

MOBA-Slice: A Time Slice Based Evaluation Framework of Relative Advantage between Teams in MOBA Games

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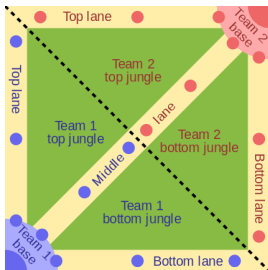
- Apply MOBA-Slice to DotA2
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Background Information

- Multiplayer Online Battle Arena (MOBA)
- Defense of the Ancients 2 (DotA2)
- Hard to evaluate real-time game situation
- Evaluation is needed in strategy analysis, AI developing ...



(a) A Typical MOBA Map



(b) DotA 2 Mini Map

Figure 1: Maps

Our Contribution

- We introduce *MOBA-Slice*, a time slice based evaluation framework of relative advantage between teams in MOBA games.
 - MOBA Game Result (MGR) Analysis
 - Describe deciding factors of MOBA game result.
 - Discounted Evaluation
 - Evaluate current state with future result.
 - Time Slice Evaluation (TSE) Model
 - Map time slices to evaluation value.
- We apply *MOBA-Slice* to *DotA2* and prove the effectiveness of *MOBA-Slice* with experiments.
 - Embody *MOBA-Slice* on a typical MOBA game, *DotA2*.
 - Process a dataset of a large number of *DotA2* match replays.
 - Prove that the model can evaluate time slices of arbitrary *DotA2* matches.
 - *MOBA-Slice* has an accuracy 3.7% higher than *DotA Plus Assistant* in predicting the game result.

MOBA Game Result (MGR) Analysis

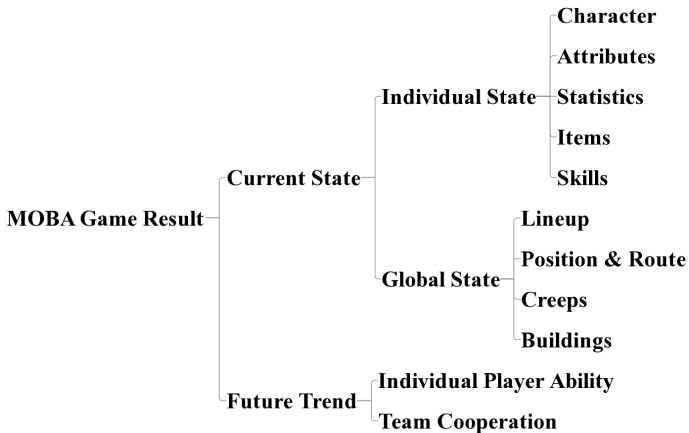


Figure 2: MGR Analysis

Definition of Discounted Evaluation Function

Definition 1

The function of discounted evaluation DE for a time slice TS is defined as:

$$DE_{TS}(R, t) = \frac{1}{\ln(1+r)^t} \times R = \frac{R}{\alpha t} \quad (1)$$

where r is the discount rate, $\alpha = \ln(1+r)$, t is the remaining time of the game, and

$$R = \begin{cases} 1, & \text{when Team A wins} \\ -1, & \text{when Team B wins} \end{cases} \quad (2)$$

Details about the Definition

- Inspired by Q learning
 - Discount factor γ : difference in importance between future rewards and immediate rewards.
 - Current value of a reward R_a after time t : $\gamma^t R_a$.
 - $\gamma = \frac{1}{1+r}$, where $r =$ discount rate.
- Use logarithmic form to simplify exponent operation.
- Properties of $DE_{TS}(R, t) = \frac{1}{\ln(1+r)^t} \times R = \frac{R}{\alpha t}$
 - ① The sign of its value represents the final result, positive for A's victory, negative for B's.
 - ② Its absolute value is inversely proportional to t .
 - ③ The value approximately represents the advantage team A has in comparison to team B.

