



Balancing Nightmares: an AI Approach to Balance Games with Overwhelming Amounts of Data

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Who are we?



Kazuko Manabe

AI Engineer

Advanced Technology Division
SQUARE ENIX CO., LTD

- Console game development
- Tool development
- Currently: QA, Game balance



Who are we?



Shigeru Awaji
Online Engineer
Advanced Technology Division
SQUARE ENIX CO., LTD

- Designed and created general Windows desktop applications and databases
- Cooperate using data analysis on more than 20 projects over the course of 3 years

Contents

- ▶ Introduction of Grimms Notes Repage
- ▶ Game balance using AI
 - ▶ Proposed method
 - ▶ Experiments and their results
 - ▶ Applications to other games
- ▶ System configuration for balance adjustment
- ▶ What could we do next?

Grimms Notes Repage

- ▶ Action battle game for smartphones
- ▶ Over 17 million downloads

Party preparation

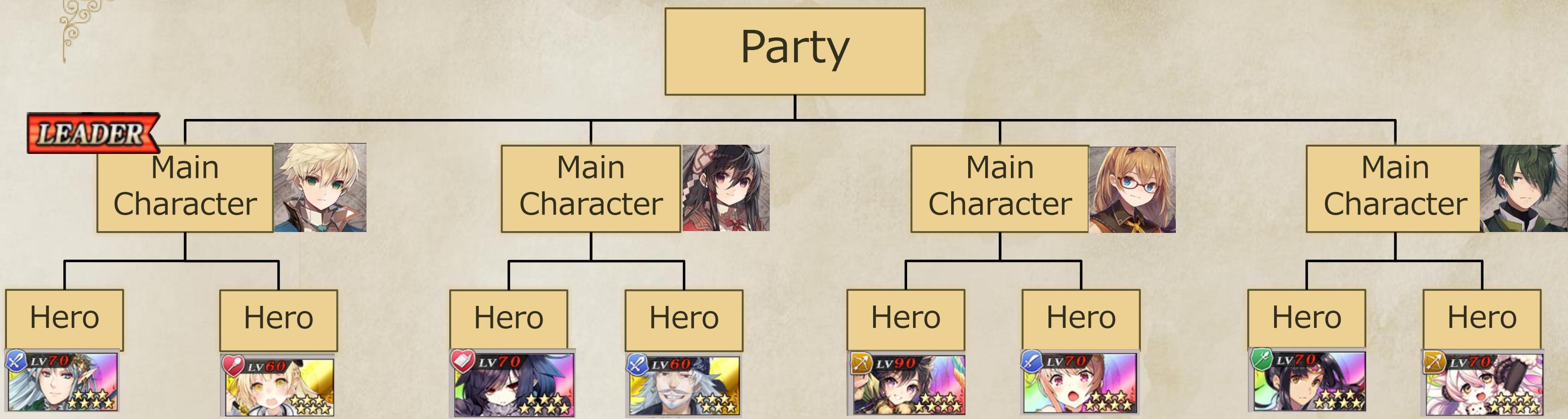


Reward, Enhancement

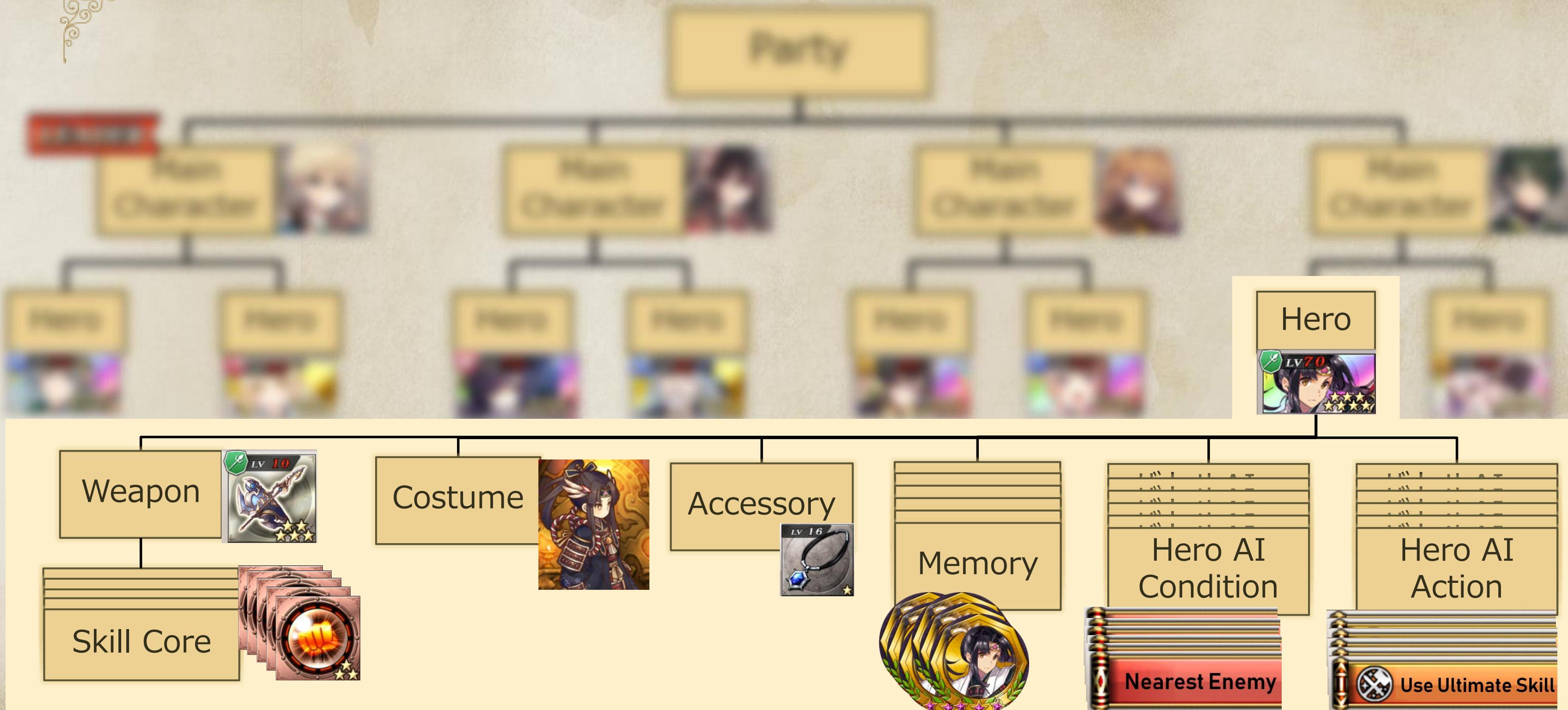


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Definition of “Party” in *Grimms Notes Repage*



Definition of “Party” in *Grimms Notes Repage*





Definition of “Party” in *Grimms Notes Repage*



Balancing *Grimms Notes Repage*, a Nightmare?

- ▶ Main characters: 8
 - ▶ Select a leader
 - ▶ Hero: 80
 - ▶ Weapon: 60
 - ▶ Skill core * 5: 65
 - ▶ Costume: 3
- ▶ Accessory: 4
- ▶ Hero AI * 6:
 - ▶ Conditions: 30
 - ▶ Actions: 20

(Approximate estimate)

Combinations:

$$\frac{8!}{4! \times (8 - 4)!} \times 4 \times 80^8 \times 60^8 \times 65^{(8*5)} \times 3^8 \times 4^8 \times \frac{30!}{(30 - 6)!}^8 \times 20^{(6*8)}$$

$\approx 1.0 * 10^{182}$

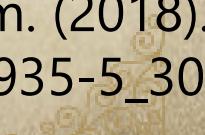
Challenge: Impossible to check all combinations of elements in a party in limited time

Idea: If there are elements which have effects that are too strong in the game, the strongest party should have these elements.

Optimization-based falsification*:

"It utilizes global optimization methods to guide the tests towards a possibly small region in the input space that lead to an incorrect system behavior"

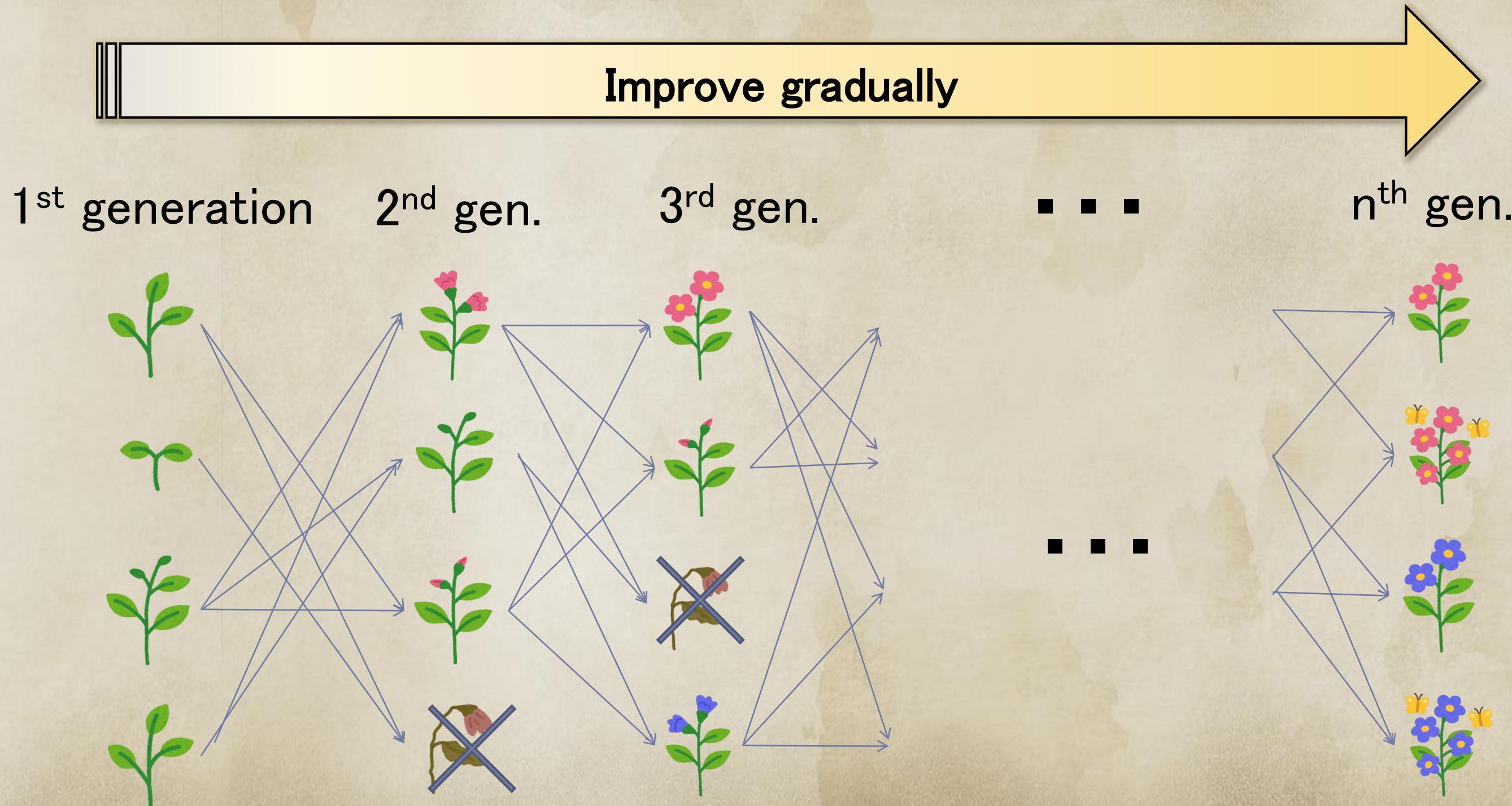
* Tuncali, Cumhur & Hoxha, Bardh & Ding, Guohui & Fainekos, Georgios & Sankaranarayanan, Sriram. (2018). Experience Report: Application of Falsification Methods on the UxAS System. 10.1007/978-3-319-77935-5_30.



We did it!



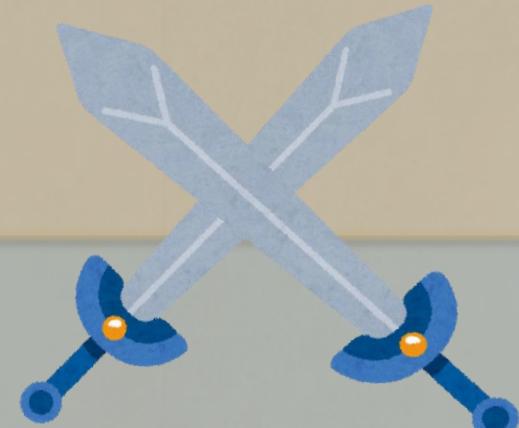
The Method: Genetic Algorithm(GA)



Corresponding terms

Genetic Algorithm

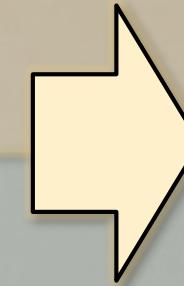
Environment



Battle

Grimms Notes

Fitness



Battle
result

Individual



Party

Why GA?

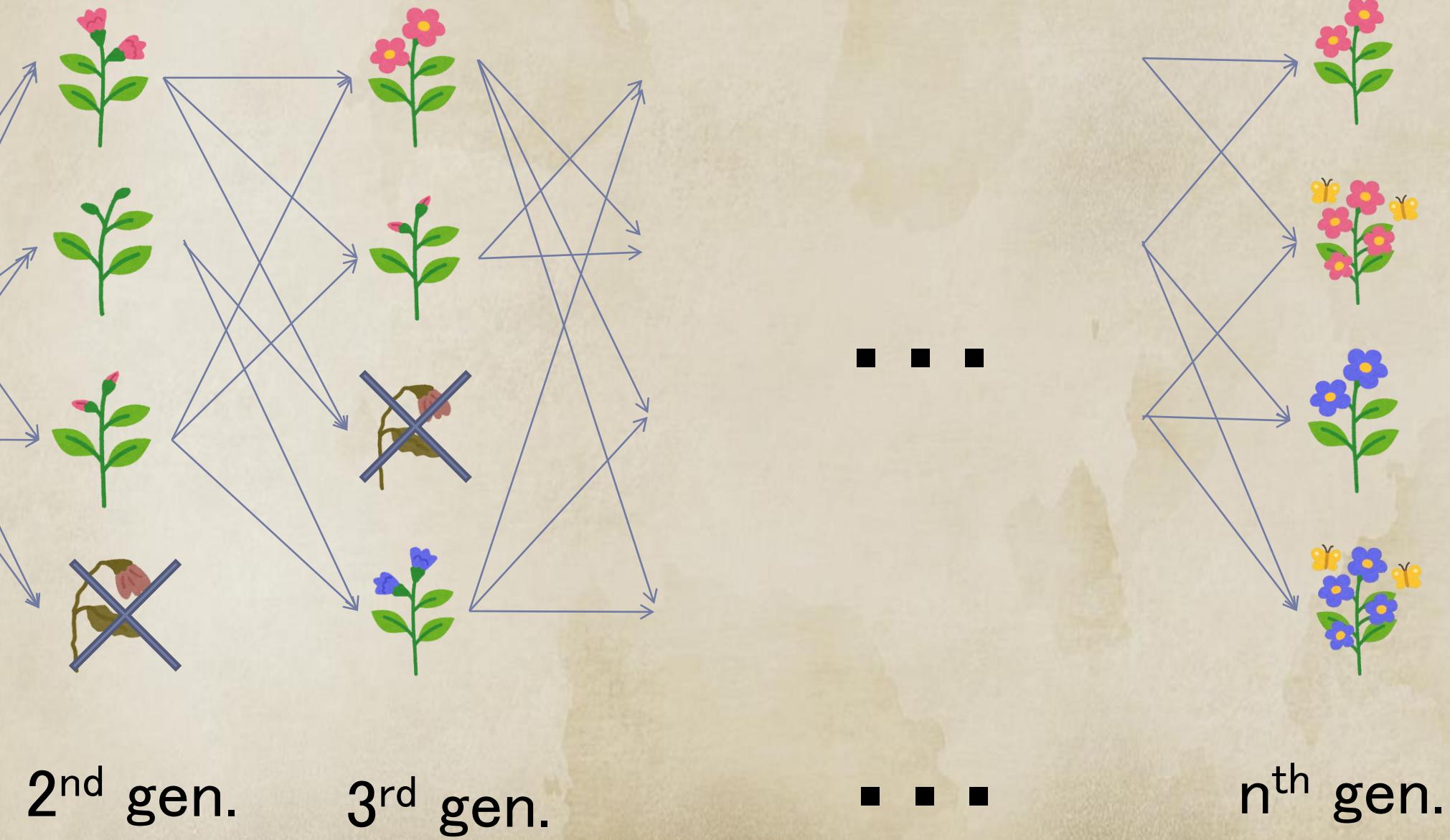
- ▶ The algorithm is simple and easy to handle
- ▶ It has a long history; there are many papers on GA
- ▶ We can get a suboptimal solution in limited time
- ▶ We can stop the execution whenever we want

GA is suitable for product development

GA Process

- ▶ 1. Create initial parties with randomly chosen genes
 - ▶ Set the initial parties as the 1st generation
- ▶ 2. Evaluate the parties in the latest generation
- ▶ 3. Select the best parties
- ▶ 4. Crossbreed the parties
- ▶ 5. May mutate a few parties (based on probability)
 - ▶ Set the created new parties in Step 4 and Step 5 as the next generation
- ▶ 6. Stop in a specified condition or back to Step 2
 - ▶ Ex. Stop if specified time has elapsed

1. Create initial parties with randomly chosen genes



1st generation

2nd gen.

