DL-DDA - Deep Learning bas Dynamic Difficulty Adjustment UX and Gameplay constrain

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Dvir Ben Or
Michael Kolomenkin
Gil Shabat
(Playtika Research)

Abstract

- Dynamic difficulty adjustment (DDA) is a process of automatically c
game difficulty for the optimization of user experience.

- Proposed a method that automatically optimizes user experience.

- Experiments with 200,000 players have shown that the UX of gam
this method is implemented outperforms manual heuristics created
design experts.

Introduction

- DDA is usually applied to each player based on the player's abilities and observed actions.
- There are two major challenges in devising a good DDA method.
  1. A precise formulation of user experience or user engagement.
  2. Interpretability and controllability.
- This study introduces a DDA system that addresses the first issue, a focuses on online games with many simultaneous users.

Key Contributions

- UX Loss Function
  - As opposed to previous methods, this formulation leverages not only the experie
player for whom the difficulty is computed, but also the experience of all other pl
- Completion rate constraint
  - Completion rate is the percentage of players who finish a level or a task. It is of
as an outside input to control the gameplay.
- A real world DDA system
  - DDA system that was tested in an online game with millions of daily users. The s
based on a deep neural network that optimizes the UX loss function mentioned
under the gameplay constraint.

UX Loss Function

Objective

The UX loss function serves as an evaluation metric for optimizing dyna
difficulty adjustment (DDA). It incorporates the following two aspects:

1. Individual Player Experience
2. Fairness Across Players

UX Loss Function

Loss Function Definition

$$\text{UX Loss}(\hat{\mathbf{D}}) = \mathbf{var}(\hat{\mathbf{D}}) + \frac{\alpha}{M}\sum_{i=0}^{M}\left(d_i - \hat{d}_i\right)^2$$

- d_i : Actual difficulty.
- $\hat{d}_i$: Target difficulty to be determined.
- $\hat{\mathbf{D}}$: The set of required difficulties of all players in the cluster of pla
- α : Weight parameter that controls the relative importance of the t components.
- M : The size of the cluster.

Completion rate constraint

Overview

Completion rate is defined as the percentage of players who successfu
complete a task or level in the game. This constraint is used to adjust U
improved gameplay experience.

Completion rate constraint

Problem definition

$$\hat{P} \triangleq \frac{1}{M} \sum_{i=1}^{M} \mathbb{1}[d_i \geq \hat{d}_i] = P$$

where $\mathbb{1}[x]$ is an indicator function:

$$\mathbb{1}[x] := \begin{cases} 1 & \text{if } x \text{ is true} \\ 0 & \text{if } x \text{ is false} \end{cases}$$

- P : The desired completion rate
- P^ : The achieved completion rate, which is the number of play
able to complete the challenge divided by the number of player

System Overview

The proposed system consists of two main stages:

1. **Player Clustering**
   - Players are grouped based on similarity (e.g., past behavior da
   - UX loss optimization is performed within each cluster to ensur experience for similar players.
2. **Iterative Optimization**
   - Alternates between minimizing UX loss and applying the comp constraint until convergence.
   - Each cluster is optimized independently.

Experiment

The goal is to keep the completion rate within 8%-10%.

1. **Tested Feature**
   - The experiment was conducted on an **8-day mini-game** feature within an online g
   - The difficulty was controlled by adjusting the points each player needed to achieve
2. **A/B Testing**
   - **Control Group (Rule-Based System)**:
     - Approximately **800,000 players**.
     - Used manually adjusted difficulty settings based on years of trial-and-error e
   - **Test Group (Proposed Method)**:
     - Approximately **200,000 players**.
     - Used a neural network-based dynamic difficulty adjustment system.
3. **System Configuration**
   - Players were divided into **200 clusters** based on similarity (e.g., behavioral data).
   - Each cluster contained at least **5,000 players**, and the optimization was performe
     for each cluster.

Result

Completion rate

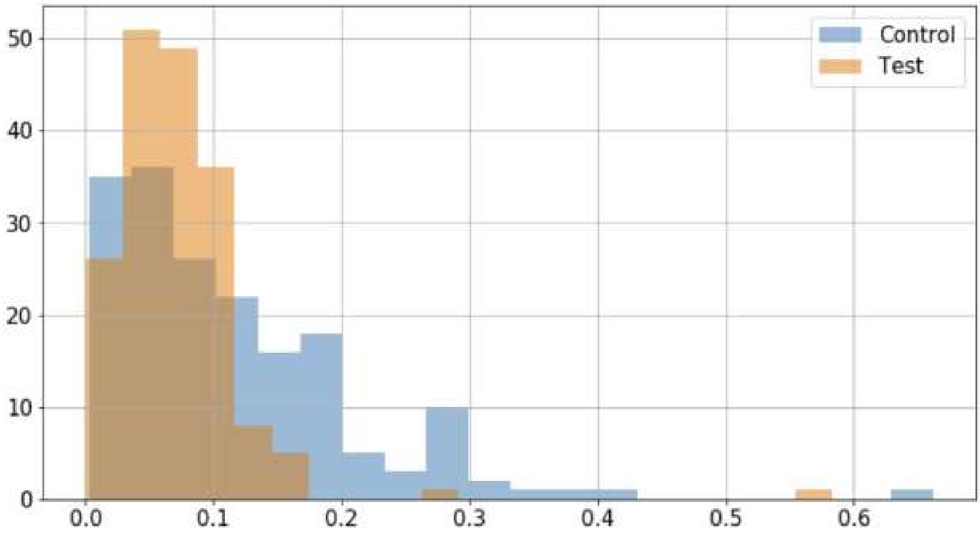

Fig. 2. A histogram of completion rate by clusters. X-axis is the completion rate, Y-axis is the number of clusters that achieved the completion rate. Blue is the control group - rule based method, orange is the test group - our system.

Target	Rule based
8-10%	12.0%

TABLE I

Result

- The proposed method achieved an average completion rate of 8.7 within the target range.
- The distribution of completion rates across clusters was significant consistent in the test group.
- In the control group, 49 clusters had a completion rate above 16%, only 5 clusters exceeded this threshold in the test group.

Conclusion

- The proposed DDA (Dynamic Difficulty Adjustment) system offers a approach to efficiently and accurately automate game difficulty adju
- Key features of the system:
  - UX Loss Function
  - Completion Rate Constraint
  - Scalability and Flexibility
- Proposed method outperformed rule-based approaches, achieving completion rates more accurately and reducing variance within pla clusters.