Overview of Time Slice Evaluation (TSE) Model

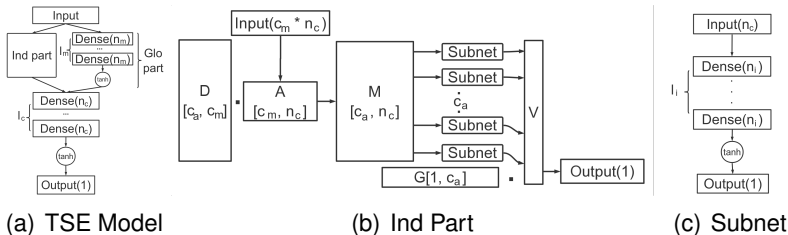


Figure 3: Model Structure

- Input: time slice
- Output: value of DE_{TS}
- 2 Parts: Individual(Ind), Global(Glo)
- Future trend in MGR analysis not implemented yet.

Individual Part of TSE Model

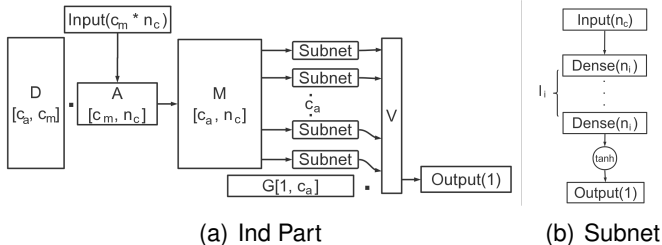
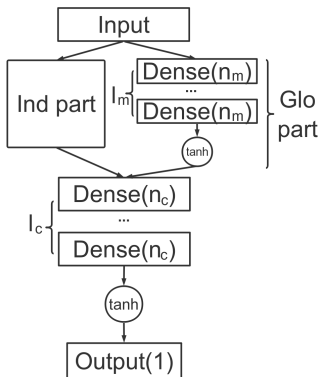


Figure 4: Structure of Ind Part

Individual(Ind) Part

- One subnet for each character to calculate its contribution separately
- Correspond to the individual state in MGR analysis
- Learn the unique features of each character, including design, strengths, and weaknesses.

Global Part of TSE Model



Global(Glo) Part

- Calculate the contribution of all the characters in a match
- Correspond to the global state in MGR analysis
- Learn the potential relationship of addition or restriction for a certain combination of characters

Figure 5: TSE Model

Output of TSE Model

- For better distribution, change output into

$$y = \frac{1}{DE_{TS}(R, t)} = \frac{\alpha t}{R} \quad (3)$$

- Transform to correspond to the range of tanh function

$$y_{scaled} = -1 + 2 \times \frac{y - y_{min}}{y_{max} - y_{min}} \in [-1, 1] \quad (4)$$

- Transform prediction back

$$\hat{y}_{rescaled} = y_{min} + \frac{\hat{y} + 1}{2} \times (y_{max} - y_{min}) \quad (5)$$

- Extract prediction of t and R as

$$\hat{t} = |\hat{y}_{rescaled}| / \alpha \quad (6)$$

$$\hat{R} = \text{sign}(\hat{y}_{rescaled}) \quad (7)$$

Metrics of TSE Model

- Mean absolute error (MAE) (also the loss function)
- Mean squared error (MSE)
- Rescaled MAE

$$MAE_{rescaled}(\hat{y}, y_{scaled}) = MAE(\hat{y}, y_{scaled}) \times \frac{y_{max} - y_{min}}{2} \quad (8)$$

Lemma 2

$$|\hat{y}_{rescaled} - y| \geq \alpha |\hat{t} - t| \quad (9)$$

Theorem 3

$$MAE_{rescaled}(\hat{y}, y_{scaled}) \geq \alpha MAE(\hat{t}, t) \quad (10)$$

The value of $MAE_{rescaled}(\hat{y}, y_{scaled})/\alpha$ can be viewed in units of time to reveal the mean error of prediction.

Apply MOBA-Slice to DotA2

- DotA2 replay file
- Replay parser from OpenDota project
- *Interval* messages
- Selected information for time slices
 - Character - hero id
 - Attributes: life state, gold, experience, coordinate(x, y)
 - Statistics:
 - deaths, kills, last hit, denials, assists
 - stacked creeps, stacked camps, killed towers, killed roshans
 - placed observer, placed sentry, rune pickup, team-fight participation
 - Items: 244 types

Data Collection and Parsing

- Steam API – get the list of all matches of professional game leagues¹.
- OpenDota API – get detailed information of matches including the URL of its replay file on Valve's servers.
- OpenDota's parser – generate *interval* messages from replay files
- 105,915 matches of professional leagues, over 3 TB.