3rd gen.

nth gen.

2. Evaluate the parties



Evaluate = Measure fitness for environment

Environment = Battle

Party

IN



Results

OUT

2. Evaluate the parties – Battle types in Grimms Notes

PvE: Player vs. Environment

- ▶ Battle against monsters (CPU)
- ▶ PvP: Player vs. Player
- ▶ One-to-one battle between human players

Auto-play battle

- ▶ After starting the battle, players can do nothing

2. Evaluate the parties – Analyze the features of the battles

	PvE	PvP
Victory condition	Wipe out the enemies or beat the boss	The most remaining life points
Rewards	Materials	Arena Points
Opponents	Can choose opponent	Cannot choose opponent
The number of challenges	Unlimited	Limited
Defeat penalty	Nothing	Lose Arena Points

2. Evaluate the parties – Analyze the features of the battles

PvE	
Victory condition	Wipe out the enemies or beat the boss
Rewards	Materials
Opponents	Can choose opponent
The number of challenges	Unlimited
Defeat penalty	Nothing

2. Evaluate the parties – Evaluation for PvE



Evaluation policy

Victory	Defeat
Battle-time	Damage dealt

Specialized for the game

2. Evaluate the parties – Analyze the features of the battles

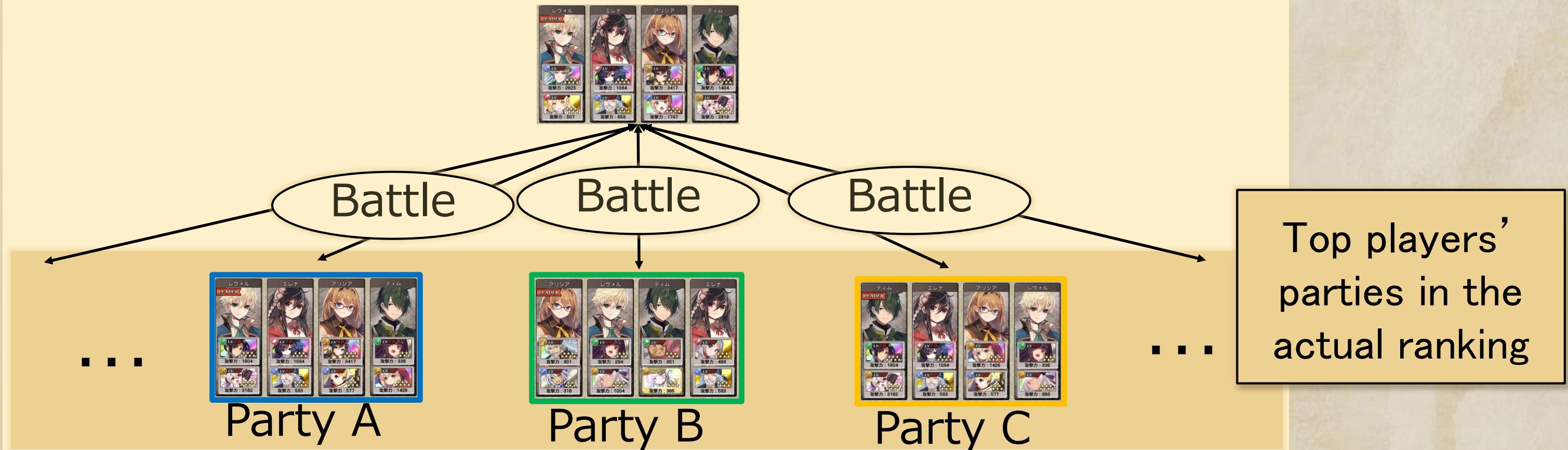
		PvP
Victory condition	The most remaining life points	
Rewards	Arena Points	
Opponents	Cannot choose opponent	
The number of challenges	Limited	
Defeat penalty	Lose Arena Points	

To measure the winning percentage

▶ Fight with parties of different fighting styles

1 evaluation

Party to be evaluated



▶ Use the average of the battle results as the evaluation value

2. Evaluate the parties – Evaluation for PvP



Evaluation policy

Victory	Defeat
Difference of remaining life points	Difference of remaining life points
+ fixed bonus points	----

Specialized for the game

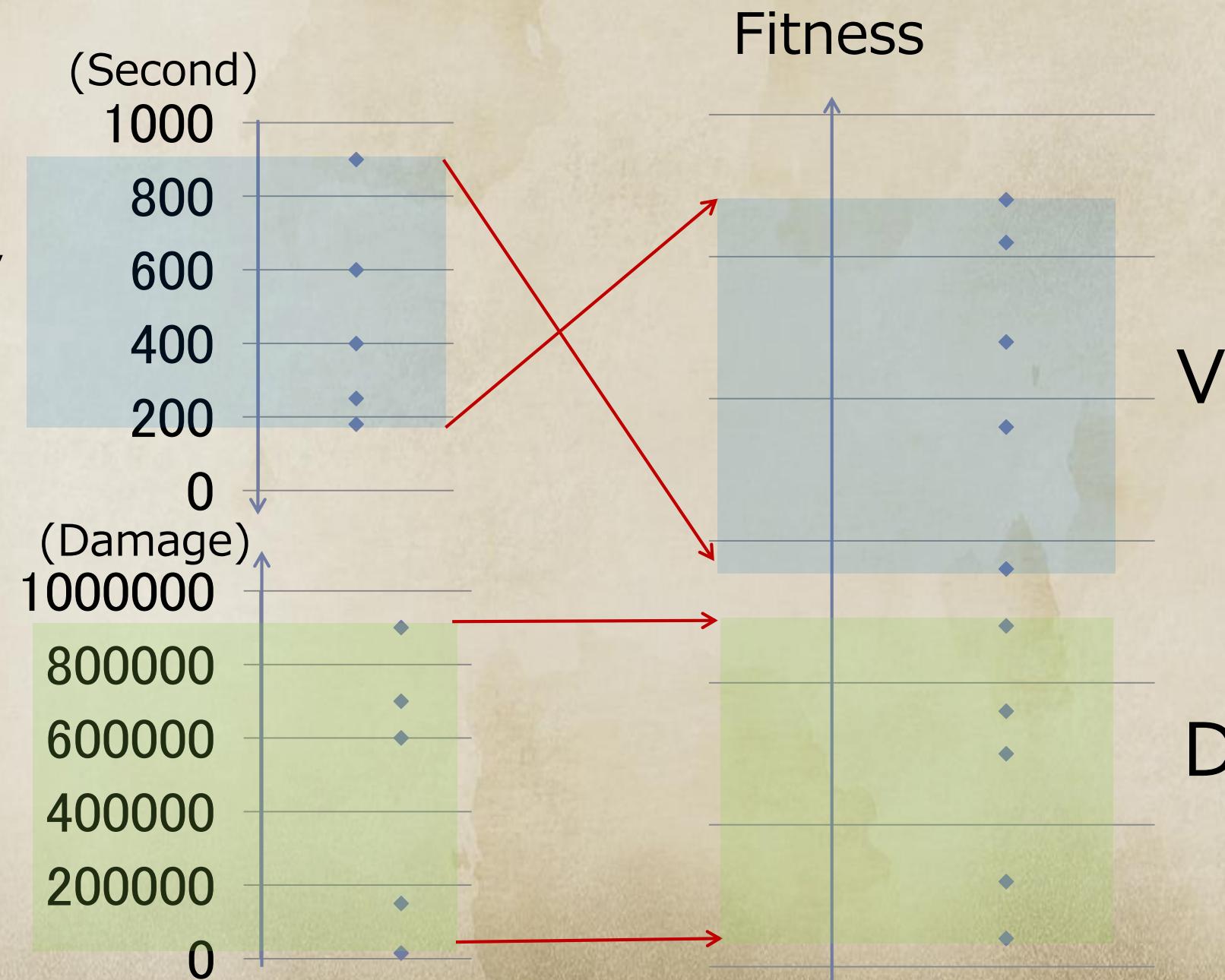
2. Evaluate the parties

➤ Mapping values in different units to the same axis

Case of PvE:

Victory

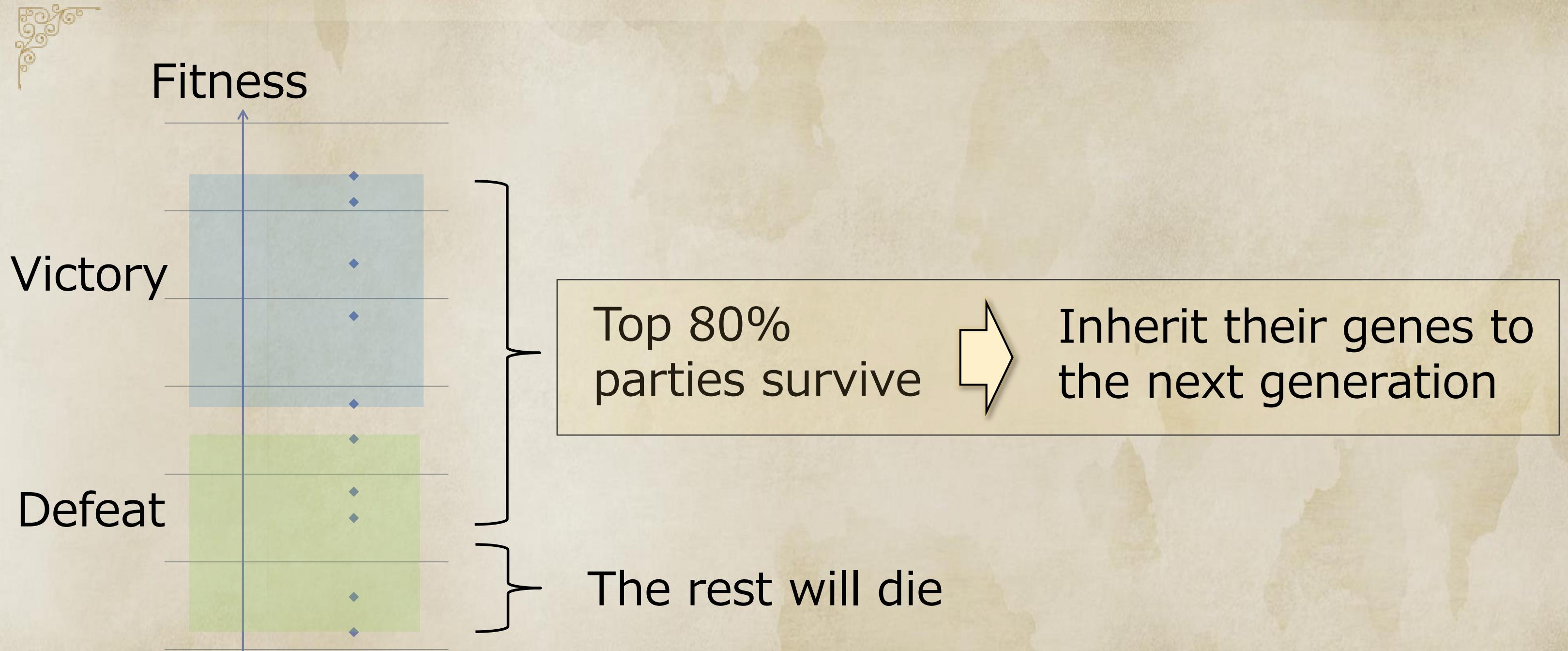
Defeat



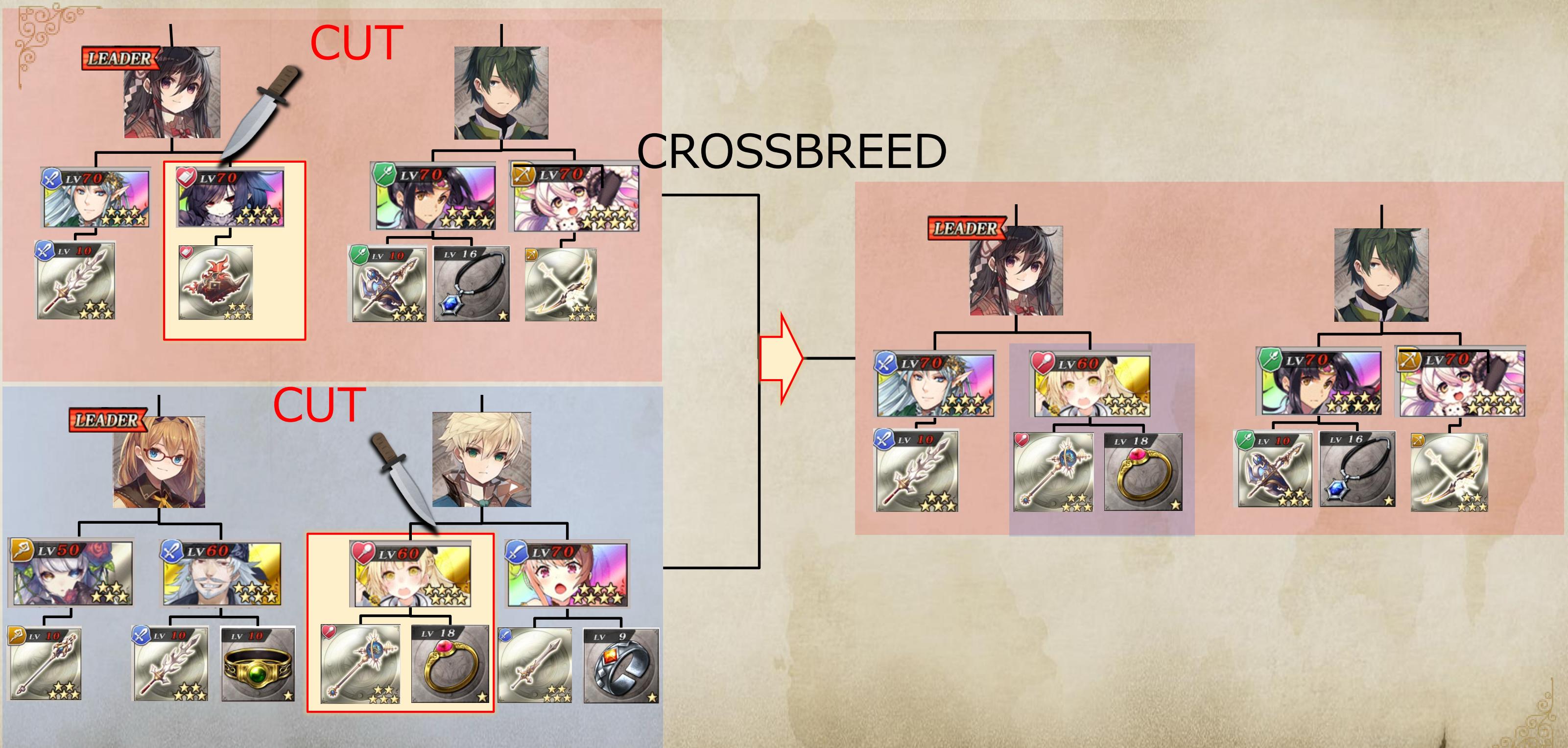
Victory

Defeat

3. Select the best parties



4. Crossbreed the parties: One-Point Crossover



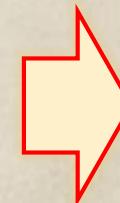
5. Mutate a part of the parties

Mutation probability: 5%

Cut and replace a subtree randomly



MUTATE



Rarely, very good (part of) elements appear

- ▶ This is an important step to improve the coverage quality

2-5. Create parties from previous generation



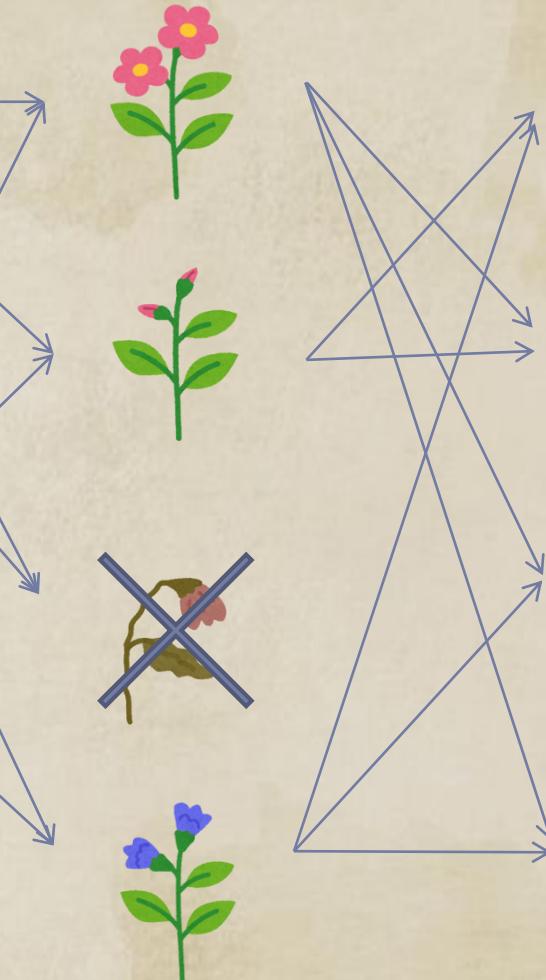
1st gen.

