTION

Multiplayer games receive millions of users every day, whether for competitive games, for fun, or for missions with friends. As one of the best-known genres today, there is the Multiplayer Online Battle Arena (MOBA). According to [11], the objective of the MOBA is based on two teams trying to destroy the opponent's base; as an example, there is the game League of Legends (LOL). For this to happen in the best possible way, it is necessary for developers to pay attention to certain aspects that will impact the user's engagement and entertainment with their game. [10] if players do not enjoy the game, they simply will not continue playing the same game. An example of these aspects is the use of Flow theory. A player - when participating in games that can be considered enjoyable, fun, or that simply makes him happy - tends to increase his engagement and performance, both during the match and in the game itself. This causes the person to be in a state of immersion, as explained by the Flow theory, developed by Csikszentmihalyi (1990). [4], during Flow, attention is freely invested to achieve a person's goals, because there is no disorder to be strengthened or threat of defense. Therefore, when the player is in this state of Flow, he is placing all his attention and focus on the tasks and objectives to be accomplished during the game. Seeking to use the concepts of Flow theory to evaluate games and their mechanics, the GameFlow model [10] was developed. Given this context, the aim of this work was to develop a GameFlow quantification model for matches in the chosen scenario: the LOL. Using variables and characteristics of the game, in addition to the opinion of players of the game through an online questionnaire, an Artificial Intelligence technique called Fuzzy logic was used, which allowed the model to return a numerical value to the GameFlow variable.

II. BACKGROUND

A. Flow Theory

In 1990, Mihaly Csikszentmihalyi launched the book "Flow - The Psychology of optimal experience". The work presents the theory of Flow. Its main objective is to examine the process of attaining happiness by controlling your inner life. Flow theory can be used in any medium, whenever the goal is to improve quality of life, Flow theory can show the way [4]. In his book, Mihaly also presents an explanation for pleasure and enjoyment. Pleasure refers to the feeling of satisfaction with biological and social issues. But pleasure does not bring happiness alone due to the fact that it does not produce psychological growth, however, it helps to maintain order. Enjoyment is characterized by a sense of novelty, of accomplishment, of moments that bring personal growth, that is moments that, for the individual to remember, he/she wants to repeat. Playing a game in which, the skills of the players are close and the match is disputed, and in the end, the player feels that his gameplay has improved, is an example of enjoyment. Based on the author's studies, enjoyment can be presented with eight Flow components, where activities that present at least one of these components are considered Flow activities. Through this study, it was possible to develop the diagram shown in Fig. 1.

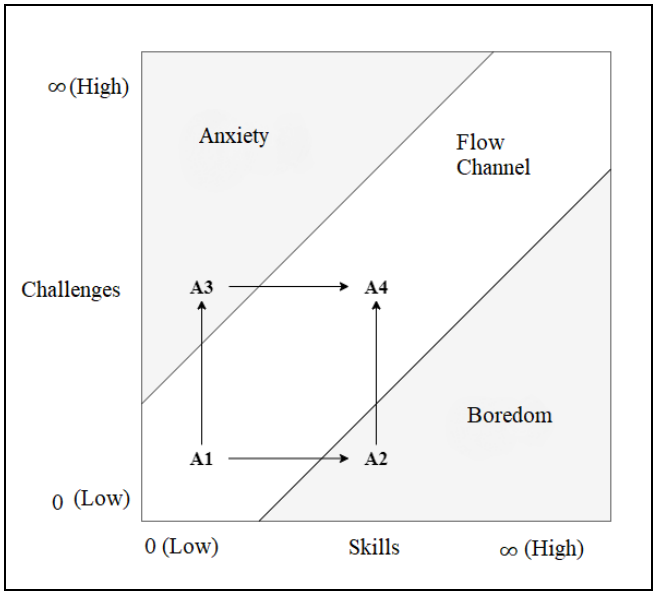

Fig. 1. Mihaly Csikszentmihalyi diagram.

