DATA ANALYSIS FOR GHOST AI CREATION IN COMMERCIAL FIGHTING GAMES

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ABSTRACT

In this paper we present a simple, rapid and efficient method for creating a ghost AI, an Artificial Intelligence that can imitate playing styles of players in fighting games. The created ghost AI can perform combination actions and make a decision about any movement in a similar fashion to a player it is copying. We scan a player's battle data, and then create situation-action pair cases for its corresponding ghost AI to use in actual battles. A ghost AI can be created and run swiftly, using small amounts of memory, making it suitable for console games. Our method is general enough to be used in most 2D and 3D fighting games. We carried out our experiment on Street Fighter Zero 3, one of the most well crafted fighting games, using AI-TEM testbed engine.

1. INTRODUCTION

1.1 Ghost AI

In fighting games there have been various attempts at ghost AIs (AIs that imitate players). Virtua Fighter 4 allowed players to train computer AIs to fight like them. Such ghosts could then be assigned to fight another player. However, feedback from players was not good at the time the game was released because it was hard to train their ghosts case by case. But in recent years, a ghost AI system has been used once more, in Tekken5: Dark resurrection. This time many things have been changed. Players do not need to train their ghosts in a training mode. They just play the game normally and the system will mechanically create their ghosts. This method makes fighting games more interesting because there will be many fighting styles for computer controlled opponents. Despite the fact that the ghost AI system is being acknowledged as the definitive AI for fighting games, the method for ghost AI creation remains undisclosed. In this paper, we propose a method for ghost AI creation using data obtained from game memory. Our method can be used in most fighting games. It also requires very small amounts of memory and therefore is suitable for console games.

1.2 Street Fighter Zero3 (SFZ3)

Street Fighter Zero3 is regarded as one of the best fighting games of all times. In a fighting game, a player must select one character from many characters, and fight one by one with an opponent character (another player or computer AI). A character can perform normal action such as move, crouch, jump, guard, punch or kick. There are also special attacks, such as firing bullets or executing a powerful flying punch. These special actions can be performed when a player presses a correct sequence of commands at the right time. A player must choose to perform actions in various situations based on the status of his character and opponent character. Getting into action with SFZ3 requires only a few minutes of tutorial. Nevertheless, the game has many ways to play a single character. For that reason, we have chosen SFZ3 as our game for experimenting with the ghost AI.

1.3 Testbed Environment

For the reliability of experimental results, game researchers may want to test their AI on real commercial game environments (Graepel et al 2004). But such environments are scarcely available. Results obtained from a researcher created game may not be convincing enough to warrant an actual use of discovered techniques in genuine games. Some researchers used mod of a commercial game (Spronck et al 2004), or a clone game (Ponsen et al 2005). Some developed test games on their own (Kendall and Kristian 2004) or used a testbed (Bailey and Katchabaw 2005). But none of those methods fit our experimental goal. (Thunputtarakul and Kotrajaras 2006) proposed a system to test AI modules in real commercial games without using any source code. They implemented a testbed from VisualboyAdvance (VBA), a Nintendo GameboyAdvance emulator. The testbed was called AI-TEM. An overview of AI-TEM is presented in figure 1 and its workflow diagram is presented in figure 2. By accessing the memory pool of the emulator, AI-TEM users are able to know states of the game at any particular moment. For fighting games, a state can consist of characters' positions, current animation frames, health points, etc. Users can insert their AI modules, in the form of C/C++ code or python script, into the testbed to control the game characters by providing controller signals. Our work uses AI-TEM as its testbed.

2. OUR APPROACH FOR CREATING GHOST AI

The main concept of our ghost AI creation is case based AI construction. We extracted a player character's reaction in various situations from battle log data created while playing, then produced situation-action pairs for the ghost of that character. Our experiment was made using SFZ3 training mode with character Ryu versus Ryu. AI-TEM was modified to suit our experiment. The ghost AI creation processes are displayed in figure 3. The following subsections describe each component in the process.

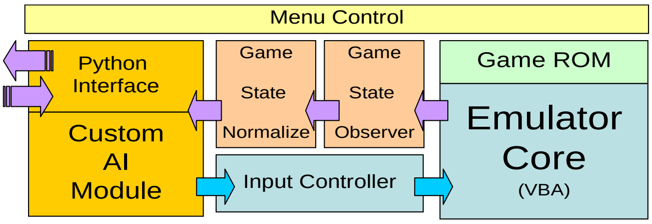

Figure 1: AI-TEM Testbed System Overview.
The Light Blue Modules are VBA Original Modules.