2nd gen.

3rd gen.

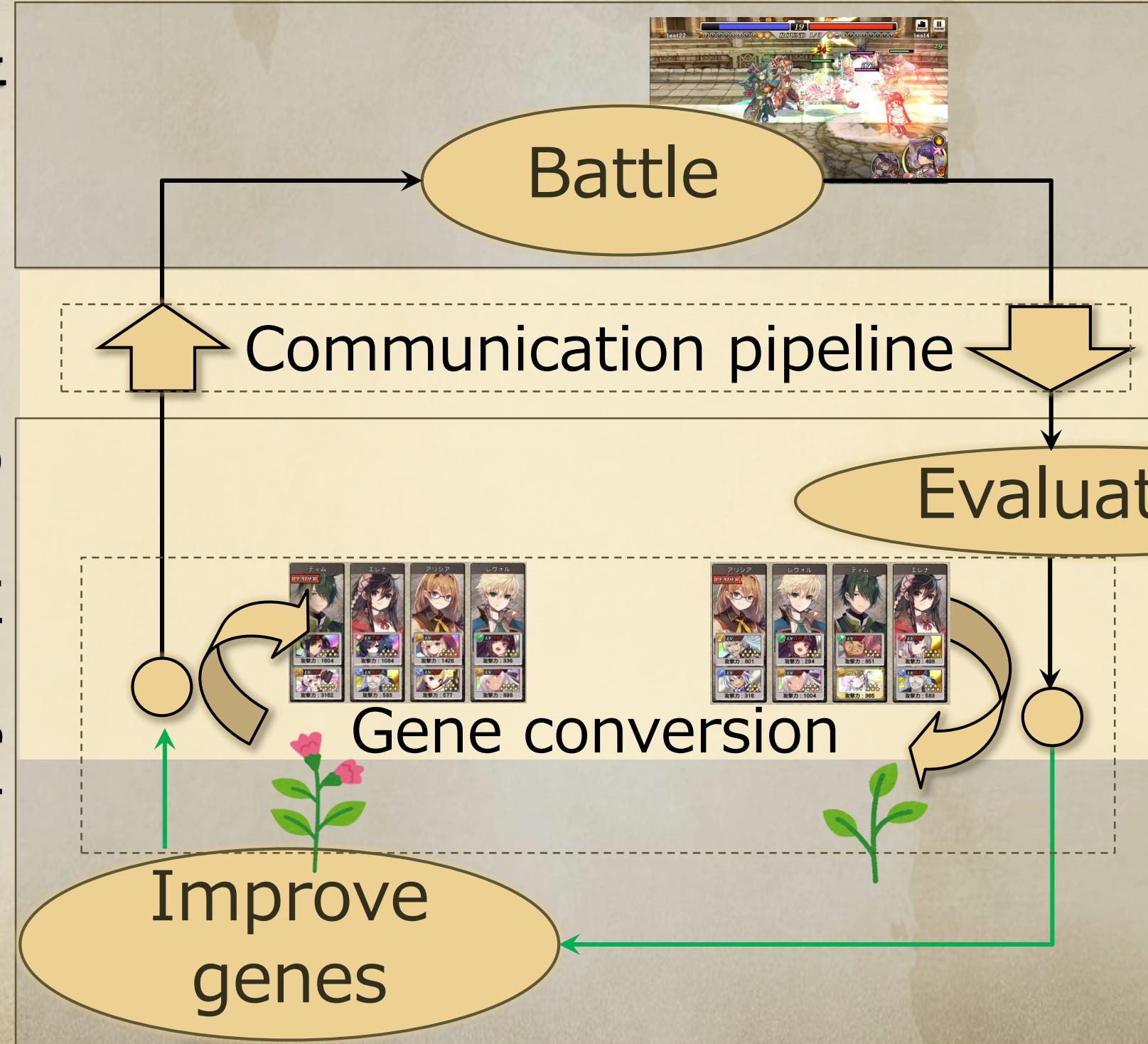
nth gen.

Improve gradually



Overview

In the game Outside of the game



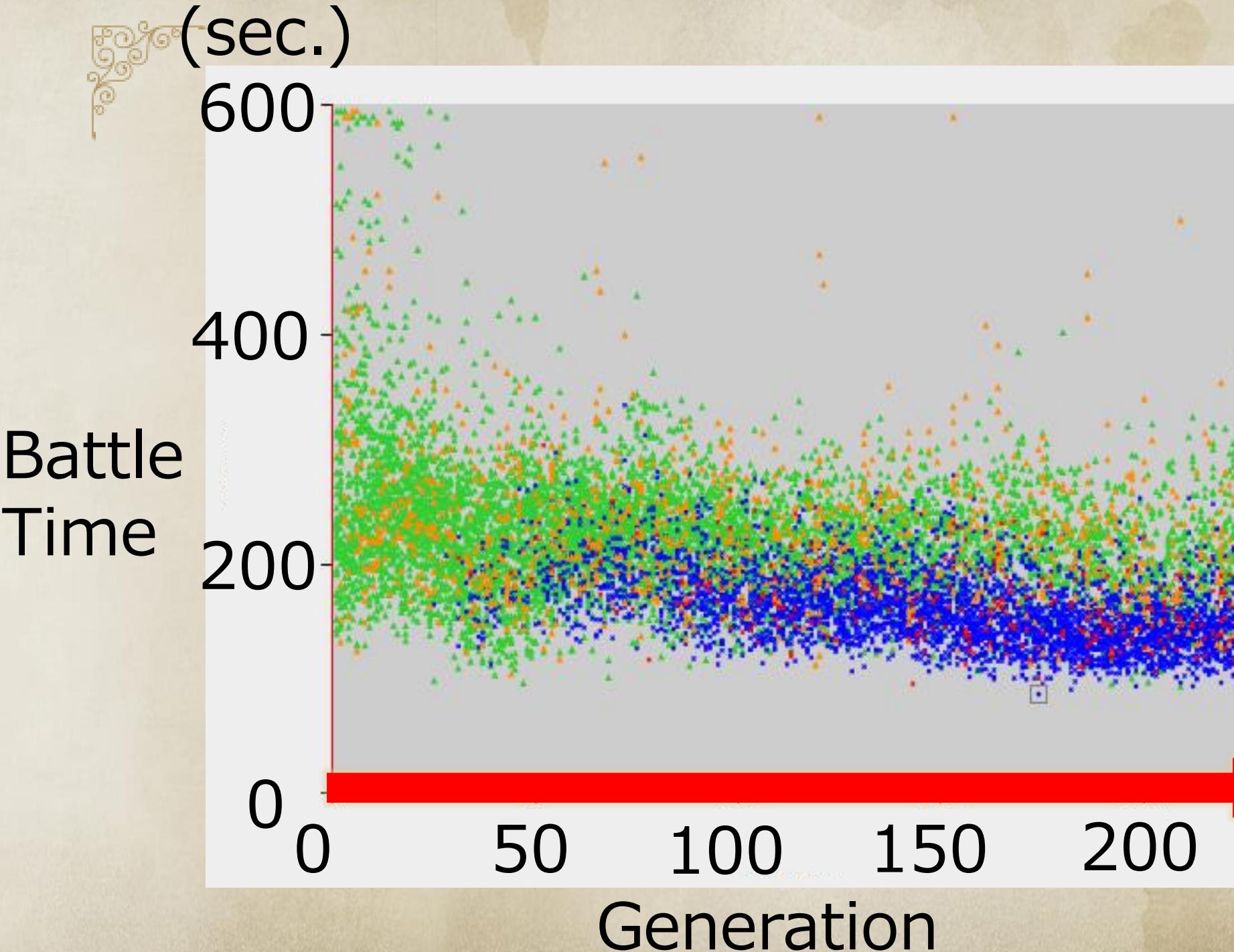
Use the actual game
almost directly

Customize

Applicable to
other games

Shared process

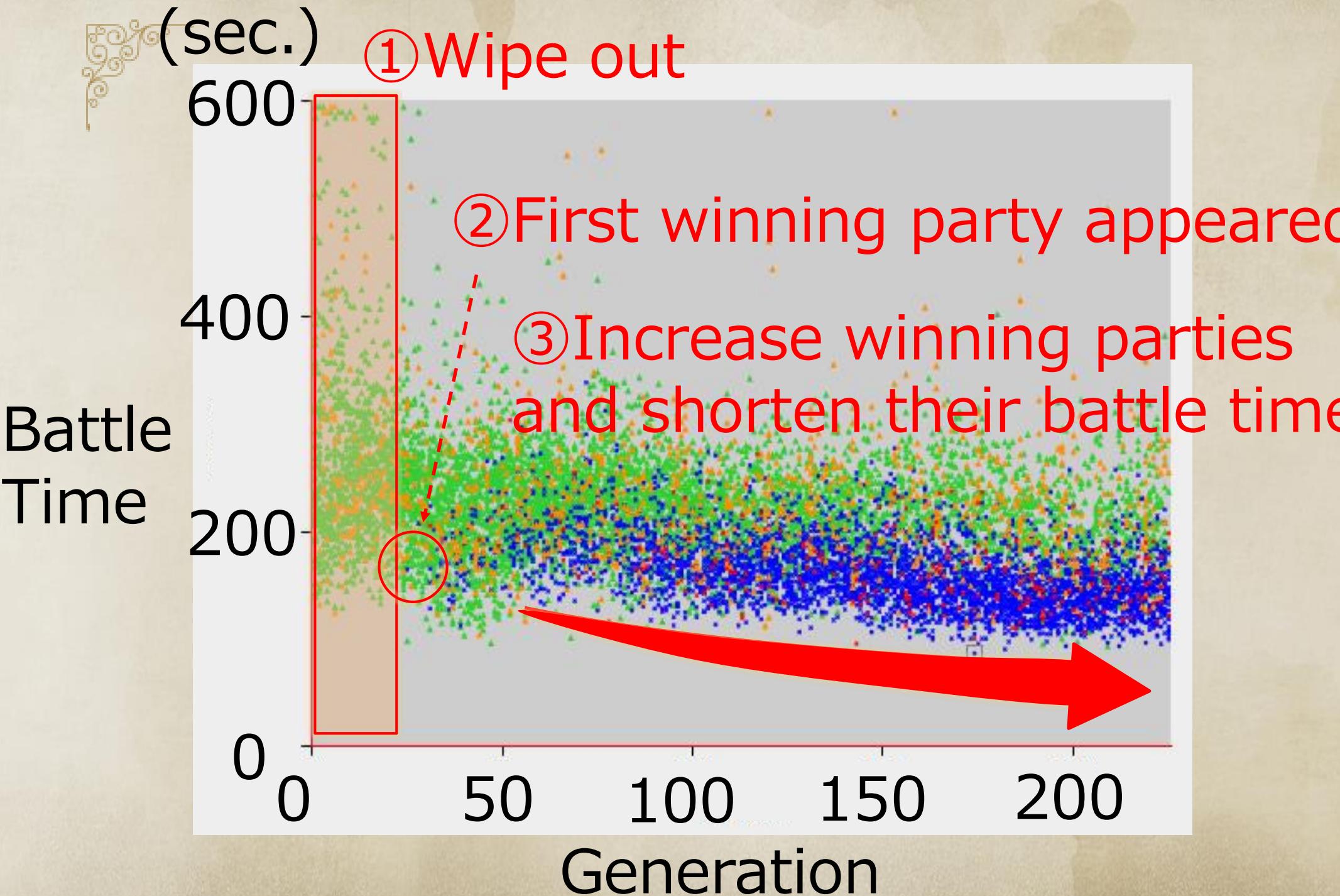
Change of fitness values in PvE



Victory party ●
Defeat party ●
(Mutated victory party ●)
(Mutated defeat party ●)



