

Finding Comfortable Settings of Mafia Game using Game Refinement Measurement

SHUO XIONG^{1,a)} XINTING MAO^{1,b)} WENLIN LI^{2,c)} HIROYUKI IIDA^{1,d)}

Abstract: This paper explores the game sophistication of a popular party game called *Mafia* or *Werewolf*. It focuses on the playing settings, i.e., the number of total players (say N) including citizen, mafia (m), sheriff (s) and doctor (d), denoted as $MFG(N, m, d, s)$. Computer simulations for a simple version of Mafia game are conducted to obtain the data while game refinement measure is employed for the assessment. The results indicate several interesting observations. For example, the measure of game refinement would reduce as the number of players increases. This may imply that Mafia game would become boring as the number of players becomes too many. $MFG(N, m, s, d)$ can be played reasonably with $N \in \{14, 15, 16\}$, $m \in \{5, 6\}$, $s = 1$ and $d \in \{1, 2\}$. In particular, $MFG(15, 5, 1, 1)$ or $MFG(15, 6, 1, 2)$ is the best under the assumption that its game refinement measure is within the sophisticated zone. Moreover, the level of players affects the game balancing and game sophistication. For example, mafia would dominate citizens if all players are weak, which implies that the game sophistication would be reduced.

Keywords: Game refinement theory, Mafia game, Game theory

1. Introduction

Mafia game, also called Werewolf, is a popular party game which can be played face to face or on the Internet. In a typical version, two groups of players – Mafia and citizens, act in several rounds. Each round has a certain progress, and the game comes to an end when one group kills out all the members of the other. As a popular multi-player game, Mafia game is a good research target because the balance of the game can be easily affected by different settings [10]. For example, it is interesting to know the optimal number of players in a specific multi-player game to maintain the attractiveness [13].

To our best knowledge, few investigations have been made in the aspect of comfortable settings of Mafia game. In order to tackle this challenge, computer simulations are performed to obtain the statistical data such as the average number of players killed and game length, whereas game refinement measure is employed for the assessment. As a benchmark in this study, we have chosen a simplest version of Mafia game, in which there are only two groups named mafia and citizens, with sheriffs and doctors in the group of citizens, but without any special characters and additional rules. A Mafia game setting can be represented as described in Notation 1.

The structure of this paper is as follows. Section 2 presents the rules of Mafia game. Section 3 shows literature review. Section 4 introduces our assessment methodology. Section 5 shows

our computer simulations and its results. Finally, concluding remarks are given in Section 6.

Notation 1 $MFG(N, m, s, d)$ denotes a game of Mafia which has totally N players which consists of m Mafia group members and $N - m$ citizen group members including s sheriffs and d doctors. $MFG(N, m)$ simply stands for a game of Mafia which has totally N players including m Mafia group members and $N - m$ citizen group members.

2. Simple Version of Mafia Game

Firstly, some participants collect in a circle and a game coordinator assigns each player to one of the two groups: mafia or citizens. Citizens know only their own identity, whereas mafia members know the identities of both sides. The target of the game is to defeat the other group. The game consists of two alternating phases – day and night. During the night the mafia members make a decision to kill one of the citizens. Then during the day time, all the players discuss together and vote for a possible mafia that they want to execute. There can also be some special characters of the citizens who can use their skills to achieve the success, such as sheriff (to investigate at night whether or not one is a mafia member) and doctors (to save a killed character at night) [10].

There are many variants of Mafia game. A typical modification of the game is to add characters with special skills as many as possible. For example, in the “Werewolf” game, besides prophet (the same as sheriff in Mafia game) and guarder (the same as doctor in Mafia game), a number of characters can be added, such as hunter (when a hunter is killed, he can kill anyone of the alive characters for revenge), witch (she has a poison to kill any character and a panacea to save a partner) and twins (two citizens knowing

¹ Japan Advanced Institute of Science and Technology, Japan

² Huazhong University of Science and Technology, China

^{a)} xiongshuo@jaist.ac.jp

^{b)} maointing@jaist.ac.jp

^{c)} liwenlin223@gmail.com

^{d)} iida@jaist.ac.jp

the identity of each other) etc. “Werewolf” game also adds some event cards to adjust the game process, which makes the game more interesting [2].