The diagram presents a graph in which the horizontal axis shows the person's skills, from low to high, and the vertical axis the challenges, also from low to high. The starting point (A1), represents a person in the initial stage of an activity, in

which his skills match up to his challenges, that is: the person is entertaining himself in the activity and remaining in the state of Flow. When performing the activity multiple times, increasing the ability to perform the task, the person tends to go to the point (A2). With repetitive activity and no real challenges, it will result in boredom and consequently, the person leaves the state of Flow. On the other hand, if your challenges grow, while the ability to perform the task does not keep up with the growth, the person will fall to (A3), becoming anxious (Anxiety), as their goals are very difficult to be met. However, when facing the point (A2) or (A3), the person will probably look for new challenges or ways to improve their ability, respectively. Thus, being able to return to the state of Flow at the point (A4), where again your skill level will match the challenges encountered.

B. *GameFlow*

Penelope Sweetser and Peta Wyeth, motivated by the lack of an accepted model of enjoyment for players in games, developed in 2005 the GameFlow model. Even with a series of game feature analysis heuristics, it is necessary to integrate these heuristics into a validated model that can be used to design, evaluate, and understand the pleasure in games [10]. The authors also state that the player's enjoyment is the most important goal of computer games. Built based on the concepts of Flow theory, GameFlow features eight components adapted for games, namely: concentration, challenges, player skill, control, clear tasks, feedback, immersion, and social interaction. For each of the eight elements of GameFlow, there are several analysis criteria. Each criterion receives a score from 0 to 5, which assigns an average to each element and then an overall assessment for a given game.

C. *Fuzzy Logic*

Fuzzy logic was proposed by Lofti Zadeh, in 1965, through the article Fuzzy Sets. According to [2], in Fuzzy logic a premise can be partially true or partially false, that is, it can present values that vary between 0 and 1. [1] explain that within the context of fuzzy logic, there is a called membership function, which is a mathematical mapping of each possible numerical value for linguistic variables. The membership value in a Fuzzy chart usually varies between any value between 0 and 1. Linguistic variables, usually called Fuzzy variables, are linguistic representations of a variable with an imprecise value, such as temperature, cold and hot, or happiness. The Fuzzy logical system can be divided into three basic operations, as shown in Fig. 2, adapted from [3].

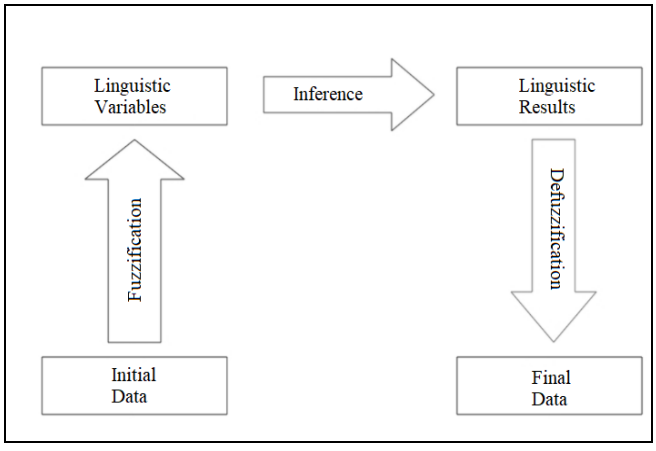

Fig. 2. Fuzzy logic system.

The first operation, fuzzification, aims to receive the input data and generate linguistic variables, taking into account all data of imprecision and uncertainty. In this stage, the membership functions for linguistic variables are also generated, based on a degree of membership [8]. The inference stage relates the variables to each other, through pre-established rules [5]. This stage can be divided into two components: aggregation and composition. The aggregation validates a rule based on the "If" portion, while the composition defines the result after inference using the "Then" portion. [3], the final stage of the Fuzzy logical system called defuzzification has the purpose of converting the Fuzzy values resulting from the inference process, into numerical values. [2] defines defuzzification as the transformation of a variable in the Fuzzy set into a variable in the discrete set.

III. DEVELOPMENT

The study and development of the model started with the construction of an online questionnaire in which the participants, players of LOL, helped in the definition of values and construction of the Fuzzy system. Fig. 3 presents an overview of the steps taken to develop the model.