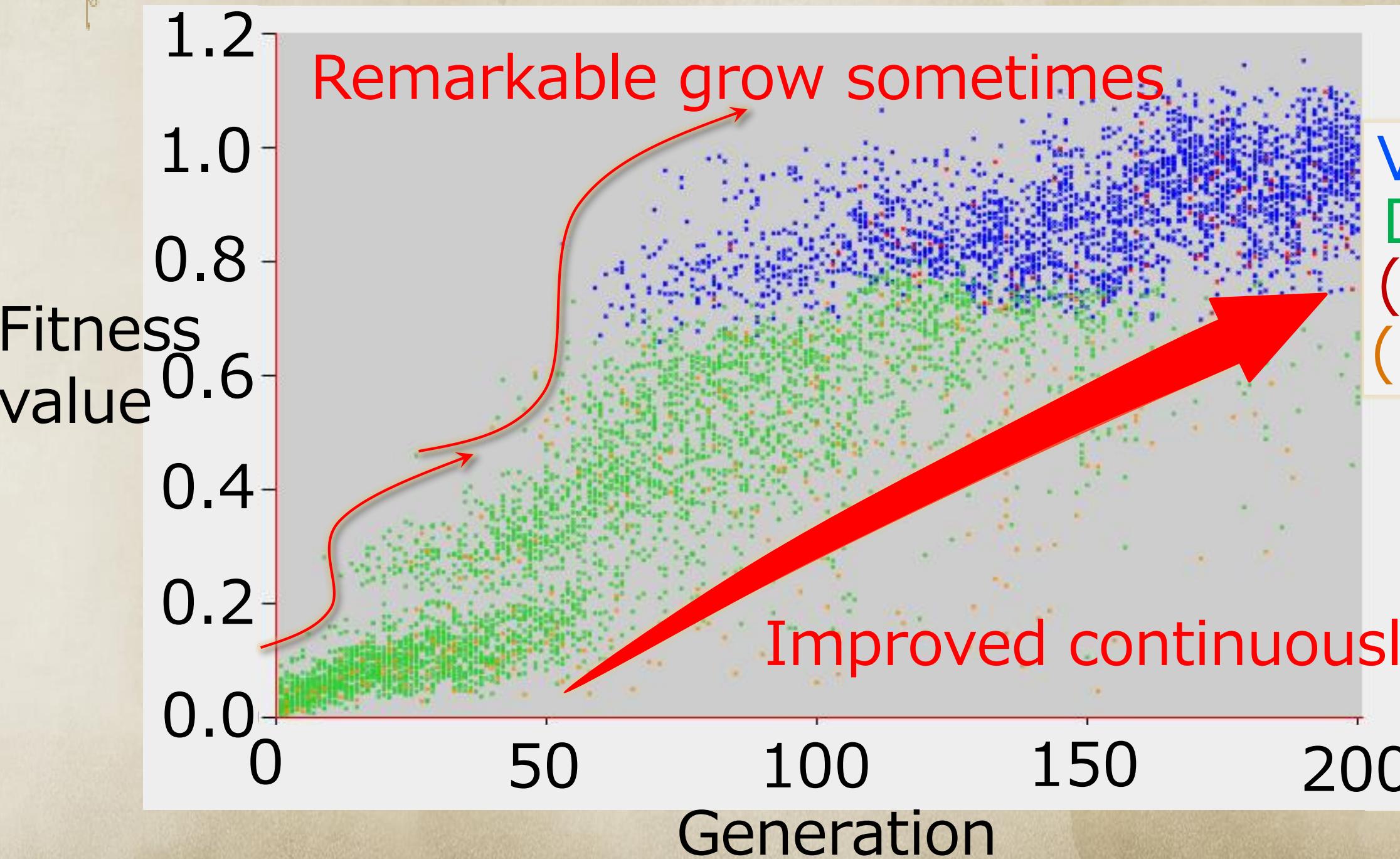
Change of fitness values in PvE



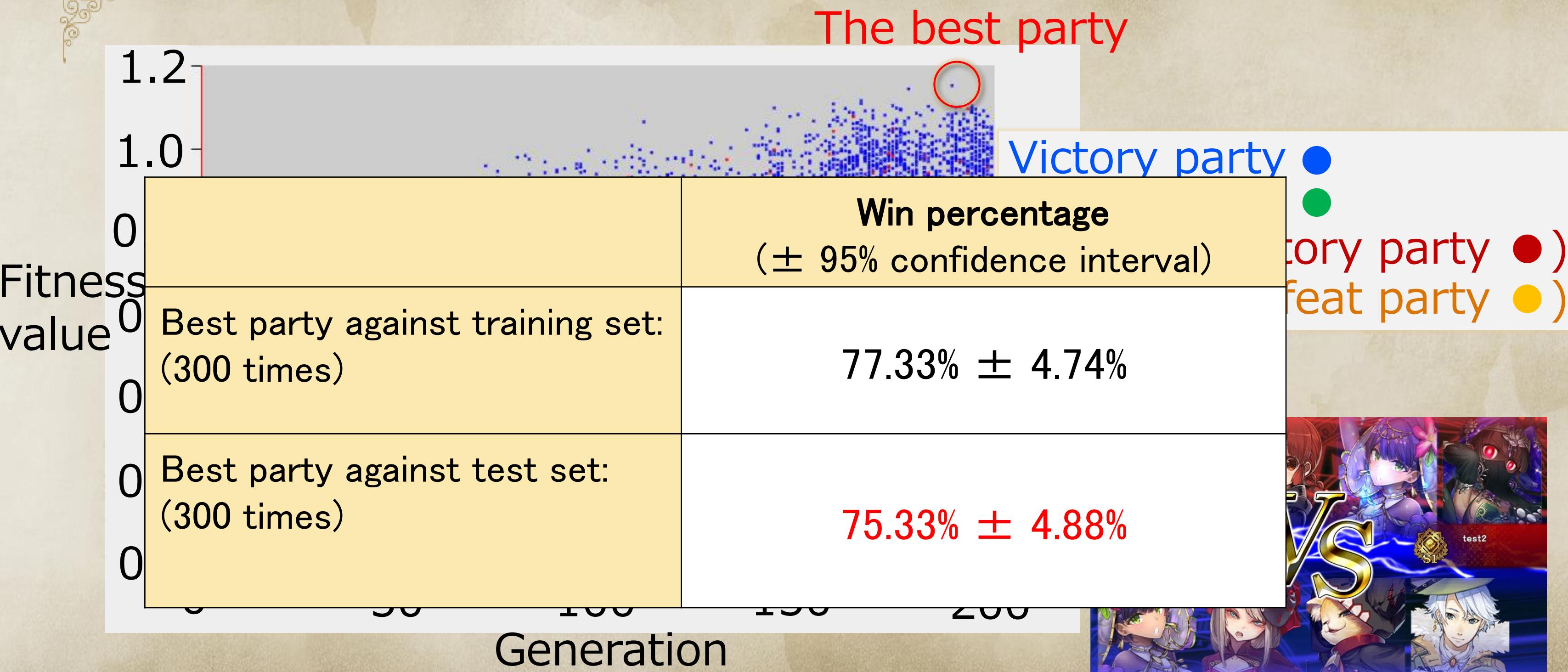
- Victory party ●
- Defeat party ●
- (Mutated victory party ●)
- (Mutated defeat party ●)



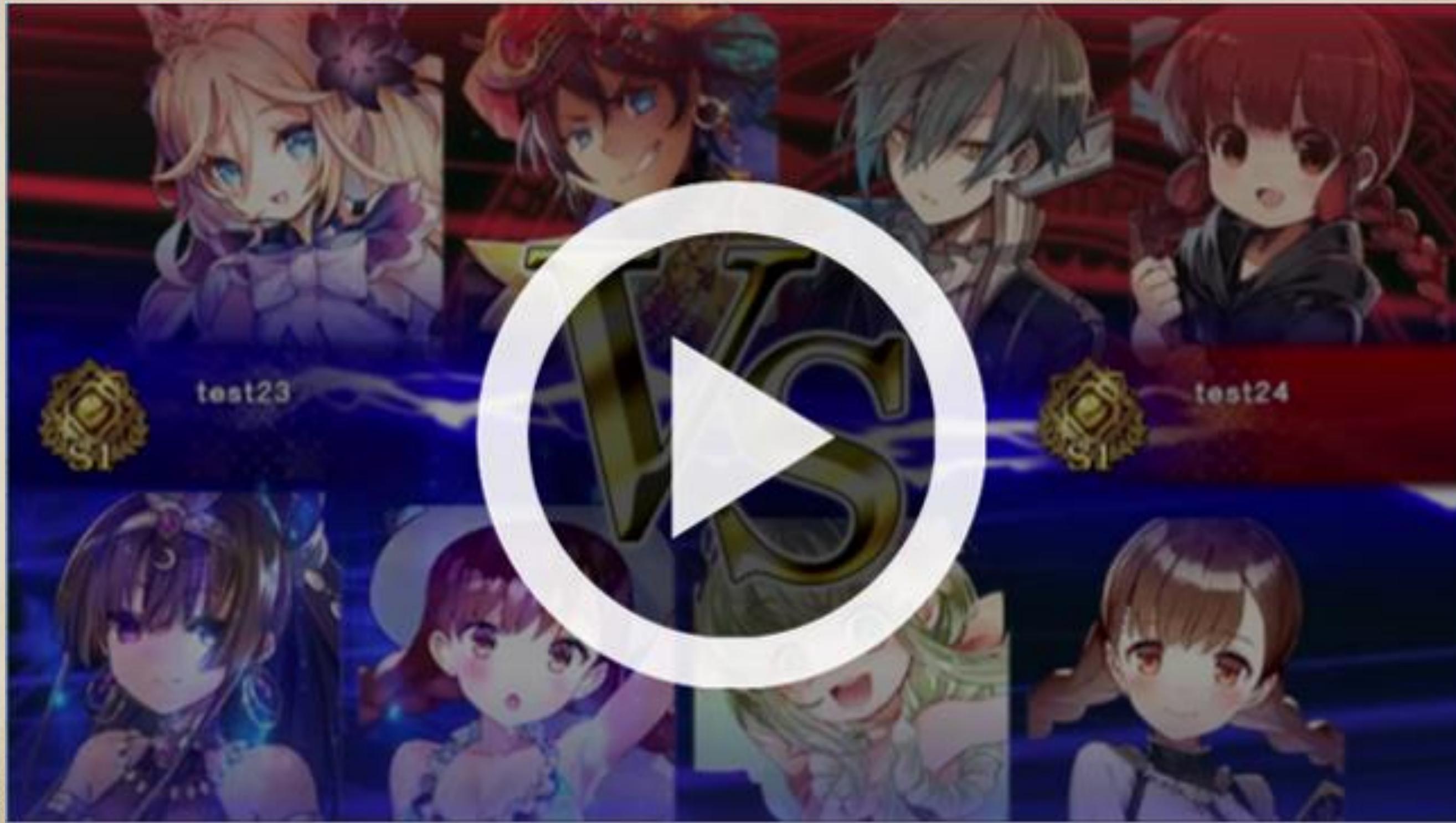
Change of fitness values in PvP



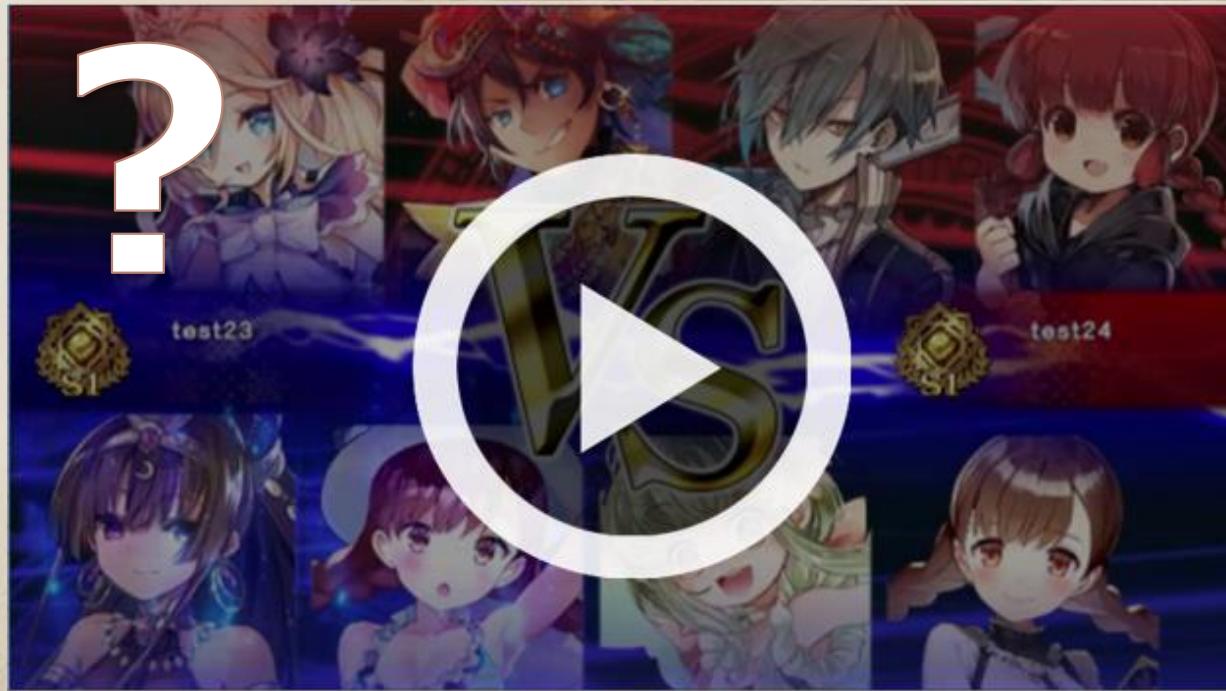
Change of fitness values in PvP



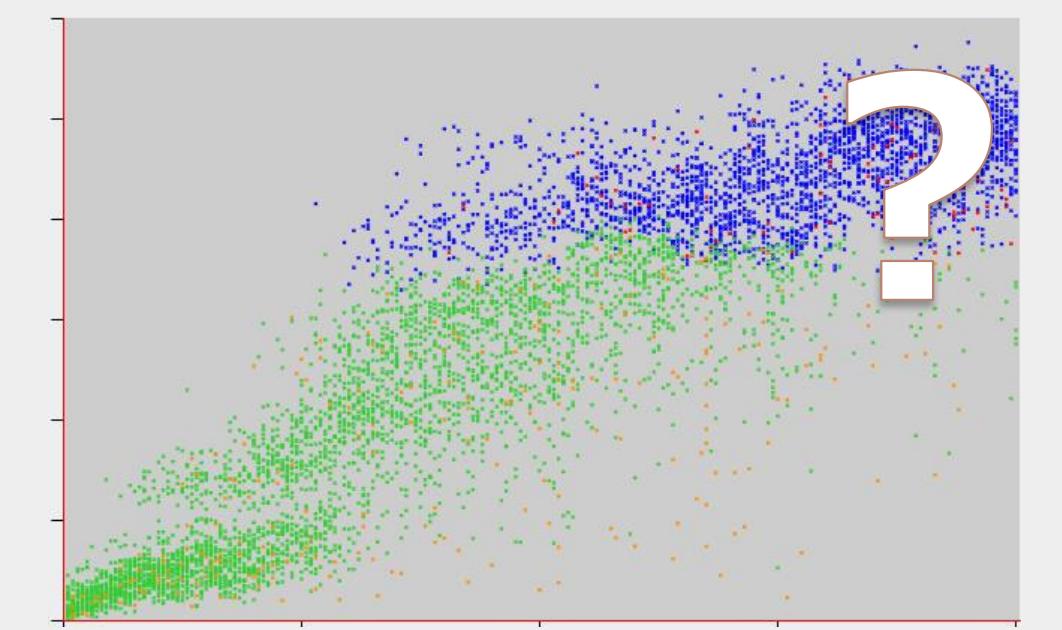
The best party – What was good?



Visualization of the information



This party is strong?
OK, but why?



Visualization tool

- ▶ The visualization should not be costly, and it should be easy to add features, or change existing ones
 - ▶ Requirements keep changing!
 - ▶ Apache Zeppelin
 - ▶ Python / R / Java (Scala)
 - ▶ JDBC / Hadoop HDFS / Google BigQuery / AWS S3
 - ▶ Ad hoc updatable
 - ▶ Scalability

How to show the achievements made by AI

技術

Fitness
(excellence)

Each row details a match's results and its party composition

bid	fitness	results	UHADS	1-Weapon:AI	RolePerformance	memo	1-2Weapon:AI	RolePerformance
1141404	1.15337	★★★★★	0CDDC	THC:UUASTW	47.655(★★★★★)	[ACE] A&H AllAlive	OHC:UUUFF	0.0(----)
1136519	1.14539	★★★★★	0CDDC	THC:UUUFF	58.244(★★★★★)	[ACE] A&H AllAlive	OHC:SUBSTW	0.0(----)
1130954	1.11714	★★★@★	0DDDC	THC:UUUFF	40.307(★○★@○)	[ACE] A&H AllAlive	OHC:SUFSTW	5.603(----)
1130848	1.11048	★★★@★	0DDDC	THC:UUUFF	37.339(★★★@★)	[ACE] A&H AllAlive	OHC:SUFSTW	4.99(----)
1127984	1.10936	★★★@★	0DDDC	THC:UUUFF	38.962(★★@★○)	[ACE] A&H AllAlive	OHC:SUBSTW	0.0(----)
1146588	1.10527	★★★@★	0CDDC	THC:UUBUFW	42.866(★@★★★)	[ACE] A&H	OHC:UUFBFF	0.0(----)
1134594	1.10517	@★★★★	0CDDC	THC:SUFSTW	43.031(★@★@★)	[ACE] A&H AllAlive	OHC:UUFBFF	0.0(----)
1138589	1.1034	★★★@★	0CDDC	THC:UUFSTW	39.217(★★○★★)	[ACE] A&H AllAlive	OHC:UUFBFF	5.459(----)

How to show the achievements made by AI



Summary
of the results

Attention point
for a character

Attention point for
a next character, ...