¹Data processing took place in Oct. 2017

Data Generating

- Time slice vectors
 - Created every 60 seconds of game time
 - $263(\text{each}) \times 10(\text{heroes}) + 1(\text{game time}) = 2,631$ dimensions
- Value of DE_{TS}
- 2,802,329 time slices generated from 71,355 matches²

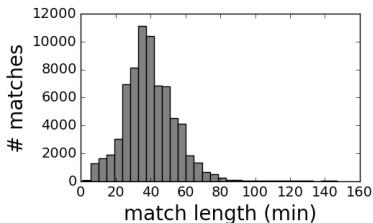


Figure 6: Distribution of Match Length

²Invalid data dropped due to game version issues, file corruption or known limitation of the parser

Setup for First Training

- Only use time slices from the last 50% time in each match³
- Begin with training and testing partially.
 - Ind part
 - Glo part
 - Whole TSE model
- Regard TSE model as a multi-output model to avoid training different parts unequally.
- Loss function

$$loss = MAE(y, \hat{y}) + \mu \times MAE(y, \hat{y}_{Ind}) + \nu \times MAE(y, \hat{y}_{Glo}) \quad (11)$$

- First 90% for training, 5% for validation, and 5% for testing, later 10-fold cross validation.

³In later experiments whole matches and other range of game time are used

Hyper-parameters and Metrics

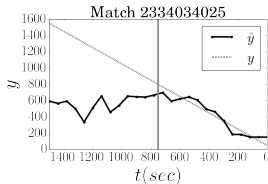
Table 1: Hyper-parameters of TSE model

name	r	c_m	c_a	n_c	l_j	n_j	r_d
value	$e - 1$	10	114	263	3	40	0.5
name	n_m	l_m	n_c	l_c	μ	ν	
value	400	4	4	3	0.3	0.3	

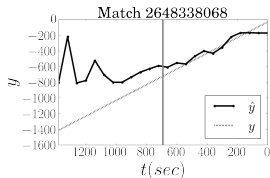
Table 2: Metrics of TSE Model

	<i>MAE</i>	<i>MSE</i>	Rescaled <i>MAE</i> (minutes)
Blind prediction	0.5178	0.3683	37.91
Ind part	0.1523	0.0339	11.15
Glo part	0.1072	0.0290	7.85
TSE model	0.1050	0.0287	7.69
TSE model (10-fold cross validation)	0.10539	0.02794	7.716

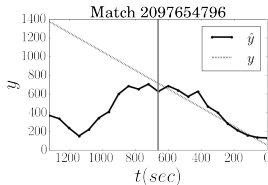
Performance on Sample Matches



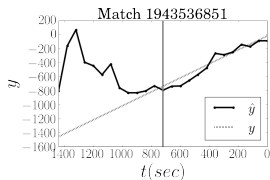
(a)



(b)



(c)



(d)

- Previous: random shuffled time slices
- Simulate working on ongoing matches
- Successfully fit y in the last half of matches (right side of the vertical line)

Figure 7: Performance on Sample Matches

DotA Plus

- Unveiled in an update of DotA2 on March 12, 2018
- Plus Assistant provides a real-time win probability graph
- Praised as the "Big Teacher" by Chinese players due to its accurate prediction

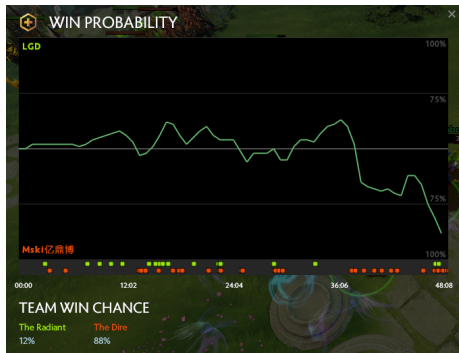


Figure 8: Win Probability Graph of DotA Plus Assistant

Compare DotA Plus Assistant with MOBA-Slice

- Tournament of DotA2 Asian Championship, March 29th - April 7th
- 72 matches valid, downloaded and manually capture winning probability graph
- Feed matches to trained TSE model to get output
- Sample prediction and compare with real result to calculate the accuracy at specific game percentage