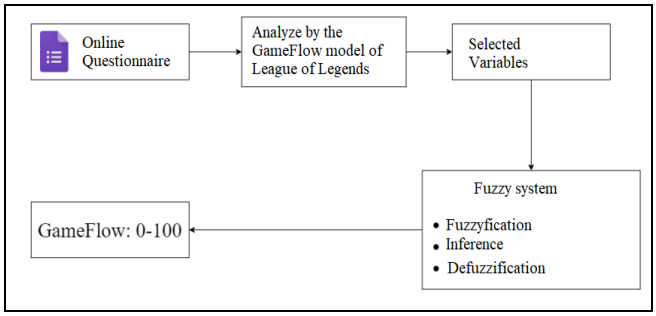

Fig. 3. Project overview.

A. *Online Questionnaire*

The questionnaire was divided into six stages where the first two were just terms of consent and participation, the third and fourth sought to better understand the public, while the final two were the main objective of the research, seeking to resolve two main questions, namely:

1. In the view of players, is the game League of Legends in GameFlow?
2. In the view of players, which characteristics and/or variables present in League of Legends are more promoters of GameFlow?

The online questionnaire was attended by 40 players. Based on the answers acquired by the questionnaire, it was possible to make an assessment of League of Legends using the GameFlow model, assigning an evaluation value for the game of approximately 78.4%. The five variables with the greatest impact on the GameFlow value were also selected, which will later serve as input variables for the Fuzzy system, namely: champion selection, kills, team composition, dragons kills, and barons kills.

B. *Fuzzy Controller*

For the development of the Fuzzy system, a Fuzzy controller was used as shown in Fig. 4, adapted from [8]. The variables obtained by the questionnaire were transformed into linguistic variables by the fuzzifier, creating their pertinence functions and consequently their graphics. A public dataset with a series of matches was used to obtain delimiting values

for the pertinence functions of the kills, dragons kills and barons kills variables.

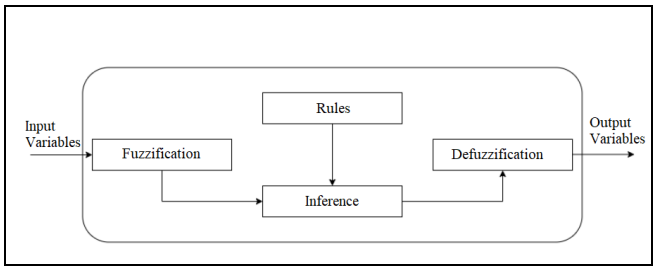

Fig. 4. Fuzzy Controller.

For the pertinence functions of the champion selection and team composition variables, a counters table approach was used. The term counter is usually assigned to a situation in which one character is better than another, regardless of the reason (skills, statistics, etc.). Based on this, a table of counters was developed, which presents the values of the historical percentage of victory among all the existing characters. Table 1 shows the sets and delimiters for the GameFlow variable.

TABLE I. GAMEFLOW VARIABLE SETS AND DELIMITERS

Fuzzy Sets	Delimiters
Low	[0, 0, 25, 50]
Average	[25, 50, 75]
High	[50, 75, 100, 100]

The creation of the rules for the inference step of the Fuzzy controller initially occurred with the construction of a decision tree. For the construction of the tree, the order of impact of the variables was used, according to the player's view, obtained as a result of the online questionnaire. Each "leaf", or final node, of the complete tree, means a possible rule, with a total of 108 leaves or rules. After that, the tree was "pruned", that is, redundant leaves were removed. As a result, the number of rules was from 108 to just 16, as seen in the Fig. 6. Its results were shown in 5 rules for when GameFlow is Low or High and another 6 for when GameFlow is Average. Finally, the defuzzification step operates for returning the final GameFlow value as a numeric value. For the defuzzification stage, the center of gravity (centroid) defuzzification method was used.

