Measuring Aesthetics of Game Behavior

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***Abstract*—The paper intends to address the measurement of a facet of game-events particular beauty. More precisely, we present our approach to measuring desirable game behavior from game history. This work shows metrics developed to fundamental aesthetic aspects of games. We deal with a multiplayer turn-based game model. However, one should assume that this model can accommodate games that are, in fact, not based in turns but arbitrarily segmented at a fixed time interval or the end of a recurrent event. We intend to supply a tool that improves the game design process and would be useful to those who see ludic artifacts as a study object.**

***Keywords*-games; aesthetics; metrics; MDA; games; computational aesthetics**

I. Intro

The aesthetics of games could be seen as a composition of aesthetics like those of player moves, strategies, gameplay, music, graphic arts, narrative and so on. In this work, we address the measurement of a facet of **game-event**'s particular beauty. We focused our efforts on those aesthetics aspects that emerge from gameplay, or from a set of players' moves. More precisely, we attempt to measure desirable game behavior from the game history.

We call game-event that space-time vortex at which the players experience the moods and emotions provided by the usage of a ludic artifact, like the *game-activit* concept in [1]. A game-event is unique. The same game-event will never occur again, even with the same people, at same place, using the same ludic artifact. From here, we indistinctly use the terms game-event and match to refer to the same concept.

The term ludic artifact was used in the previous assertions in the sense as defined by Koster [2]. So, as the artifact from which emerges the players' experience.

We look at the match from the beginning until a moment that is not necessarily its end and, based on measurements from its game history, could conclude about its aesthetics. We differ our subject from those usually seen in chess aesthetic studies, for example, by the length of the analyzed match segment. While chess aesthetics generally focus on analyzing compositions or a limited set of moves, we are interested in the full match. In fact, we attempt to conclude about the infinite set of game-events that can emerge from a single abstract game. To achieve that, we see the observed set of matches as a sample from an infinite population from which we can draw inferences.

We deal with a turn-based game model. Moreover, we assume a turn as a match segment in which all players make their moves, simultaneously or not. At each turn, we apply an evaluation function to determine how close to win players are. This turn-based game model can accommodate games that are, in fact, not based in turns but arbitrarily segmented at a fixed time interval or the end of a recurrent event.

One can't deny that games and art artifacts overlap and combine under different perspectives when approached by distinct communities like game developers, scholars or artists, for instance [3]. Furthermore, one should note that this paper assumes that games are, without any doubt, cultural artifacts [1], [4].

The paper is organized as follow. In the next section, we present some background knowledge about computational aesthetics, and the MDA framework. In the third section, we present our approach to measuring game aesthetics. In the section that follows, we present our conclusions.

II. Background Knowledge

A. Computational Aesthetics

Hoenig [5] defines Computational Aesthetics as "the research of computational methods that can make applicable aesthetic decisions in a similar fashion as humans can". Computational methods, as put in the definition, are prior to computers as stated by Fazi and Fuller [6]. The field of Computational Aesthetics encompasses works with different focus related to aesthetics using computational methods. However this broad view, Hoening detected that the field's scope was biased for works of visual aesthetics, also his particular interest.

That term has been used to address the creation of art objects by computers or computational techniques [6], as well as the aesthetic analysis of art or design artifacts using the same tools [5]. In that realm, models and mathematical formulas define aesthetics criteria that will be the object of analysis or the target for the characteristics of automatically generated artifacts. The art or design objects created using computers as a mean or a tool, even those not automatically generated but crafted by a human, are also classified in the Computer Aesthetics domain by some authors, as in [6]. In this work, we are interested in the former meaning. We should also expand it to embrace other cultural artifacts, like games. Doing so, we comprise more vigorously those aspects undervalued by Hoening when he proposed to "reduce the focus to form, rather than to content" [5].

B. MDA framework

Hunicke at al. [7] proposed, in a seminal paper, that game design can be studied under a framework know as MDA, which stands for Mechanics, Dynamics, and Aesthetic. The main idea of this framework is that designers manipulate game mechanics, i.e., "the particular components of games, at the level of data representation and algorithms" [7], aiming to achieve certain aesthetics, i.e., the "emotional responses evoked in the player, when she interacts with the game system" [7]. The dynamics are the "run-time behavior of the mechanics acting on player inputs and each others' outputs over time" [7]. Therefore, there are two perspectives to the game, one from the side of the designer, and other from the side of the player, as seen in Figure 1.

This work assumes the Aesthetics meaning present in the MDA framework.