The screenshot shows a spreadsheet interface with several columns of data. The columns are labeled: bid, fitness, results, UHADS, 1-1Weapon:AI, RolePerformance, memo, 1-2Weapon:AI, and RolePerformance. The data consists of eight rows, each representing a different character or entry. The 'results' column contains star ratings (e.g., ★★★★★, ★★★★☆). The 'UHADS' column contains codes like 0CDDC and 0DDDC. The 'RolePerformance' columns contain numerical values and star ratings (e.g., 47.655(★★★★★), 58.244(★★★★★)). The 'memo' column contains text entries like 【ACE】 A&H AllAlive. The '1-2Weapon:AI' and 'RolePerformance' columns for the last two rows are currently empty.

bid	fitness	results	UHADS	1-1Weapon:AI	RolePerformance	memo	1-2Weapon:AI	RolePerformance
1141404	1.15337	★★★★★	0CDDC	THC:UUASTW	47.655(★★★★★)	【ACE】 A&H AllAlive	OHC:UUUFF	0.0(----)
1136519	1.14539	★★★★★	0CDDC	THC:UUUFF	58.244(★★★★★)	【ACE】 A&H AllAlive	OHC:SUBSTW	0.0(----)
1130954	1.11714	★★★◎★	0DDDC	THC:UUUFF	40.307(★○★◎○)	【ACE】 A&H AllAlive	OHC:SUFSTW	5.603(----)
1130848	1.11048	★★★◎★	0DDDC	THC:UUUFF	37.339(★★★◎★)	【ACE】 A&H AllAlive	OHC:SUFSTW	4.99(----)
1127984	1.10936	★★★◎★	0DDDC	THC:UUUFF	38.962(★★◎★○)	【ACE】 A&H AllAlive	OHC:SUBSTW	0.0(----)
1146588	1.10527	★★★◎★	0CDDC	THC:UUBUFW	42.866(★◎★★★)	【ACE】 A&H	OHC:UUFBFF	0.0(----)
1134594	1.10517	◎★★★★	0CDDC	THC:SUFSTW	43.031(★◎★◎★)	【ACE】 A&H AllAlive	OHC:UUFBFF	0.0(----)
1138589	1.1034	★★★◎★	0CDDC	THC:UUFSW	39.217(★★○★★)	【ACE】 A&H AllAlive	OHC:UUFBFF	5.459(----)

Methods used to make information easier to see

1) Dimensionality Reduction

- Principal Component Analysis

2) Abstraction

- 1) Standard deviation
- 2) Granularity change
- 3) Summarization

1) Dimensionality Reduction

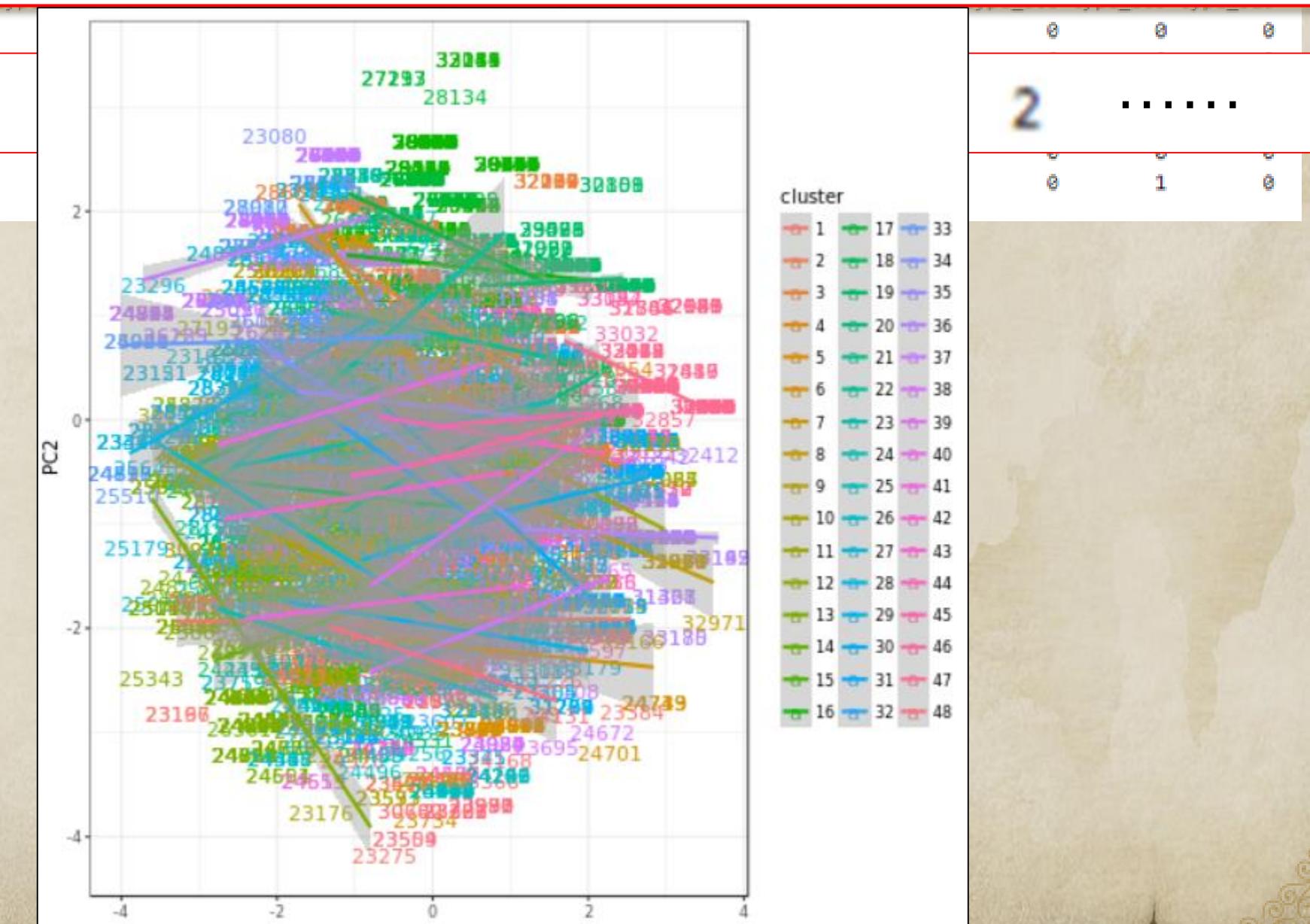
The number of time a specific type of weapon
is equipped in this party

1) Dimensionality Reduction

Party ID Type1 Type2 Type3 ... Type20

1	29842	1	0	0	0	1	0	1
24944		1	1	0	0	1	1	0
6	30350	1	0	0	0	1	1	1

21 dimensions to
2 dimensions



1) Dimensionality Reduction

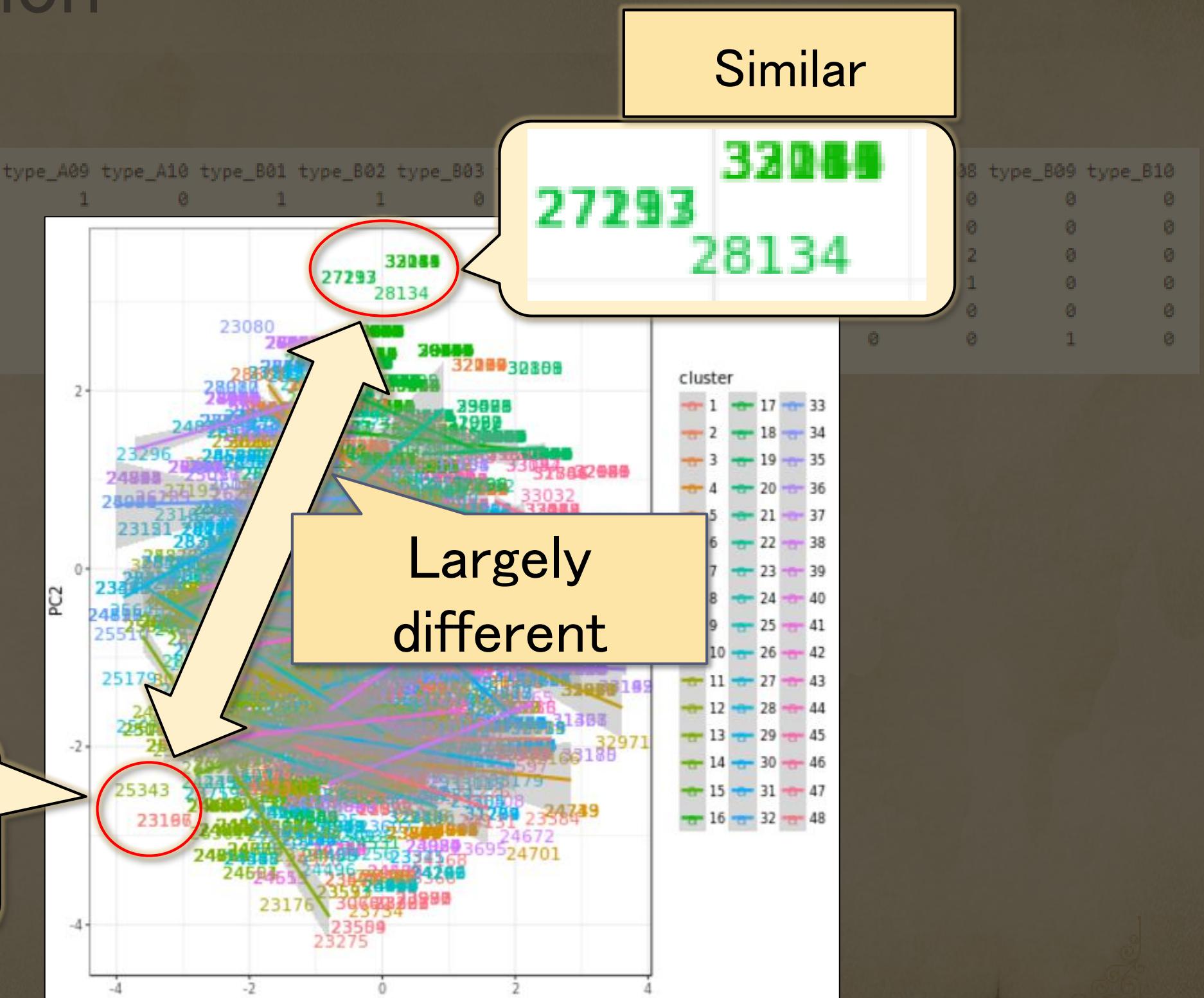


party_id	type_A01	type_A02	type_A03	type_A04	type_A05	type_A06	type_A07	type_A08	type_A09	type_A10	type_B01	type_B02	type_B03	type_B04	type_B05	type_B06	type_B07	type_B08	type_B09	type_B10
1	29842	1	0	0	0	1	0	1	1	0	1	0	0	0	0	0	0	0	0	
2	30398	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	
3	24944	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
4	23792	1	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	
5	23580	1	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	
6	30350	1	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	

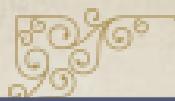
21 dimensions to
2 dimensions

Similar

25343
23100



2) Abstraction – 1) Standard deviation



Status

U = gauge to use Ultimate Skill

HADS = HP/Attack/Defense-Speed

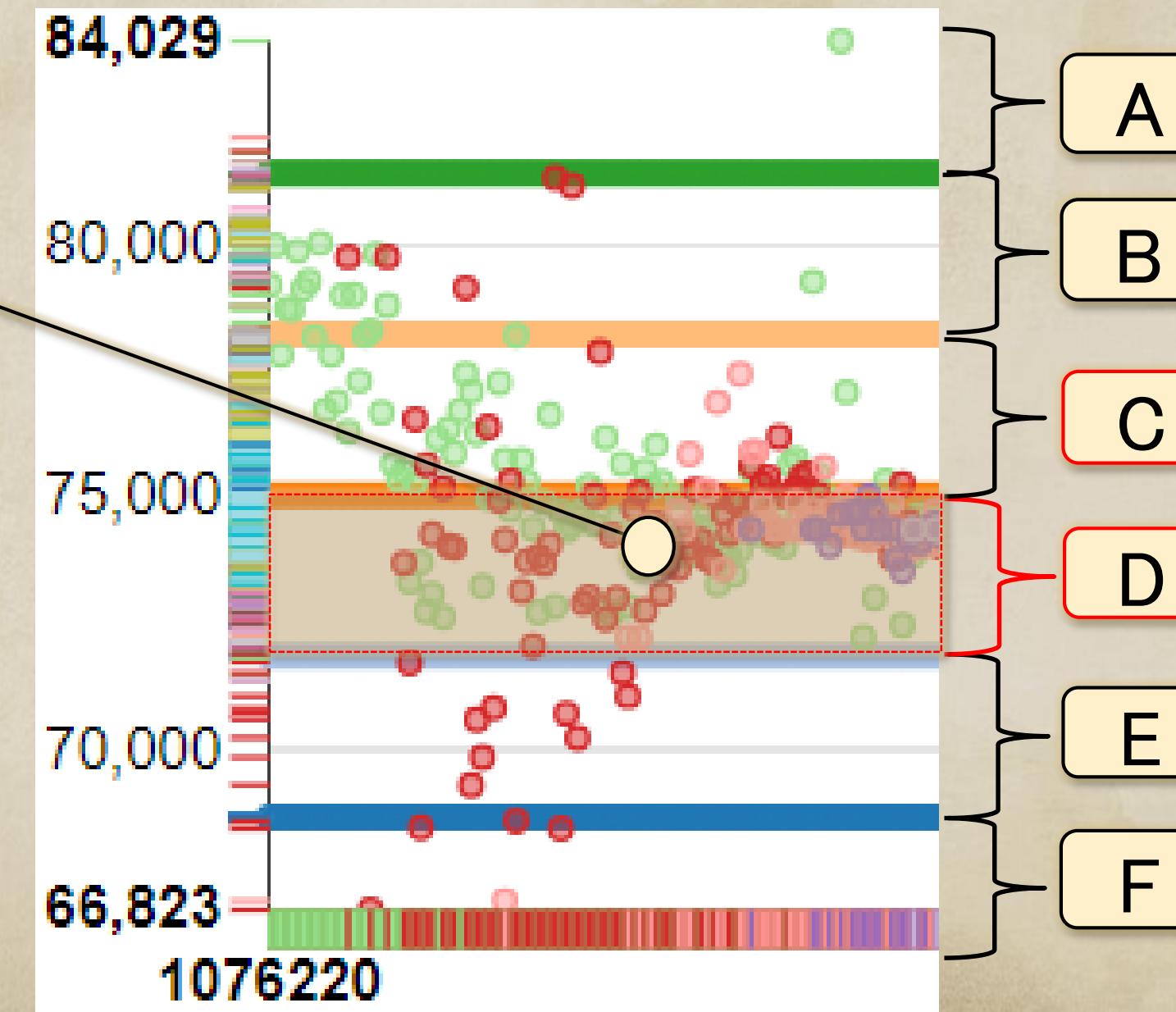
HP: 74000

Is this high?

bid	fitness	result	UHADS	Weapon:AI	RolePerformance	memo	1-2Weapon:AI	RolePerformance
1141404	1.15337	★★★★★ 0CDDC	THC:UUASTW	47.655(★★★★★)	【ACE】 A&H AllAlive	OHC:UUUFF	0.0(----)	
1136519	1.14539	★★★★★ 0CDDC	THC:UUUFF	58.244(★★★★★)	【ACE】 A&H AllAlive	OHC:SUBSTW	0.0(----)	
1130954	1.11714	★★★@★ 0DDDC	THC:UUUFF	40.307(★○★@○)	【ACE】 A&H AllAlive	OHC:SUFSTW	5.603(----)	
1130848	1.11048	★★★@★ 0DDDC	THC:UUUFF	37.339(★★★@★)	【ACE】 A&H AllAlive	OHC:SUFSTW	4.99(----)	
1127984	1.10936	★★★@★ 0DDDC	THC:UUUFF	38.962(★★@★○)	【ACE】 A&H AllAlive	OHC:SUBSTW	0.0(----)	
1146588	1.10527	★★★@★ 0CDDC	THC:UUBUFW	42.866(★@★★★)	【ACE】 A&H	OHC:UUFBFF	0.0(----)	
1134594	1.10517	@★★★★ 0CDDC	THC:SUFSTW	43.031(★@★@★)	【ACE】 A&H AllAlive	OHC:UUFBFF	0.0(----)	
1138589	1.1034	★★★@★ 0CDDC	THC:UUFSTW	39.217(★★○★★)	【ACE】 A&H AllAlive	OHC:UUFBFF	5.459(----)	

2) Abstraction – 1) Standard deviation

HP: 74000



= Volume zone

2) Abstraction – 1) Standard deviation

Status value

HP/Attack/Defense-Speed							
74000 / 27000 / 21000 / 1100							
bid	fitness	results	UHADS	1	THC:JASTW	47.655(★★★★★)	[ACE] A&H AllAlive OHC:UUUFF 0.0(----)
1141404	1.15337	★★★★★	0CDDC	THC:UUUFF	58.244(★★★★★)	[ACE] A&H AllAlive OHC:SUBSTW 0.0(----)	
1136519	1.14539	★★★★★	0CDDC	THC:UUUFF	40.307(★○★○○)	[ACE] A&H AllAlive OHC:SUFSTW 5.603(----)	
1130954	1.11714	★★★	D DDC	THC:UUUFF	37.339(★★★○★)	[ACE] A&H AllAlive OHC:SUFSTW 4.99(----)	
1130848	1.11048	★★★○★	0DDDC	THC:UUUFF	38.962(★★○★○○)	[ACE] A&H AllAlive OHC:SUBSTW 0.0(----)	
1127984	1.10936	★★★○★	0DDDC	THC:UUUFF	42.866(★○★★★)	[ACE] A&H AllAlive OHC:UUFBFF 0.0(----)	
1146588	1.10527	★★★○★	0CDDC	THC:UUBUFW	43.031(★○★○○★)	[ACE] A&H AllAlive OHC:UUFBFF 0.0(----)	
1134594	1.10517	○★★★★	0CDDC	THC:SUFSTW	39.217(★★○★★)	[ACE] A&H AllAlive OHC:UUFBFF 5.459(----)	

2) Abstraction – 2) Granularity change

Characteristics of the Hero AI

bid	fitness	results	UHADS	1-1Weapon:AI	RolePerformance	memo	1-2Weapon:AI	RolePerformance
1141404	1.15337	★★★★★	0CDDC	THC:UUASTW	47.655(★★★★★)	[ACE] A&H AllAlive	OHC:UUUFF	0.0(----)
1136519	1.14539	★★★★★	0CDDC	THC:UUFUFF	58.244(★★★★★)	[ACE] A&H AllAlive	OHC:SUBSTW	0.0(----)
1130954	1.11714	★★★@★	0DDDC	THC:UUFUFF	40.307(★○★@○)	[ACE] A&H AllAlive	OHC:SUFSTW	5.603(----)
1130848	1.11048	★★★@★	0DDDC	THC:UUFUFF	37.339(★★★@★)	[ACE] A&H AllAlive	OHC:SUFSTW	4.99(----)
1127984	1.10936	★★★@★	0DDDC	THC:UUFUFF	38.962(★★@★○)	[ACE] A&H AllAlive	OHC:SUBSTW	0.0(----)
1146588	1.10527	★★★@★	0CDDC	THC:UUBUFW	42.866(★@★★★)	[ACE] A&H	OHC:UUFBFF	0.0(----)
1134594	1.10517	@★★★★	0CDDC	THC:SUFSTW	43.031(★@★@★)	[ACE] A&H AllAlive	OHC:UUFBFF	0.0(----)
1138589	1.1034	★★★@★	0CDDC	THC:UUFSTW	39.217(★★○★★)	[ACE] A&H AllAlive	OHC:UUFBFF	5.459(----)

What was the Hero AI?