The implementation of the Fuzzy controller and other scripts were developed with the Python programming language, using the JetBrains Pycharm IDE. The Skfuzzy library in version 0.4.2 was used to build the Fuzzy logic. The algorithm developed for the Fuzzy system takes as parameters the values for the five input variables used and returns the final calculated GameFlow value. Your objective is to calculate the GameFlow value of a specific match in the eyes of a player. Throughout the execution, graphs are generated for all variables, as well as a graph of the result of the execution, as shown in Fig. 5, where a value of approximately 67.22% was returned for an example execution.

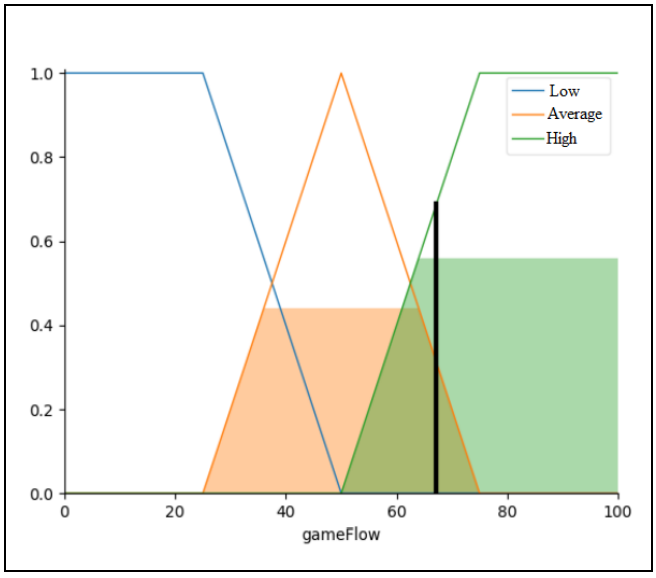

Fig. 5. Result of an execution of the Fuzzy stage.

The testing stage took place using two study approaches. The first was the acquisition of data from the last game of each of the participants in the questionnaire since they were given information on whether they were fun or not. The second stage focused on the analysis of the last ten matches of each participant, being considered, only matches in which they were played on the main map, Summoner's Rift, and that the game mode presents the five main routes.