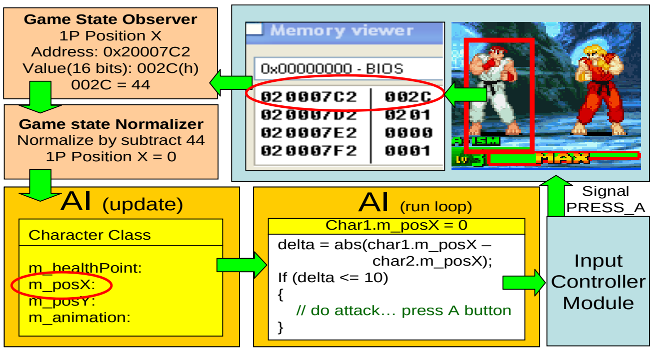

Figure 2: Workflow Diagram of AI-TEM System in SFZ3.

2.1 Obtaining Player Battle Log Data

First, while a player is playing, game states data need to be dumped from memory onto a battle log file. The data are used to identify each case in the case based AI system. The data consist of characters animation, characters positions in x and y axes, characters health points, characters bullet positions in x axes, damage that characters obtain in that frame, player character's facing direction and the corner status of characters. Recorded battle log data is in the following form:

```
Frame Data no: 00001
P1:Ani=002,X=120,Y=40,bullet=0,damage=0,HP=90
P2:Ani=002,X=240,Y=40,bullet=0,damage=0,HP=90
  :
Frame Data no: 00720
P1:Ani=016,X=150,Y=40,bullet=0,damage=0,HP=30
P2:Ani=030,X=560,Y=40,bullet=0,damage=5,HP=20
```

These criteria can change depending on game or user. Creating the ghost AI while the game is running without creating the battle log file is possible if complete information about the game mechanic is known (such as short or shared animation frame, that will be described in section 2.3). For SFZ3 on AI-TEM, we did not have such information. Therefore we had to use the log file.

2.2 Animation Set Database

An animation set database is used for identifying whether a character animation frame belongs to an animation set. An example is illustrated in Figure 4. Ryu animation frame number 0 to 6 belong to animation set ID 0, which represents Ryu's standing animation, while frame number 707 to 713 belong to Ryu's medium punch action, set ID 15. Together with the battle log file, the animation sets are used to create situation-action pair cases. In our experiment, we manually defined this database. There are totally 912 frames for character Ryu. This seems daunting. However, it is relatively easy for a game company to do because any game development team usually has access to animation data.

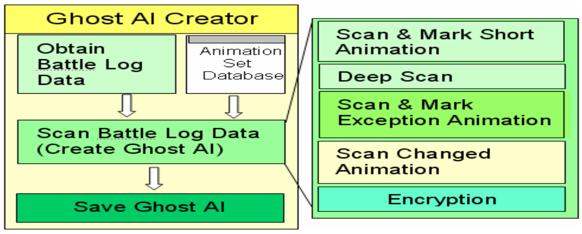

Figure 3: Ghost AI Creation Processes.

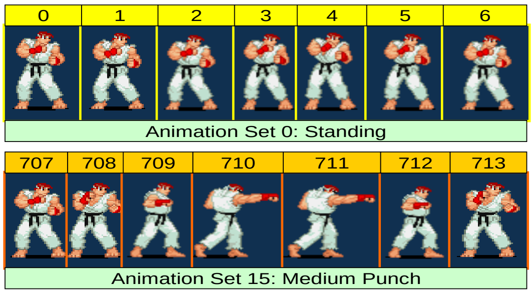

Figure 4: Example of Animation Set Database.

2.3 Scanning Battle Log Data

This process scans through every frame of a player's battle log data, trying to find which situation the player decided to begin his new animation set. For example, in situation *A* player1 is standing on the ground at position x=120 and player2 approaches player1 by jumping in the air at position x=150, both characters have full health bars and no bullets. Player1 decides to perform the special anti-air attack called Shoryuken punch. In short, the following situation-action pair will eventually be created:

```
if (Situation == A) do SHORYUKEN;
```

Now we look at this process in more detail. The process contains the following subtasks:

2.3.1 Finding Short Animation

Short animation means any animation that occurs for a very short period of time. It takes place mostly when a character is changing over from any standing animation loop to crouching animation loop. See an example animation time frame in figure 5. In figure 5, our character is standing then intends to do a crouching kick, but the crouching kick is not performed immediately. Before the crouching kick is carried out, a short period of moving forward and crouching animation is performed. This can happen due to the player not inputting the right command. For a crouching kick to be performed correctly without any prefix animation, the player needs to press down and kick at the same time on his control pad. In figure 5, the player presses down before kick and also unintentionally presses forward at the same time as down. Therefore extra animation is triggered. Nevertheless, the crouching kick is eventually performed and the prefix animation is so fast a human eye cannot see. We cannot avoid such minor mistakes made by players.