For Arena

Hero AI: Little Red Riding Hood

Condition Action

- 1 Negative status
- 2 Surrounded by enemies
- 3 Nearest enemy
- 4 Ultimate Skill gauge is more than 6
- 5 Enemy party healer
- 6 Always

Switch hero and use Switch Skill

Ultimate Skill (melee range)

Run away

Attack (long range)

Ultimate Skill (long range)

Act freely

AI / ON

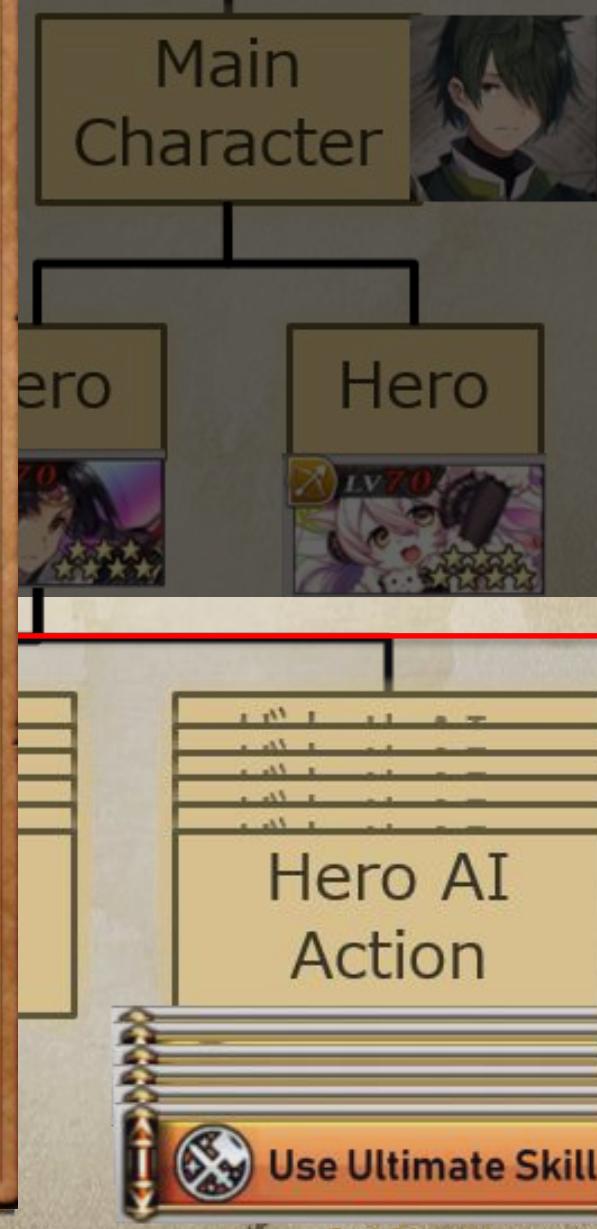
Copy

Paste

0

Add space

```
graph TD; Main[Main Character] --> Hero[Hero]; Hero --> HAI[Hero AI Action];
```



2) Abstraction – 2) Granularity change

Hero AI Actions:

U : “Ultimate Skill” category

- ▶ “Ultimate Skill immediately”
- ▶ “Ultimate Skill (melee range)”
- ▶ “Ultimate Skill (close range)”
- ▶ “Ultimate Skill (long range)”
- ▶ “Ultimate Skill on the same line”

F : “Full combo attack” category

- ▶ “Full combo (melee range)”
- ▶ “Full combo (close range)”
- ▶ “Full combo (long range)”

S : “Switch” category

- ▶ “Switch hero”
- ▶ “Switch hero and use Switch Skill”

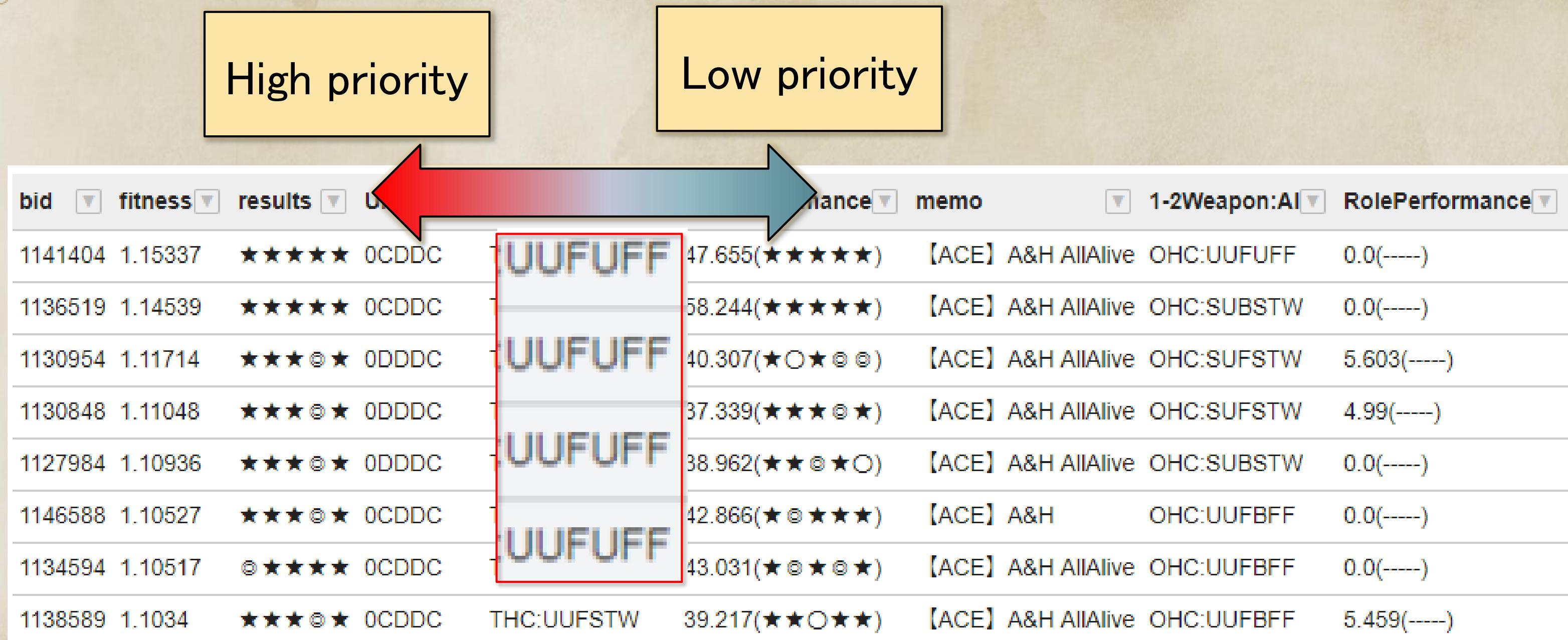
And so on.

2) Abstraction – 2) Granularity change

Characteristics of the Hero AI

bid	fitness	results	UHADS	1-1Weapon:AI	RolePerformance	memo	1-2Weapon:AI	RolePerformance
1130954	1.11714	★★★◎★	0DDDC	UUUFF	47.655(★★★★★)	【ACE】 A&H AllAlive	OHC:UUUFF	0.0(----)
1130848	1.11048	★★★◎★	0DDDC	UUUFF	58.244(★★★★★)	【ACE】 A&H AllAlive	OHC:SUBSTW	0.0(----)
1127984	1.10936	★★★◎★	0DDDC	UUUFF	40.307(★○★◎○)	【ACE】 A&H AllAlive	OHC:SUFSTW	5.603(----)
1146588	1.10527	★★★◎★	0CDDC	UUUFF	37.339(★★★◎★)	【ACE】 A&H AllAlive	OHC:SUFSTW	4.99(----)
1134594	1.10517	◎★★★★	0CDDC	UUUFF	38.962(★★◎★○)	【ACE】 A&H AllAlive	OHC:SUBSTW	0.0(----)
1138589	1.1034	★★★◎★	0CDDC	THC:UUFSTW	42.866(★○★★★)	【ACE】 A&H	OHC:UUFBFF	0.0(----)
					43.031(★◎★○★)	【ACE】 A&H AllAlive	OHC:UUFBFF	0.0(----)
					39.217(★★○★★)	【ACE】 A&H AllAlive	OHC:UUFBFF	5.459(----)

2) Abstraction – 2) Granularity change

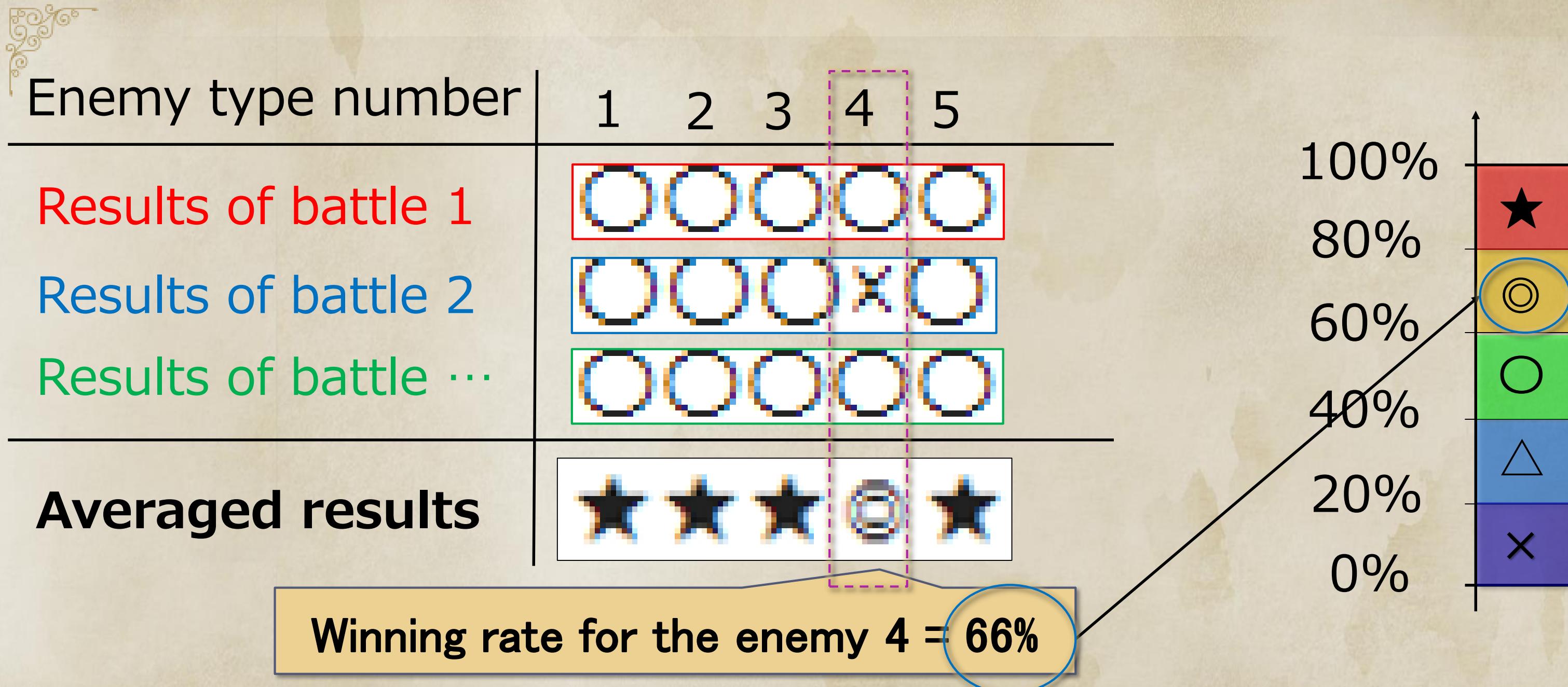


2) Abstraction – 2) Granularity change

Express excellence
by the kind of marks

bid	fitness	results	HADS	1-1Weapon:AI	RolePerformance	memo	1-2Weapon:AI	RolePerformance
1141404	1.15337	★★★★★	0CDDC	THC:UUASTW	47.655(★★★★★)	【ACE】 A&H AllAlive	OHC:UUUFF	0.0(----)
1136519	1.14539	★★★★★	0CDDC	THC:UUFUFF	58.244(★★★★★)	【ACE】 A&H AllAlive	OHC:SUBSTW	0.0(----)
1130954	1.11	★★★★★	0CDDC	THC:UUFUFF	40.307(★○★○○)	【ACE】 A&H AllAlive	OHC:SUFSTW	5.603(----)
1130848	1.11048	★★★@★	0DDDC	THC:UUFUFF	37.339(★★★@★)	【ACE】 A&H AllAlive	OHC:SUFSTW	4.99(----)
1127984	1.10936	★★★@★	0DDDC	THC:UUFUFF	38.962(★★@★○)	【ACE】 A&H AllAlive	OHC:SUBSTW	0.0(----)
1146588	1.10527	★★★@★	0CDDC	THC:UUBUFW	42.866(★@★★★)	【ACE】 A&H	OHC:UUFBFF	0.0(----)
1134594	1.10517	○★★★★	0CDDC	THC:SUFSTW	43.031(★○★○★)	【ACE】 A&H AllAlive	OHC:UUFBFF	0.0(----)
1138589	1.1034	★★★@★	0CDDC	THC:UUFSTW	39.217(★★○★★)	【ACE】 A&H AllAlive	OHC:UUFBFF	5.459(----)