People play Mafia game in a party or just to kill time. Currently, there are two types of Mafia game. One is the traditional card game, in which players get together and pick cards to decide their roles. They also need to choose one person as the compere master, who have to control the game period such as to remind mafia, sheriff and doctor to do their works. The other one is Mafia video game in which players use computers to play. Players are assigned to their characters by the game system, and can use skills by pressing a simple button. The game system can also judge which group is the winner automatically. The platform of the most famous Mafia video game is the custom map in StarCraft II as shown in Figure 1. Later we detail the simple version of Mafia game.



Fig. 1: A screenshot of Mafia game map in StarCraft II

3. Literature Review

As such a popular game, Mafia game was not known as a game at the beginning. The history of this game can date back to 1970s that it was created for a psychology research [18]. Then the game evolved into a party game for fun and has been played for many years. Generally, there are four aspects to focus on: psychology and game theory, artificial intelligence, team work (or collaborative) strategy, and game design. For example, studies using various features to determine whether or not a player is a mafia are focusing on the aspects of human behaviors and psychology, like how a certain round is impacted by the number of words used in each utterance [15]; by hand and head-movements [3]; or by players' utterances, utterance lengths and the number of interruptions [8] to determine identities of players.

Particularly, in 2008, Braverman et al. [2] performed a theoretical study concentrating on finding the optimal strategies for the different groups and tried to calculate the winning rate. They were interested in the best strategies for different groups in such scenarios and in evaluating their relative power, then analyzed two variants with or without a sheriff or also called detective and found it that the best strategy in the absence of a sheriff is when the total number of players is R and the number of mafia members is $O(\sqrt{R})$, there will be an equal rate for each group to win. Conversely, when the number of mafia members is linear in R , it is proved to be fair when there are sheriffs in the game, which

means even a single sheriff could change the qualitative behavior of the game.

In 2014, Katagami et al. [8] studied the nonverbal information in Mafia game. They made investigations about influences of nonverbal information, such as gestures and facial expressions, on the winning rate. It was observed that nonverbal information is important for the victory of the game. Based on this study, Kobayashi et al. [9] developed a match system for humans with life-like agents. With this system, they tried to analyze nonverbal information from movies of games played by human to verify whether a life-like agent can give impressions like a human if they mount the analyzed movement on a life-like agent. They found that the movement felt doubtful would also be doubtful even if a life-like agent expressed, though there is a difference in an impression that is influenced by the contents of utterances.

Later in 2016, Bi [1] concentrated in a werewolf-side strategy called “stealth werewolf” strategy, with which each of the werewolf-side players (Mafia members) behaves like a citizen without showing his special role. They also limited some of the human-side behaviors and calculated ϵ -Nash equilibrium for both sides under this limitation. It was found that this strategy is not friendly for the group of Mafia to win.

Besides, several audio-visual corpora containing dialogue data in Mafia game were constructed in order to get known of group communication [6] [12]. A behavioral model was also made by Hirata et al. [5], containing behavioral information from playing logs, to describe playing process between humans. This model identifies an action selection probability to realize an agent that can behave like humans.

Furthermore, in the area of game design, a custom game in Blizzard's StarCraft II called “SC2Mafia” was created by Dark Revenant [4]. Similar to other web-based Mafia games, SC2Mafia is inspired by the classic party game with the same name, but features a faster pace and a wider range of different role options. The only requirement for playing SC2Mafia is a copy of StarCraft II. People who have not purchased the game can also download StarCraft II Starter Edition, which has been made available for free by Blizzard. SC2Mafia features a strong player base and loyal community of users who are playing games at almost any time during a day. The most interesting feature in SC2Mafia game is that every player has his special ability, and every player has his own room number, for instance, a Spy can wiretap the talking of Mafia or Triad group in night, a Lookout can observe any player and see who “visited” them during a particular night etc. SC2Mafia seems to be a challenging target in the future because of its complexity, hence a further discussion will be made later in this paper.

Basically, the previous works have been focusing mainly on the human behaviors, artificial intelligence and natural language processing as academic contributions. There are hardly any studies about Mafia game's settings or the balance of the game itself. However, balance is crucial for attractive games, as a root, and this paper will therefore mainly propose a method to show how to make a good balance between both sides and maintain comfortable settings of Mafia game by testing an assessment way using game refinement measure.