Table 3: Discretization of outputs

Result	DotA Plus Assistant	MOBA-Slice
Radiant's victory	Above the middle line	Positive value
Dire's victory	Below the middle line	Negative value
Unknown	At the middle line	Zero

Result of Comparison

- The average accuracy of MOBA-Slice is **3.7% higher** than DotA Plus Assistant at predicting the game result.

Table 4: Prediction Accuracy of MOBA-Slice and DotA Plus Assistant

Game time percent	10%	20%	30%	40%	
DotA Plus Assistant	0.4167	0.5139	0.5972	0.6111	
MOBA-Slice	0.5694	0.5417	0.6111	0.7083	
	50%	60%	70%	80%	90%
	0.6806	0.7500	0.7778	0.8472	0.9444
	0.7083	0.7222	0.8056	0.8611	0.9444
					0.7191

The Disparity of Instability in Different Parts of Matches

- Train Glo part with data of every 10 percent of game time.
- Loss decreases as a match goes on, indicating the decline of instability.

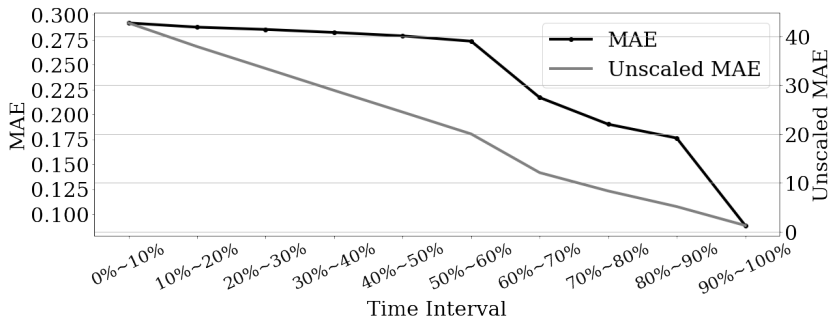


Figure 9: Experiments on Different Intervals

Find a Proper Range of Training Data

- Experiments on larger intervals.
- Loss decreases as the game progresses.
- As time interval gets larger, the model learns from more time slices but the loss keeps growing.

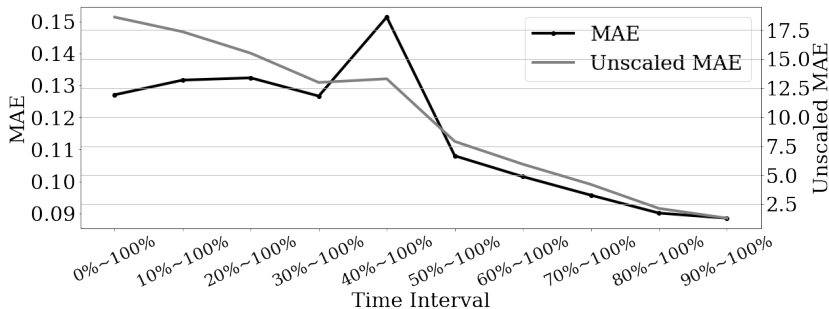


Figure 10: Experiments on Larger Intervals

Conclusion

- MOBA-Slice - a well-designed framework evaluating relative advantage between teams
 - MGR analysis
 - Discounted evaluation
 - TSE model
- MOBA-Slice on DotA2: effectiveness, better at result prediction than DotA Plus Assistant
- Foundation for further MOBA related research which requires evaluation methods

Future Work

- Include the part of future trend in MGR analysis into TSE model, design rating algorithm for players and teams.
- Apply and test MOBA-Slice on more MOBA games.
- Improve TSE model to sequential prediction model.

Thanks

Thanks for your attention!