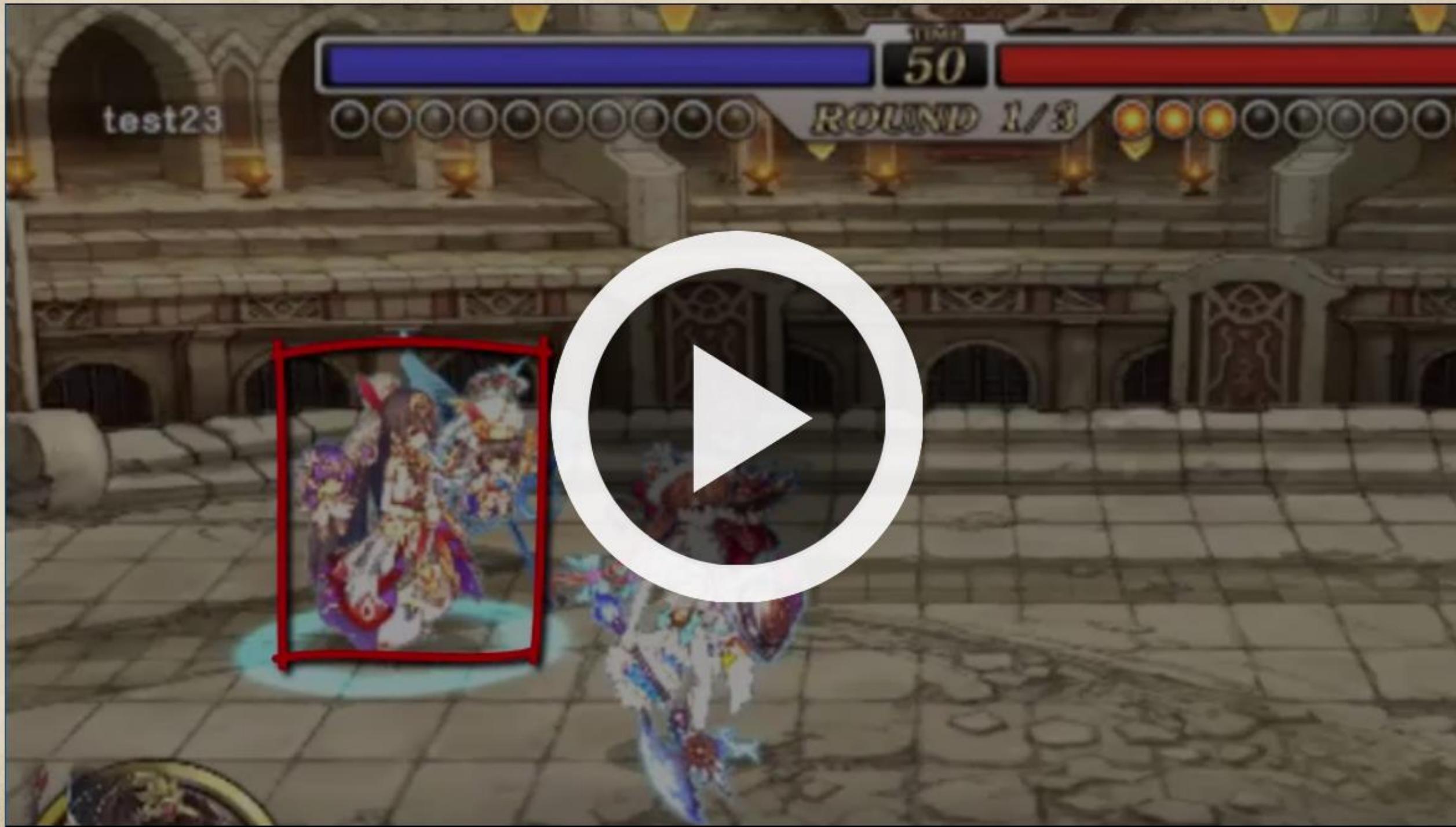
2) Abstraction – 2) Granularity change



2) Abstraction – 3) Summarization

bid	RolePerformance	memo	1-2Weapon:AI	RolePerformance	memo	...
1141404	47.655(★★★★★)	【ACE】 A&H AllAlive	OHC:UUUFF	0.0(----)	DoNotFight	
1136519	58.2	【ACE】 A&H AllAlive	OHC:SUSTW	0.0(----)	DoNotFight	
1130954	40.307(★○★○○)	【ACE】 A&H AllAlive	OHC:SUFSTW	5.603(----)	DoNotFight	
1130848	1.11048 ★★★○★ 0DDDC	THC:UUUFF	37.339(★★★○★)	【ACE】 A&H AllAlive	OHC:SUFSTW	DoNotFight
1127984	1.10936 ★★★○★ 0DDDC	THC:UUUFF	38.962(★★○★○○)	【ACE】 A&H AllAlive	OHC:SUFSTW	DoNotFight
1146588	1.10527 ★★★○★ 0CDDC	THC:UUBUFW	42.866(★○★★★)	【ACE】 A&H	OHC:SUFSTW	AllAlive
1134594	1.10517 ○★★★★ 0CDDC	THC:SUFSTW	43.031(★○★○★)	【ACE】 A&H AllAlive	OHC:UUFBFF	0.0(----)
1138589	1.1034 ★★★○★ 0CDDC	THC:UUFSTW	39.217(★★○★★)	【ACE】 A&H AllAlive	OHC:UUFBFF	5.459(----)

The best character: Scheherazade

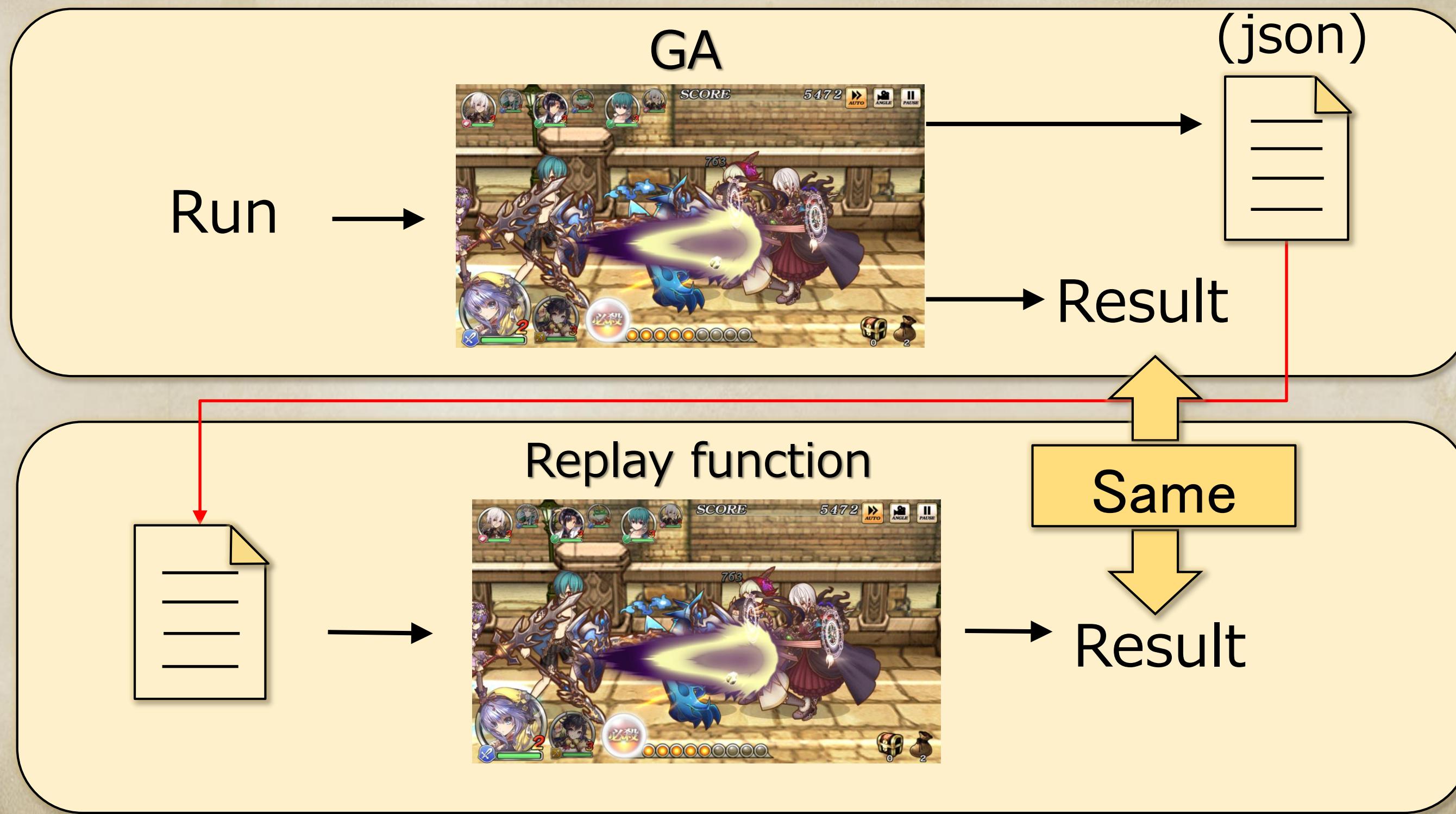


The best support: disable enemies



Battle replay function

Battle information



Is “Scheherazade” a balance breaker?



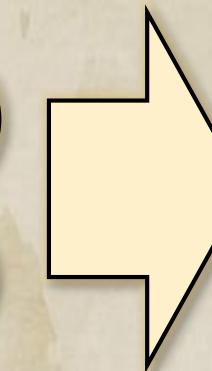
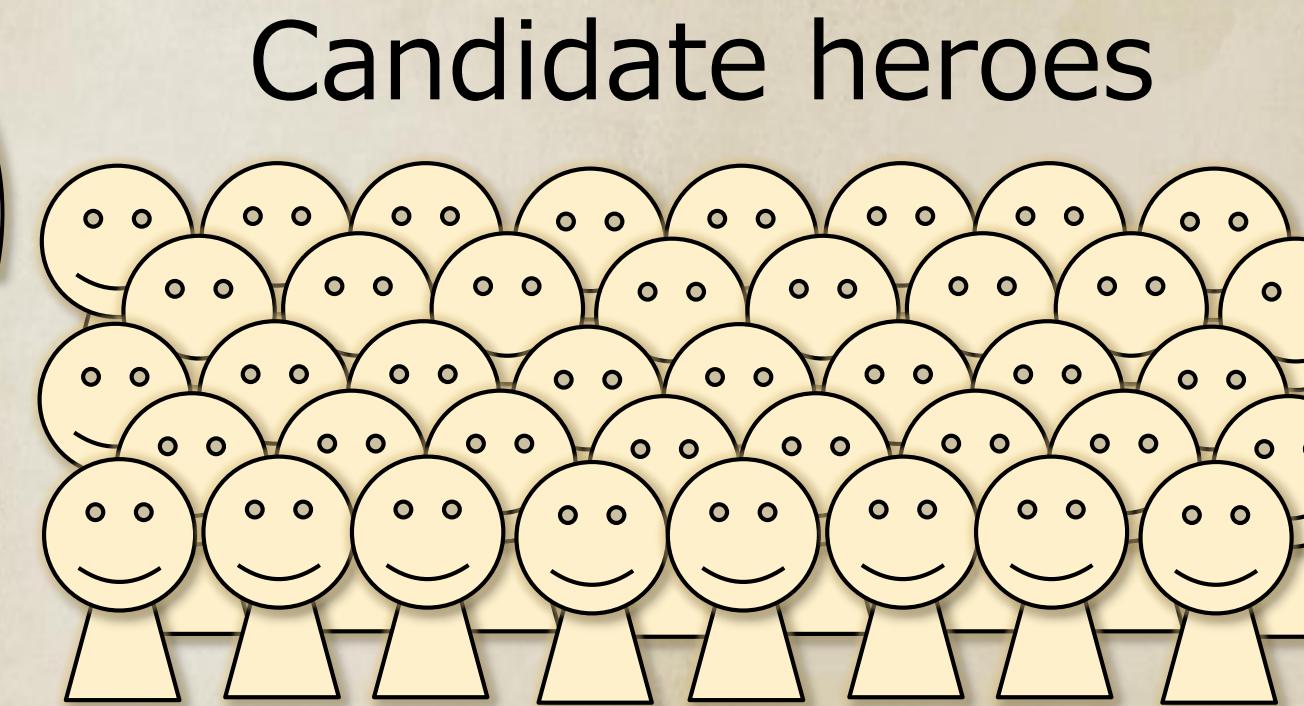
To find other balance breakers