4. Assessment Methodology

This section presents the assessment methodology to find out the best settings of Mafia game in the sense of game sophistication.

4.1 Game Refinement Measure

Game refinement theory [7] gives a measure to quantify the sophistication of a game. This enables to obtain the deep insight into the current game and improve the quality of the game [11]. Game process will be divided into two elements. One is game speed or scoring rate. Another one is game information progress with a focus on the game outcome, which presents the degree of certainty of a game's result in time or in steps. Then, we use a physical model to obtain the acceleration value (say GR) of game [16]. The value of GR is derived from the average number of goal scores (say $x(t_k)$) over the average number of goal attempts (say t_k), where game information certainty $x(t)$ is a function of time t with $0 \leq t \leq t_k$ and $0 \leq x(t) \leq x(t_k)$ which corresponds to the average number of possible moves and game length in boardgames. For the continuous movement games such as sports and video games, a game progress model can be figured out to find the measure of game refinement [14]. Various types of games such as boardgames and sports have been analyzed while applying game refinement measures [17], summarized in Table 1. The results

Table 1: Measures of game refinement for various types of games

	$x(t_k)$	t_k	GR
Chess	35	80	0.074
Shogi	80	115	0.078
Go	250	208	0.076
Basketball	36.38	82.01	0.073
Soccer	2.64	22	0.073
Badminton	46.336	79.344	0.086
Table tennis	54.863	96.465	0.077
DotA ver 6.80	68.6	106.2	0.078
StarCraft II Terran	1.64	16	0.081
The king of the fighters 98	14.6	36.7	0.104

reasonably enable us to assume an important characteristic of sophisticated games, as stated below.

Remark 1 Sophisticated games have a common factor (i.e., same or nearly same degree of informatical acceleration value, say 0.07-0.08) to feel engaged or excited regardless of different type of games.

Therefore, it is highly expected that a sophisticated version or comfortable setting of Mafia game would have the nearly same degree of game sophistication.

4.2 Game Progress Model of Mafia Game

Let us consider the game progress of Mafia game. In every day and night, players will use their skills and logic to kill citizens or execute the mafia member, while the number of players is reduced to a certain value, then game is over. Therefore, let K and L be the average number of players killed and average game length, respectively. If one knows the game information progress, for example, after the game, the game progress $x(t)$ will be given as a linear function of time t with $0 \leq t \leq L$ and $0 \leq x(t) \leq K$, as shown in Eq. (1).

$$x(t) = \frac{K}{L} t \quad (1)$$

However, the game information progress given by Eq. (1) is usually unknown during the in-game period. Hence, the game information progress is reasonably assumed to be exponential. This is because the game outcome is uncertain until the very end of game in many games. Hence, a realistic model of game information progress is given by Eq. (2).

$$x(t) = K \left(\frac{t}{L} \right)^n \quad (2)$$

Here n stands for a constant parameter which is given based on the perspective of an observer in the game considered. Then the acceleration of game information progress is obtained by deriving Eq. (2) twice. Solving it at $t = L$, the equation becomes

$$x''(L) = \frac{Kn(n-1)}{L^n} t^{n-2} = \frac{K}{L^2} n(n-1)$$

Similarly, we get the refinement value $GR = \frac{\sqrt{K}}{L}$.

Here, we consider how to find the average game length. In a real Mafia game, there would be some survivals who will join the game at a certain round. Let Q and T be the average number of survivals and average number of rounds for survivals, respectively. Then we have $L = QT$. Thus, the final form of game refinement value is given by Eq. (3).

$$GR = \frac{\sqrt{K}}{QT} \quad (3)$$

5. Simulations and its Results

This section presents the detail of our computer simulation and the results are discussed.

5.1 Simulations

Below we list the regulations of Mafia game with a focus on important characteristics, which are incorporated in our computer program for the simulations in this study.

- * The different groups
 - There are N players in total and one more additional player (neither a Mafia nor a citizen) to coordinate the game.
 - Players are divided into two groups randomly. One group is m mafia members, and the other is $(N - m)$ citizens.
- At the beginning of the game, following information is given to players:
 - Mafia members are given the identity of both sides.
 - Citizens members are given the identity of themselves (which means that they do not know who are Mafia members).
- * The different rounds
 - There are two alternative phases: day and night.
 - During the day, there are two consecutive subphases:
 - * Debate. Everyone still alive can say anything related to accusing or defending.
 - * Vote. Everyone has one chance to vote for who should

be executed. The player who gets the highest number of votes is eliminated (in case of a tie, random again). The victims faction is revealed.