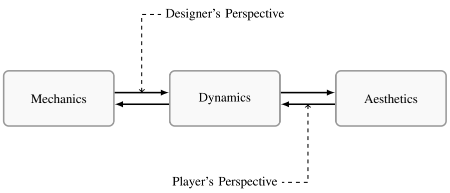

Figure 1. MDA diagram [7]

III. MEASURING GAME AESTHETICS

This work proposes modeling the beauty of game-events, as already stated. Our approach uses game history and an evaluation function to extract information about matches of multiplayer turn-based games. The game history is a representation of the player's campaigns throughout the match similar to that in [8] but expanded to an arbitrary number of players and non-combinatorial games as in [9], [10].

Figure 2 shows the representation of a game history from a match with four turns and three players. The players' positions are on the vertical axis in which the first position is at the top. In that particular match, the winner starts in the second position after the first turn and achieve the leading only after the last one. Also, all players lead at some turn.

We also use an extended version of the original idea of an evaluation function proposed by Shannon [11]. We evaluate the player's campaign at the end of each turn but, rather than try to determine if the current game state leads a

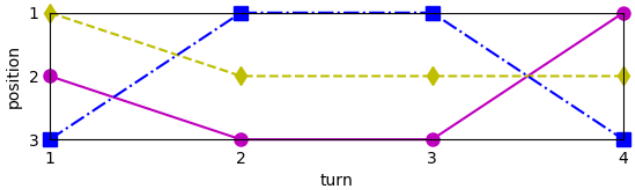

Figure 2. Multiplayer Game History

particular player to win, we compare the players and order their campaigns based on the function's result. Hence, we try, always imperfectly, as stated by Shannon [11], determine how close to winning the players are. Each game needs a proper evaluation function, which could be not unique or easy to define. We often assume that players' scores, if available, are the result of an evaluation function or, at least, a good proxy for it.

We translate the definition of desirable behaviors of a game to mathematical formulations and use it to measure the degree of those behaviors occurrence in a match. The measures of a certain number of matches of the same game compose a sample of an infinite population of all the possible matches of that game.

Many works used mathematical formulas to express and measure aesthetics or aesthetic criteria relations, as stated by Hoening [5]. A small yet beautiful example is the Birkhoff's [12] formulation of the problem, as shown in Equation 1. It states that aesthetic measure (M) is as a relation between order (O) and complexity (C) so "determined by the density of order relations in the aesthetic object" [12].

$$M = \frac{O}{C} \tag{1}$$

Previous works presented a set of game attractiveness criteria modeled to mathematical formulas that can be used to measure aesthetic aspects of a game [8] [13] [14] [15]. In this work, we show those criteria that translate general game aesthetics, regarding the player's cultural context, because they are related to fundamental aspects of games. Thus, the mathematical representation of **drama**, **uncertainty**, and **lead change** are presented.

A. Drama

Drama is a characteristic of a good game as stated by Thompson and exists when remaining "possible for a player to recover from a weaker position and still win the game". The evidence used by him was matches of chess in which one player resigns when the drama ends. Is worth noting that his definition also states that "a player's recovery should not occur in a single killer move".

In order to model this behavior, Xexéo, Mangeli and Oliveira propose a metric based on the distance between the winner campaign and the most dramatic one. So, they introduced the concept of the **Maximum Drama Path (MDP)** in a match and presented it as in Equation 2.

$$MDP(m) = \left\lceil |P| + \frac{(1-|P|)(m-1)}{|M|-1} \right\rceil \quad (2)$$

In this equation, and in those that follow, P is the set of players so $|P|$ is the number of players, M is the match seen as a set of turns m thus $|M|$ is the number of turns.

Equation 2 returns the position for the most dramatic campaign at the turn m for a match with $|M|$ turns and $|P|$ players. Figure 3 shows the MDP for a match with 4 players and 8 turns.

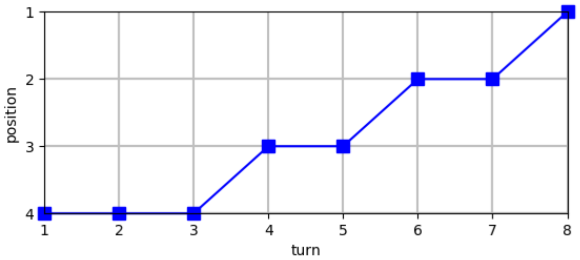

Figure 3. Maximum Drama Path (MDP) for 4 players and 8 turns

The Equation 3 shows the **Drama by Path** metric. It measures the drama in a match. The metric considers the summation of the distances between the winner actual path to the MDP, at the end of each turn, and normalized it in the face of the maximum possible distance. So, if the winner path was the MDP, the result is 1 that represents the maximum degree of drama. The position function $P_f : P \mapsto \{\mathbf{N} - 0\}$ returns the position of a player at the end of a turn. P_w is the winner, so $P_f(P_w, m)$ returns the actual position of the winner at the end of the turn m. The relation outside the parentheses is a penalty factor that decreases the function result if the winner leads the match before its ending.