In our ghost AI model, detected animation frames tell us about a player's intention. Therefore, having the short animation taking place before the intended animation can misinform us. We must either identify a player's intention from the overall animation or get rid of the short animation before processing. In our experiment, we chose to do the latter.

All battle log data need to be scanned to find which animation set appears unusually brief, then that set is marked. Marked animation will not be considered when creating the AI. For a set of animation to be considered short, it depends on the set. In our experiment with SFZ3, short animation was no longer than 6 frames for most of the animation sets. The only exception was the crouching animation, of which short animation was no longer than 14 frames because changing from standing to crouching already took 8 frames.

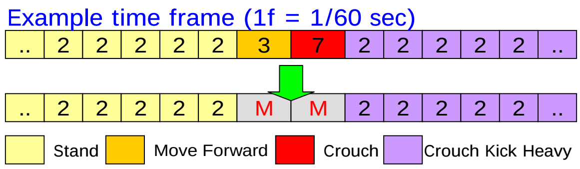

Figure 5: Short Animation Marking.

2.3.2 Deep Scanning

Some animation frames are shared between many animation sets. In such case, scanning ahead becomes necessary in order to identify the correct animation set. For example, jump straight, jump forward and jump backward begin with the same animation frames at the beginning. With the first frame obtained, we can only conclude that the character is doing an anonymous jump. With further scanning, we then know which jump the player intends to do and can go back to change from an anonymous jump to a specific jump. This step can be omitted if the controller signal can be completely analyzed. But this is not always the case.

2.3.3 Exception Animation Sets

Some animation sets should be omitted from our case base because they do not take place under players' control. Obvious examples are various damage animation sets. They occur as the results of opponent attacks. This type of animation that appears in the battle log data will be marked here.

2.3.4 Scanning Changed Animation

This step is the core of our ghost AI creation. After matching all animation frames to their corresponding animation sets and marking useless animation, it is time to scan the battle log data once more to find the situation that causes the player character to change its animation. Such situation and the changed animation set that it causes will be paired to create a situation-action case.

An example is shown in figure 6, where a player executes a crouching heavy kick. In 7^{th}-8^{th} frame, our character changes its animation set from standing to moving forward. But moving forward lasts only 2 frames so it is a short animation. It is marked useless and the next animation to consider will be crouching. However, this crouching is also a short animation and therefore marked useless (a proper crouching must last 14 frames or more). As a result, the next animation (crouching heavy kick) will be taken into account. The crouching heavy kick does not fit the useless animation category, so it is regarded as the changed animation set. Therefore the (situation at 7^{th} frame, crouching heavy kick) is added to the case based AI.

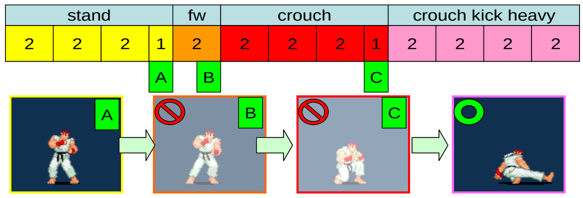

Figure 6: Scan Animation Change.

2.3.5 Situation Encryption

If the game needs to compare ten or more criteria (animation, position, bullet, etc.) to judge whether the current situation in the game is the same as any existing condition in our situation-action database, it will be a waste of processing power. Any game situation should be defined in simple form for easy comparison and discovery. We propose a method to encrypt a fighting game state situation into a 32-bit integer (capable of holding 4,294,967,296 values). The bits can be divided into small 1-8bits sections as shown in table 1.

Table 1: Detail of Situation Encryption.

Bit no.	nBits	nValues	Meanings
1-8	8	256	Player character animation set ID. [As said in section 2.2]
9-12	4	16	Delta position in X axis. [Divide distance into 9 ranges]
13-14	2	4	Delta position in Y axis. [Divide distance into 4 ranges]
15-18	4	16	Enemy character state. [Group into 6 stages: Normal, Attacking, Blocking, Dizzy, Damaged, Invulnerable]
19	1	2	Character's bullet state. [Have or not]
20-22	3	8	Delta position in X axis between player character and enemy's bullet. [Divide distance into 8 ranges]
23-29	7	128	Damage value that enemy got in that frame (use for combination attack decision).
30	1	2	Player character side. [Left or Right]
31	1	2	Is player at corner. [Yes or No]
32	1	2	Is enemy at corner. [Yes or No]

There are ten criteria that we use for identifying the game state (ten rows in table1). Bit 1 to 8 store the animation set ID of the action that the player character performs in that frame situation. The animation set value comes from the animation set database described in section 2.2. When the player character is in any normal standing frame (frame id 0 to 6), the value in the first 8 bit will be 0. As a brief example, the situation that two characters are standing at the beginning of a battle will be encrypted as "1,792". Every criterion for this particular scene will have 0 as its value, except the delta position in the x axis, which will have its value equal to 7 due to the distance between characters at the beginning of battle (150 units). Details of this encryption can be changed to match other games or other platforms.