- During the night:
 - * Sheriff decides whom he wants to inspect, then the game compere will tell Sheriff the object that was inspected belong to Mafia or citizens.
 - * Mafia members jointly decide whom they want to kill.
 - * Doctor decides whom he wants to save.
 - * Game compere announces the night finished, and all the players open their eyes and are mentioned who has been killed or that nobody has been killed and it was a peace night.
- Repeat the process. The game continues until there is only one group (either the citizens or mafia) left and that group wins.

Here, we use a program to simulate the process of Mafia game $MFG(N, m, 1, 1)$. Every round is divided into 4 parts: (1) Night citizens' strategy, (2) Night Mafia's strategy, (3) Day discussion, and (4) Day vote. Then, we have the game theory and the algorithm idea as below.

- * Sheriff will check the identity of a specific target player at night, then write his identity in "last word". If he finds out the mafia member and can be alive until the next day, he will show his sheriff status and ask citizens to execute the mafia.
- * The doctor will save himself at night, while he knows who is the sheriff. The doctor will always protect sheriff, unless he was killed.
- * Mafia members will kill a player each night, because mafia members do not know whether the doctor is alive or not and his decision, even if they know who is sheriff, they still keep killing a player randomly. We show, in Figure 2, the strategic aspect with a focus on Nash equilibrium for doctor and mafia, v means the gambling value for Mafia group and doctor.
- * Citizen will vote and execute a player at the day time. If sheriff has information, then they will vote somebody by sheriff's suggestion. Otherwise, they will vote a player (who was not investigated by sheriff) randomly. If several players have the same poll, randomly vote again until someone can be executed.
- * All the players repeat this process, until one group wins the game.

Table 2: Nash equilibrium in Mafia game for doctor and mafia

Doctor \ Mafia	Kill Sheriff	Kill Randomly
Save Sheriff	(1, 0)	$(0 \leq v \leq 1, 0 \leq v \leq 1)$
Save Randomly	$(0 \leq v \leq 1, 0 \leq v \leq 1)$	$(0 \leq v \leq 1, 0 \leq v \leq 1)$

5.2 Data Collection and Analysis

We develop a computer program using Python for our simulation of the simple version of Mafia game. We show, in Algorithm 1, the pseudo code. It shows the process of the game, while

including important parameters such as the number of players, the number of mafia, the number of doctor, and the number of sheriff. We show, in Table 3, the results of 10,000 times simulations carried out for each setting.

Algorithm 1 Computer simulation of Mafia game

```

1: function ASSIGNMENT( $N, m$ )
2:   count(mafia)=m,      count(sheriff)=1,      count(doctor)=1,
   count(players)=n
3:   Random(n,m);
4:    $N \leftarrow$  mafia, sheriff, doctor, citizen
5: end function
6: function INVESTIGATE( $sheriff$ )
7:   Random( $left\ players$ )
8:   if checked
9:     return -1
10:  else
11:    get character of target player  $i$ 
12:     $i \leftarrow m, d, c$ 
13:    return 0
14: end function
15: function KILL( $mafia$ )
16:   Random( $left\ players$ )
17:   if mafia member
18:     return -1
19:   else
20:     kill target player  $j$ 
21:     return 0
22: end function
23: function SAVE( $doctor$ )
24:   Random( $left\ players$ )
25:   if Sheriff=1
26:     protect sheriff  $k$ 
27:   else
28:     protect ( $left\ players$ )  $k$ 
29:   return 0
30:   if  $j = k$ 
31:      $n = n - 1$ ;
32: end function
33: function DISCUSSION( $players$ )
34:   if  $i = m$ 
35:     show sheriff's status
36:   else
37:     keep silence
38: end function
39: function VOTE( $players$ )
40:   if  $i = 1$ 
41:     vote  $i$ 
42:   else
43:     vote  $N-i$ -sheriff
44:    $n = n - 1$ ;
45:   return 0
46: end function
47: function MAIN( $players$ )
48:   while  $m > \frac{n}{2}$ 
49:     return 0
50:   else
51:     repeat
52: end function