Scheherazade

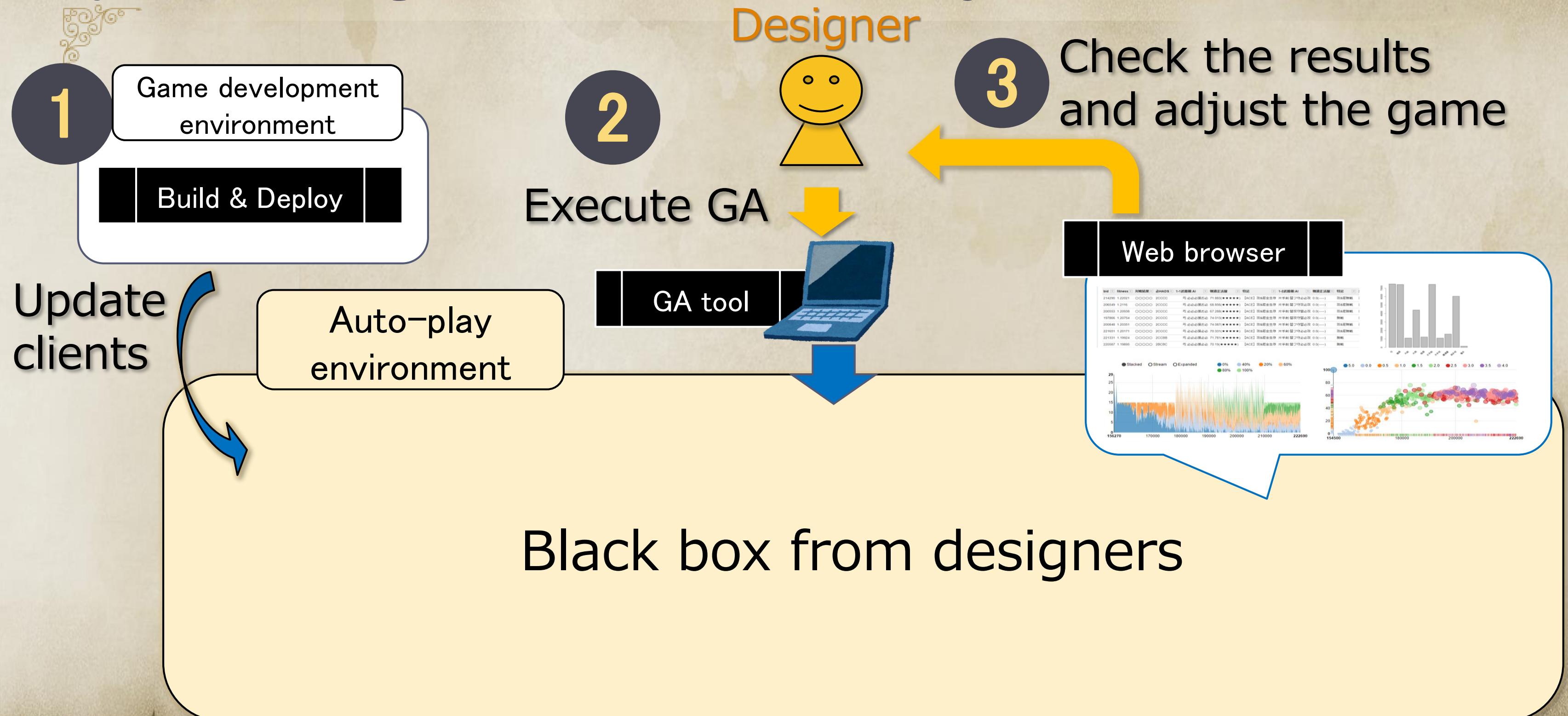


Exclusion



Re-execution
of GA

System configuration for balance adjustment



System configuration for balance adjustment

Designer

1

Game development environment

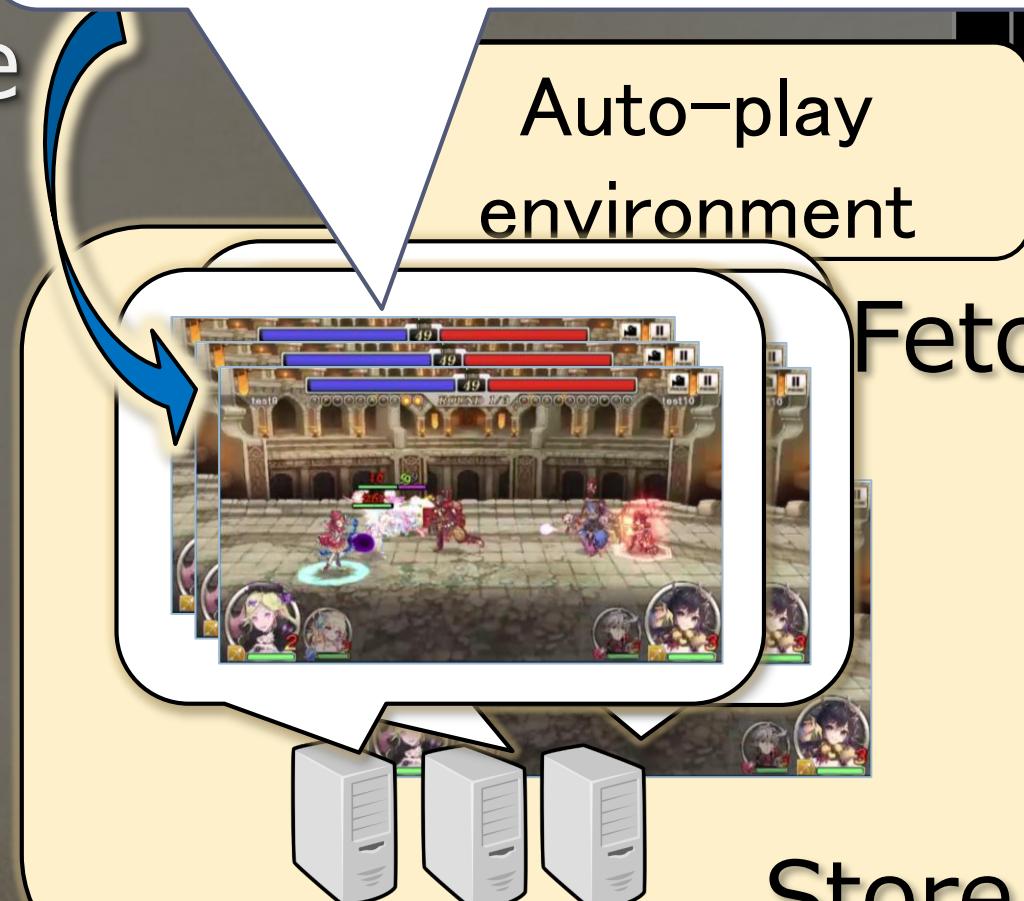
2

Execute multiple game processes on each server

3

Check the results and adjust the game

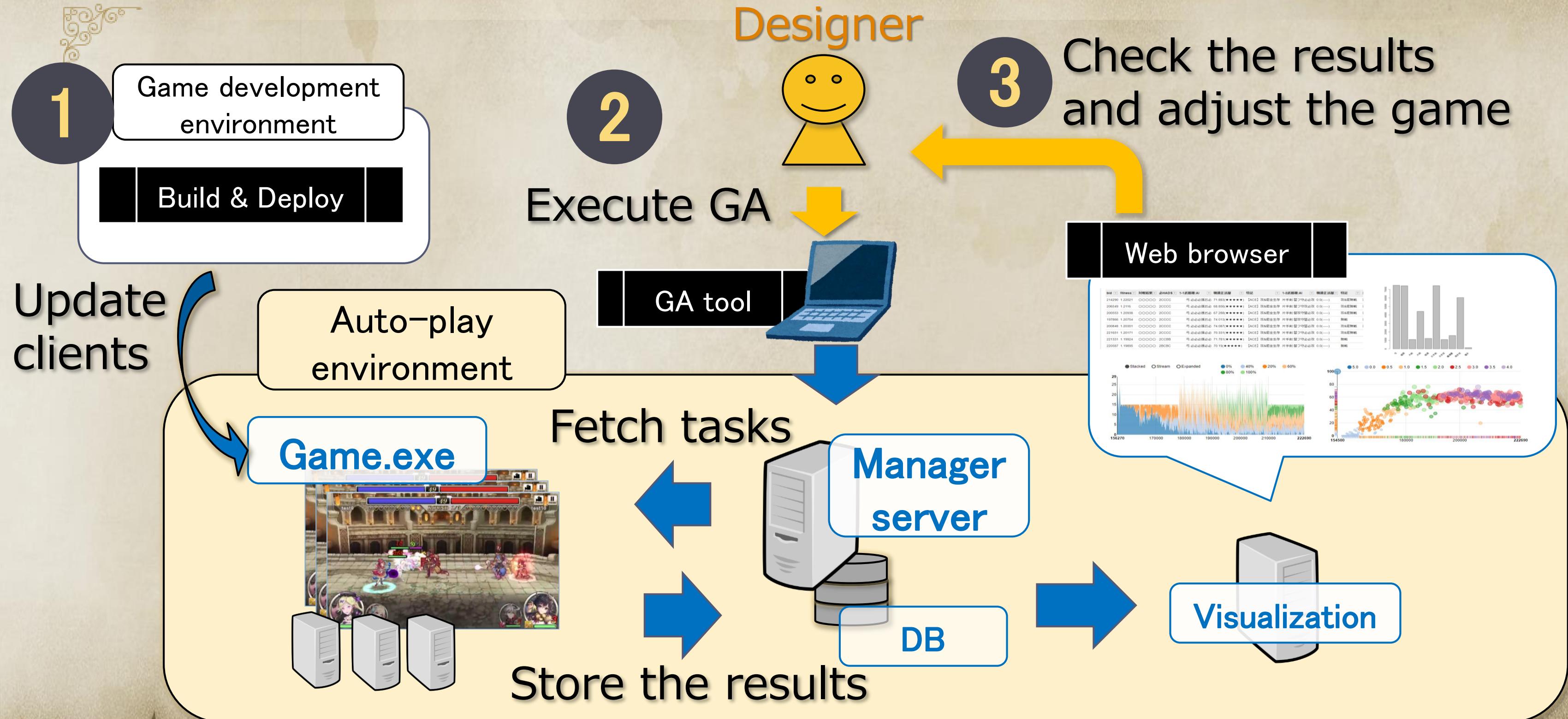
Update clients



Fetch tasks

Store the results

System configuration for balance adjustment

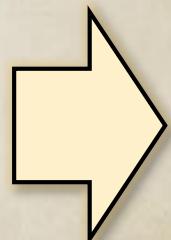


What about performance?

1: Separate simulation

► A simulator that shows battle results by numeric calculation

- + Fast execution: about 1 second / 1 battle
- Not the same precision as actual game
- Updating simulator manually

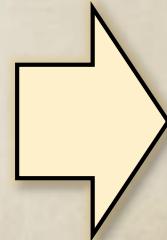


This solution was not kept

2: Use in-game logic

► Connect to the in game logic

- + Guaranteed to be the same as in game
- + Designers can see the results
- SLOW
- COST



This is the current solution



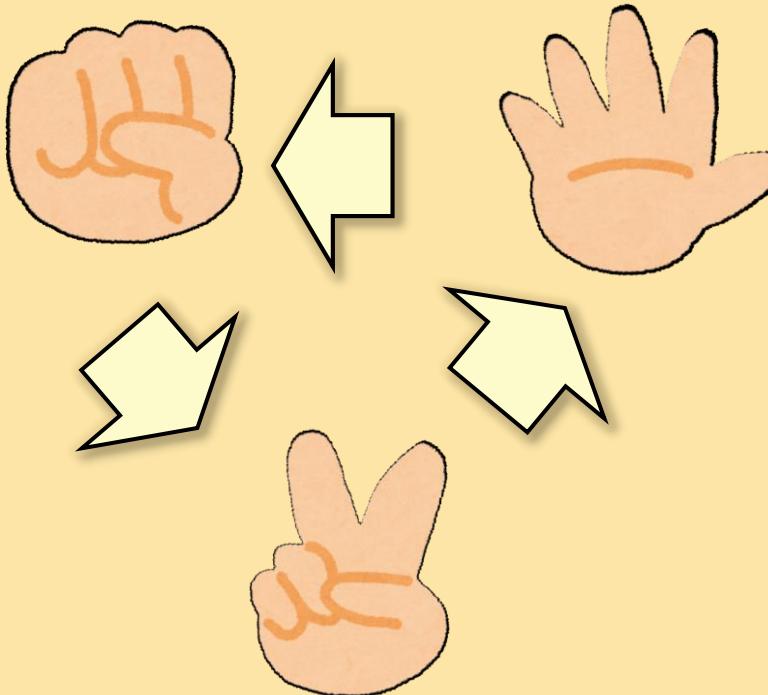
3: What could be the best solution?

- ▶ Use in-game logic
 - ▶ Support accelerated simulation
 - ▶ Run in a cloud
- => These need to be supported by the game code

What could we do next?

► Confirm the cyclic balance

Ideal correlation



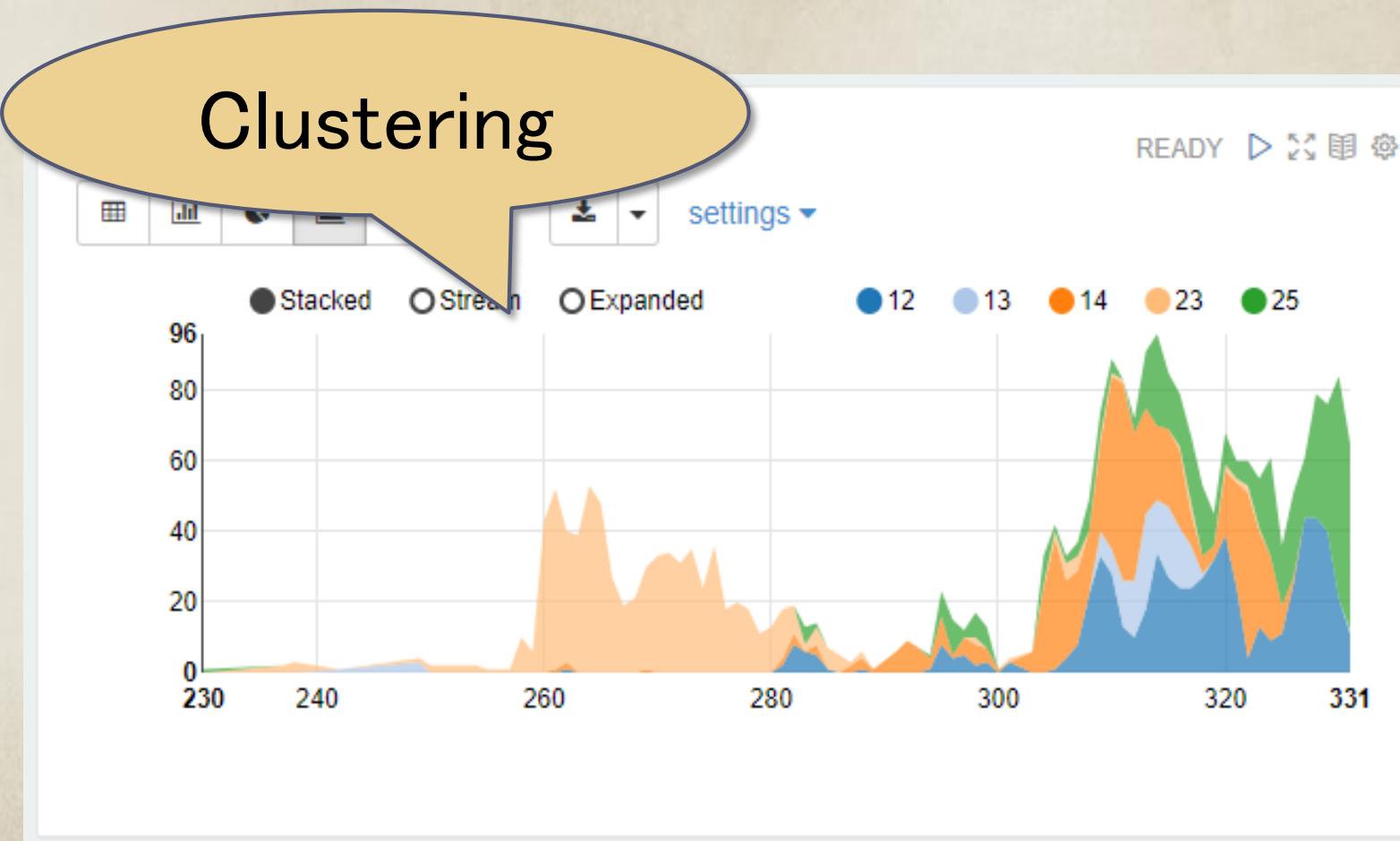
What could we do next?



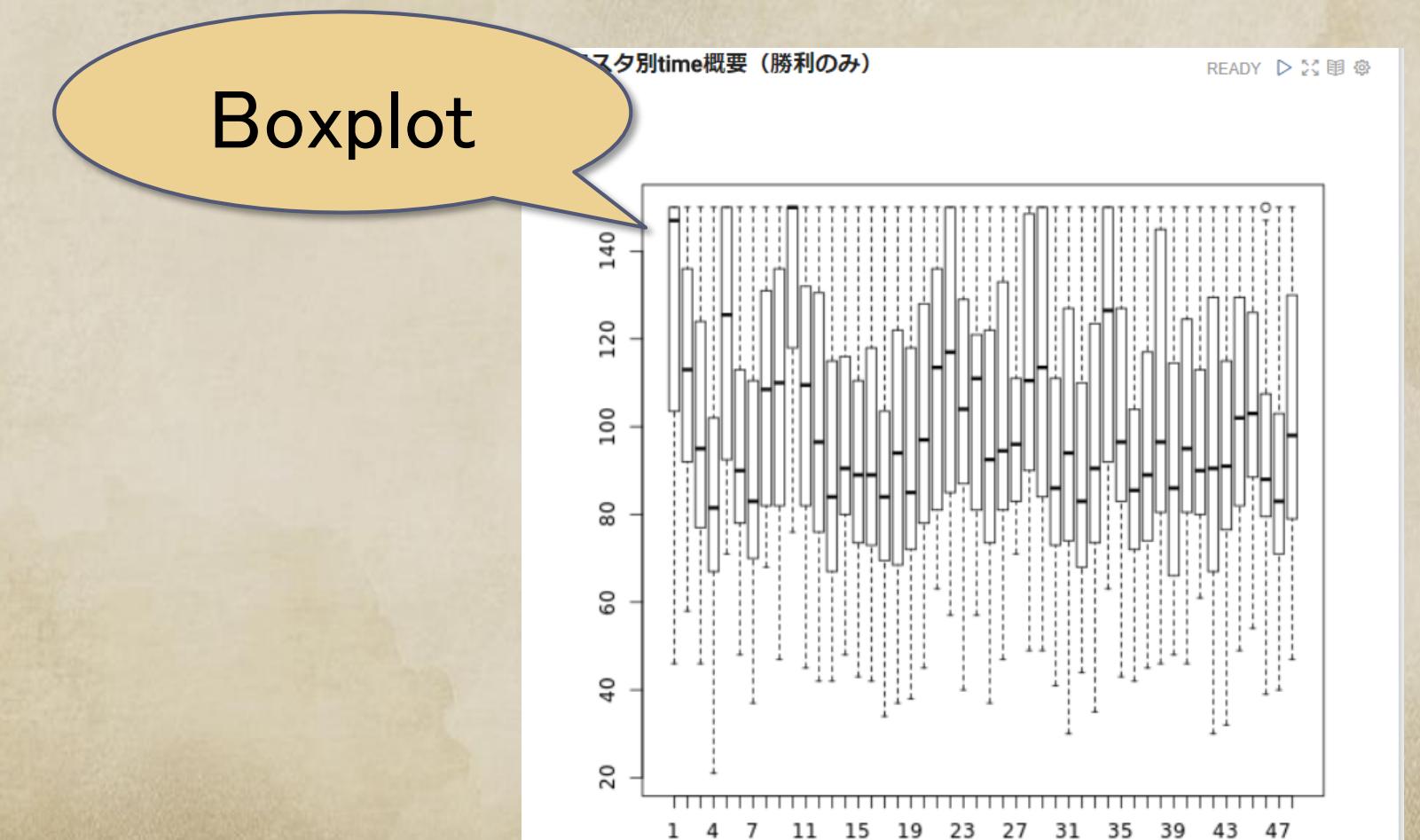
Method for observing growth as a group

- ▶ Clustering of the abstracted party compositions
- ▶ Use boxplot to visualize the potential on a group basis

Clustering



Boxplot



Takeaways

- ▶ Finding strong agent saves you from the nightmare
 - ▶ For example, by Genetic Algorithm
 - ▶ Data visualization and analysis are essential
 - ▶ Auto-play environment should be accurate and updated automatically
- ▶ You should prepare in the early development

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Questions?

Slowly, simply, please!
(Seriously)