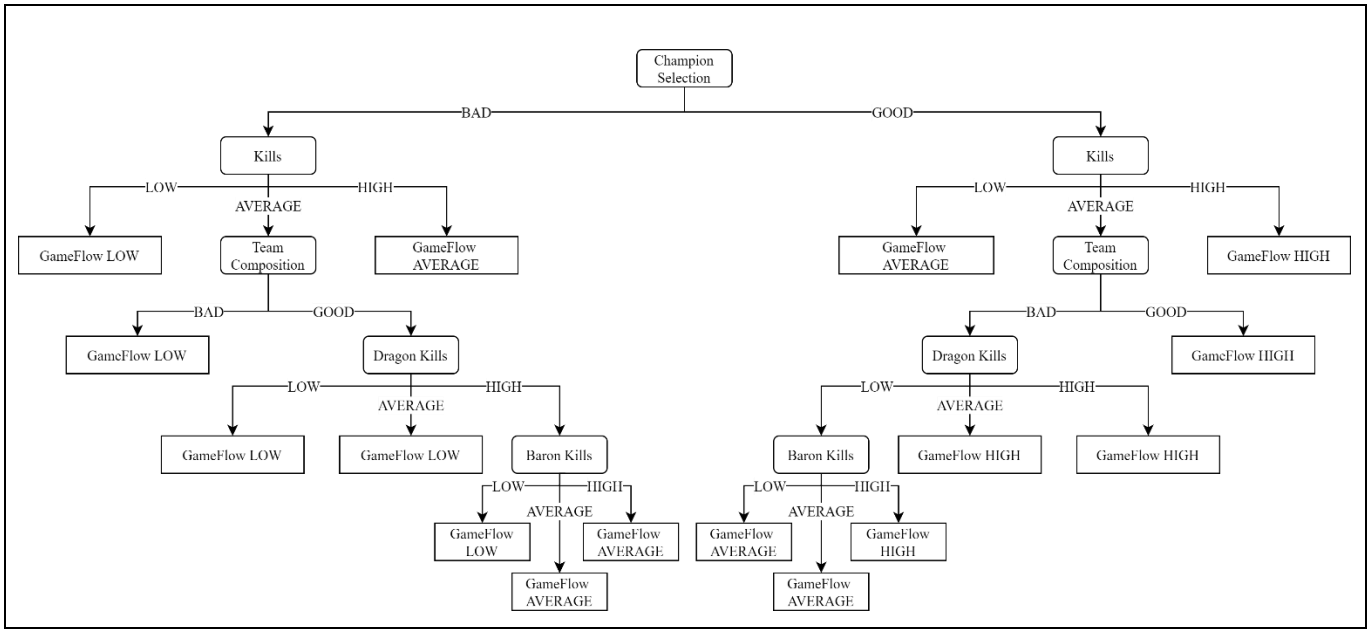

Fig. 6. Pruned decision tree.

IV. Results

The tests performed were possible with the use of data provided by the research participants. The first stage of testing used a specific game by the participants, with the information of whether the game was fun or not. The average GameFlow score obtained for games considered fun is approximately 52.92, while that not fun was 47.76. The graph of the GameFlow variable consists of values between 0 and 100. Based on this, the results still show that in general, games considered fun, have values higher than the median value of the GameFlow graph. Non-fun matches are generally below the value of 50. However, it is still possible to check items with values nonstandard, this can happen for a number of reasons, the ones that stand out are: something happened in the match that the model doesn't cover, for example, a player has left the match or discussions that spoiled the match, a match is very outdated based on the table of counters or even some relationship of the values with the route selected.

The second stage used the last 10 matches of each participant in the online questionnaire. Of the 40 participants, it was possible to get matches from 26 of them totaling a total of 187 matches, with 12 participants having a complete history of 10 matches, while the others had fewer matches than 10. Based on graphs of GameFlow values generated in this stage, it is possible to notice that the GameFlow values obtained, follow the tendency to vary between smaller and larger values than the median of the GameFlow graph. Fig. 7 shows the graph with average GameFlow values per game of the analyzed players. It is noticed that the average values remain in the middle of the graph, this occurs for moments when some players have a high GameFlow value, others have low values.

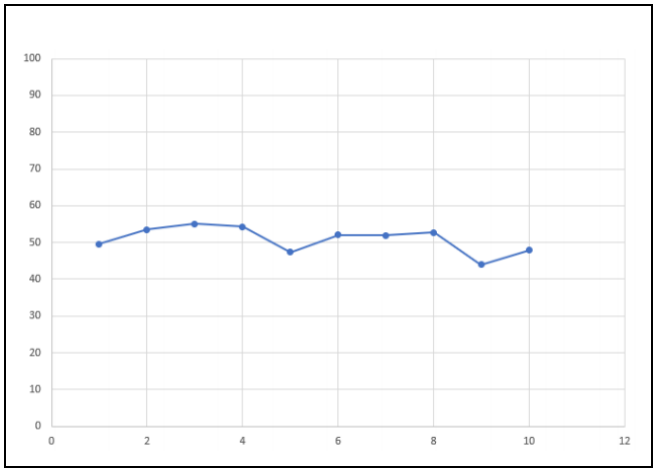

Fig. 7. Average GameFlow graph by number of matches.

V. Conclusion

This work is a starting point for the study and development of a more detailed model that, using the Fuzzy logic technique, allows us to quantify GameFlow values for an analyzed match. Through the analysis of the results obtained, it was possible to verify some promising patterns and results of the model's behavior and, consequently, the enjoyment of the players in a match. It was concluded that the model developed meets the established objective, quantifying numerical values of GameFlow for LOL matches. However, there is still a need for an application in a larger data set, justified by the lack of a dataset with the necessary information for processing. Thus, obtaining a greater amount of results and enabling optimizations in the model. With the development of this work, it was found that there are some themes of study and improvements to the model that can be given as a focus to evolve the model, as it is a very comprehensive theme. An example is the use of this gameflow value in the creation of matchmaking matches.

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