```

In order to make the game more interesting, we not only consider the game refinement value, but also firstly need to analyze

Table 3: The results of simulation for $MFG(12, m)$

N	m	Win for citizens	Rounds	Death	Win for mafia	Rounds	Death
12	6	267	6.07	10.63	9733	1.12	1.22
12	5	3284	5.38	10.01	6716	3.44	5.82
12	4	5975	5.04	9.52	4025	4.64	8.21
12	3	7859	4.60	8.76	2141	5.36	9.63
12	2	9003	3.97	7.60	997	5.78	10.46
12	1	9578	2.91	5.58	422	6.07	11.00

the setting balance. For example, Table 3 shows that the winning ratio of citizens group is significantly low in $MFG(12, 6)$ while the winning ratio of the mafia group is low in $MFG(12, 1)$. Therefore, we need to choose the balancing setting. Considering the game played by human with full of emotional behaviors, also mafia members know each other and they have the information advantage, here we pick out the settings in which the winning ratio of the citizens group is a little higher than the mafia side, such as $MFG(12, 4)$ and $MFG(12, 3)$. We show, in Table 4, the results of simulation for various settings with 12 players.

Conjecture 1 For the citizens group, sheriff is much more important than doctor from the viewpoint of game balancing.

Conjecture 2 $MFG(12, m, s, d)$ is the best to play with $m = 5, s = 1, d = 2$ or $m = 4, s = 1, d = 1$ from the viewpoint of game balancing while minimizing the difference of winning ratio between mafia and citizens.

Further simulations will be conducted to find comfortable settings with a focus on game refinement and game balancing for $MFG(N, m, s, d)$ with $9 \leq N \leq 20$.

(20,9,4,4), (20,8,1,2), (19,7,1,1), (19,6,1,1), (18,7,1,2), (18,6,1,1), (17,7,1,2), (17,7,1,1), (16,6,1,2), (16,6,1,1), (15,6,1,2), (15,5,1,1), (14,5,1,2), (14,5,1,1), (13,6,1,2), (13,5,1,1), (12,5,1,2), (12,4,1,1), (11,4,1,1), (10,3,1,1), (9,4,2,1), (8,3,1,1)

As Table 4 shows, we also can get the average number of player killed. In the case of $MFG(12, 5, 1, 2)$, the average number of player killed K is calculated by $K = \frac{5216+9.86+4784+5.41}{10000} = 7.73$. Similarly we can get the average number of turn T , then we can simulate to get the refinement value of previous 21 balance settings as shown in Table 5. Table 5 suggests following two conjectures.

Conjecture 3 The measure of game refinement would reduce as the number of players increases. This may imply that a game of Mafia would become boring as the number of players becomes larger.

Conjecture 4 $MFG(n, m, s, d)$ can be played reasonably with $N \in \{14, 15, 16\}$, $m \in \{5, 6\}$, $s = 1$ and $d \in \{1, 2\}$. In particular, $MFG(15, 5, 1, 1)$ or $MFG(15, 6, 1, 2)$ is the best under the assumption that its GR value is within the sophisticated zone 0.07 – 0.08.

In this study, we notice that the most suitable players' number is 15. Here, we find an interesting phenomenon that in StarCraft II complex Mafia game map, with any defeat setting, the player number turns out to be 15. Figure 2 shows this setting that we can find in the bottom right corner. Therefore, it can be inferred that the game designer uses his experience to set 15 players, coincide with our research results.



Fig. 2: A screenshot of StarCraft II

To observe the relation between the performance quality and game characteristics, further simulations are conducted using two different level of AIs— fair level and weak level.

- The strong AI always follow the Nash equilibrium as algorithm 1. shows.
- The fair AI, doctor will protect randomly and mafia member will kill randomly. We change the save function in algorithm 1.
- The weak AI, doctor will protect randomly, mafia will kill randomly and sheriff will not show their identity. We change the sava and discussion function in algorithm 1.

Then, the simulations are performed using these different AIs for the two settings: $MFG(15, 5, 1, 1)$ and $MFG(20, 9, 4, 4)$. The results are given in Table 6, and we have a conjecture.

Conjecture 5 The level of players affects the game balancing and game sophistication. For example, mafia would dominate citizens if all players are weak, which implies that the game sophistication would be reduced.