$$\begin{gathered} Drama\,by\,Path_{mch} = \\ \frac{|\{m|P_f(P_w,m)>1)\}|}{|M|-1} \times \\ \left(1 - \sum_{m=1}^{M} \frac{|P_f(P_w,m) - MDP(m)|}{(|P|-1)(|M|-1)}\right) \end{gathered} \quad (3)$$

B. Uncertainty

Maybe the more fundamental facet of games, the uncertainty was addressed by a pleiad of authors. Shannon [11] stated that if we could determine the outcome of a chess match, this game would lose most of its interest. Cailois, for your turn, noted that play "is also uncertain activity. Doubt must remain until the end, and hinges upon the denouement" [16]. Iida et al. [15] also related games' attractiveness and uncertainty with the assertion: "Interesting games are always uncertain until the last end of games". Salen and Zimmerman recognized that uncertainty is "a key component of meaningful play" [17]. Despite our interest in the uncertainty of the final match outcome, so which player will win it, it is worth noting that uncertainty exists in a game even if it "is a game of skill, not chance" [17]. Malaby [18], in that sense, proposed a classification concerning the sources of "contingency" that was later expanded by Costikyan [19] as a taxonomy of sources of uncertainty in games.

$$\begin{gathered} Uncertainty\ by\ Entropy_{mch} = \\ -\sum_{n=1}^{|M|-1} \sum_{p \in P} \frac{\mathbb{P}(p,m_n)\log_2(\mathbb{P}(p,m_n))}{\log_2(|P|)\cdot(|M|-1)} \end{gathered} \quad (4)$$

The Equation 4 shows **Uncertainty by Entropy**, one of the metrics proposed by Mangeli [10] to evaluate the degree of uncertainty in a match. As in the Equation 3, the function result will be in the range between 0 and 1. In this case, 0 represents the total lack of uncertainty so a match in which the outcome is known at its beginning. On the other hand, if the function results in 1, the final outcome of the game remains uncertain until its end. In order to do the calculations, one must define the function $\mathbb{P}$ that returns the probability of winning for specific player p at the end of the turn m. This function is game dependent so must be specially specified to the subject of the measures.

C. Lead Change

Lead Change is closely related to uncertainty. Abuhamdeh et al. [20] argue that in a match in which the score gap is tight, the uncertainty is higher. Sports are a type of game in which lead changes are frequently observed and appreciated. Clauset et al. [21] when dealing with competitive sports, formally define lead changes as 'the times in a game when the lead changes" that "occurs whenever the score difference X(t) returns to 0" and state that they are "often the most exciting" moments. This criterion is also present in Browne analyses [8]. He assumes the ratio between the number of lead changes and the number of turns in a match as a valid metric for it. One should pay attention to the fact that he was dealing with two-players games.

$$\begin{gathered} Lead\,Change_{mch} = \\ \frac{\sqrt{\frac{|L|-1}{|P|-1}} + \sqrt{\frac{|LChange|}{|M|-1}}}{2} \end{gathered} \quad (5)$$

The Equation 5 presents the metric proposed by [10] for this criterion. As in the previous metrics, the function results in values in the range between 0 and 1. L represents the set of players that lead, so $|L|$ is the number of players that lead the match at the end of, at least, one turn. $LChange$ is the set of turns in which the lead changes, so $|Lchanges|$ is the number of turns in which that change occurs.

D. An overall aesthetic metric

Mangeli [10] combined the exposed metrics into an overall aesthetic metric. His proposed overall metric allegedly fit a generic player model as it addresses fundamental aspects of games as an artifact *per se*. He used the concept of fuzzy sets to combine the resulting output of mathematical formulas like those exposed in this work. As the result of each one of them is in the range $[0, 1]$, they can be understood as pertinence degrees for fuzzy sets representing the games that have those characteristics measured by the equations.

To infer about the aesthetic properties of an individual game, one must analyze the available sample of matches for, from that, draw any conclusion. The output of a set of metrics similar to those in this work has been compared to human assessment of games using this premises and obtained good results predicting the human evaluation [10].

IV. Conclusion

This work aims to present concepts and technics to measure the aesthetic facet of games. We focus on the game-event particular beauty so present mathematical formulations that translate some aesthetic criteria presented by the ludology literature into quantifiable values.

Furthermore, we show our approach to mathematically model aesthetic aspects of games. We believe that this approach could lead to a more assertive and economic game design process.

We also think that improve the quality of the overall metric, in the sense of how close the method result is to human decisions, would be very useful to the game development community.

As future work, we are interested in expanding the presented set of metrics could make use of the shown approach to model other game aesthetic criteria.

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