6. Concluding Remarks

The results of our computer simulations using a simple version of Mafia game show some interesting aspects of Mafia game and suggest the reasonable settings from the perspective of game sophistication, as summarized below. For the citizens group, sheriff is much more important than doctor from the viewpoint of game balancing. For $N = 12$, $MFG(12, m, s, d)$ is the best to play with $m = 5, s = 1, d = 2$ or $m = 4, s = 1, d = 1$ from the viewpoint of game balancing while minimizing the difference of winning ratio between two groups of mafia and citizens. The measure of game refinement would reduce as the number of players increases. This may imply that Mafia game would become boring as the number of players becomes too many. $MFG(N, m, s, d)$ can be played reasonably with $N \in \{14, 15, 16\}$, $m \in \{5, 6\}$, $s = 1$ and

Table 4: The results of simulation for $MFG(12, m, s, d)$

Setting	Win for citizens	Rounds	Death	Win for mafia	Rounds	Death
MFG(12,5,1,2)	5216	5.21	9.86	4784	3.21	5.41
MFG(12,4,1,1)	6716	4.96	9.49	3284	4.49	7.93
MFG(12,3,0,1)	7722	4.44	8.88	2278	5.29	9.52
MFG(12,3,1,0)	2170	5.15	9.65	7830	5.05	8.97

Table 5: The results of simulation for $MFG(N, m, s, d)$ and its game refinement measure

Setting	Win for citizens	Average death	Round	Average length	GR
MFG(20,9,4,4)	6635	13.20	7.61	76.09	0.0478
MFG(20,8,1,2)	5782	14.74	7.80	78.03	0.0492
MFG(19,7,1,1)	6532	15.12	7.83	74.40	0.0523
MFG(19,6,1,1)	7798	15.56	8.03	76.24	0.0517
MFG(18,7,1,2)	6347	13.56	7.17	64.55	0.0571
MFG(18,6,1,1)	6541	14.12	7.43	66.88	0.0562
MFG(17,7,1,2)	6938	13.27	6.89	58.58	0.0622
MFG(17,7,1,1)	5128	12.27	6.37	54.15	0.0647
MFG(16,6,1,2)	6980	12.22	6.46	51.72	0.0676
MFG(16,6,1,1)	5241	11.62	6.23	49.84	0.0684
MFG(15,6,1,2)	7548	11.95	6.21	46.61	0.0742
MFG(15,5,1,1)	7575	12.06	6.25	46.90	0.0740
MFG(14,5,1,2)	7612	10.72	5.67	39.66	0.0825
MFG(14,5,1,1)	5838	10.34	5.55	38.87	0.0827
MFG(13,6,1,2)	5117	8.35	4.38	28.45	0.1016
MFG(13,5,1,1)	6540	9.96	5.20	33.80	0.0934
MFG(12,5,1,2)	5292	7.75	4.27	25.59	0.1088
MFG(12,4,1,1)	6554	8.93	4.80	28.79	0.1038
MFG(11,4,1,1)	7269	8.51	4.46	24.54	0.1189
MFG(10,3,1,1)	7464	7.33	3.94	19.71	0.1373
MFG(9,4,2,1)	5424	5.74	3.27	14.69	0.1630
MFG(8,3,1,1)	5393	5.29	3.00	12.01	0.1916

Table 6: The results of simulation using different AIs for two settings

Setting	AI level	Win for citizens	Average death	Round	Average length	GR
$MFG(15, 5, 1, 1)$	Strong	7575	12.06	6.25	46.90	0.0740
	Fair	7552	12.11	6.16	46.20	0.0753
	Weak	1781	10.34	7.93	59.49	0.0541
$MFG(20, 9, 4, 4)$	Strong	6635	13.20	7.61	76.09	0.0478
	Fair	4691	11.51	6.29	62.9	0.0554
	Weak	380	8.60	5.79	57.6	0.0509

$d \in \{1, 2\}$. In particular, $MFG(15, 5, 1, 1)$ or $MFG(15, 6, 1, 2)$ is the best under the assumption that its GR value is within the sophisticated zone. Moreover, the level of players affects the game balancing and game sophistication. For example, mafia would dominate citizens if all players are weak, which implies that the game sophistication would be reduced.

Future works may include the analysis of complicated versions of Mafia game in StarCrat II custom map (SC2Mafia).

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