2.4 Creating Ghost AI File

When the scanning process discovers that animation set change takes place, the situation in the frame before that discovered frame is encrypted into 32-bit data (integer) by the process in section 2.3.5. Its corresponding case base can now be created by combining the situation ID (32-bit situation encryption result) with its response action list. An example of our case base is shown below.

```
SituationID: 0000000000
TotalRatio: 03 TotalNextAni: 02
    NextAni: Punch-Light-Close Ratio 2
    NextAni: Kick-Heavy-Close  Ratio 1
:
SituationID: 2684356352
TotalRatio: 01 TotalNextAni: 01
    NextAni: Hadouken          Ratio 1
```

Each case will have `situationID` for representing each game situation. `TotalRatio` is the number of incidents the player encounters that situation. `TotalNextAni` is the number of different animation sets that the player performs when facing that situation. It is followed by the list of those animation sets and the number of times the player performs each animation set. The ratio of each animation set and the total number of sets will be used in response selection while the ghost AI is actually running.

From above example cases, the player encountered situation 0 three times and decided to do a light-punch twice and a heavy kick once. These cases should be kept in a data structure that is convenient and fast to insert and find because we need to know whether the situation is a new situation that player never encounters (so we can add new data from scratch), or an old situation that updates the response action list. In our experiment we chose *map* of standard template library (STL), which is a balanced binary search tree, to store the cases. The tree was written into our ghost AI file. Using file allows for future modifications of the knowledge base.

3. USING GHOST AI

To run the ghost AI, first, the game needs to load any required database such as the animation set database. Then it needs to load the ghost AI case base into some data structure that allows quick finding and matching. A new case is never inserted while running the ghost AI.

From the data in section 2.4, the game first loads all cases into the *map*. When the `situationID` 0 takes place, the case that has `situationID` 0 in the *map* is searched. It will be found and returned. That case has a total ratio of 3 and has two next animations (light-punch with ratio 2 and heavy-kick with ratio 1). The game then randomly selects one of these actions corresponding to the ratio value and sends a command to perform that action.

When a ghost AI is running, if used with a suitable data structure such as a balanced binary search tree, searching any case is guaranteed to use $O(\log n)$ amount of time (when n is the number of cases). A ghost AI with one thousand cases should find a result in the tenth search. Each case based data uses approximately 40 bytes of memory. Therefore, a thousand-case ghost requires only 40KB of memory. In short, creating and running our ghost AI does not slow down the game or consume much memory at all.

4. VERIFYING METHOD AND RESULTS

The best way to evaluate a ghost AI's similarity to its creator should be: letting its creator verify with his own eyes. But sometimes, people can make incorrect judgments, forgetting even their own playing styles. Therefore we designed a measurable method for evaluating the ghost AI.

4.1 The Experiment

We appointed thirty two SFZ3 players and let them play the game for approximately 2 to 10 minutes. We recorded their game events in VMV file format (recording the beginning game state and controller sequence) and created their ghost AI. After that, we let the player semi-play the game again two more times, while their ghost AI was playing and while their own playing movie was playing. The term semi-play means players see their ghosts or their own movies playing while pressing the controller, imagining that they are controlling their characters in that situation. We wanted to compare the controller signals of the ghosts with the players' signals. We also wanted to compare the players against their video.

Controller signals should not be compared frame-by-frame, because only 1 frame delay (1/60 second) will cause the rest of the matching process to fail.

Therefore the controller signals need to be normalized before any comparison can be done. In our approach, we normalized the signals by splitting the signals into parts. Each part contained approximately 5 to 15 signals. After that, we combined all the same signals that appear continuous into one signal (when a player presses one button normally, it takes approximately 6-8 frame, so it gives out 6-8 continuous signals). For example, if the signals are as follows:

```
Raw ghost signal:
16,16,16,32,32,32,64,64,64,64,128,128,256,256,256
Raw player signal:
16,16,16,16,16,16,32,32,32,32,64,64,128,128,128
```

After normalized they will be like these.

```
Normalized ghost signal: 16,32,64,128,256
Normalized player signal:16,32,64,128,0
```

It can be seen from the example that if we compare raw signals directly the result will be 3 of 15 signals match. The matching result is not correct because identical commands that are pressed for slightly different amount of time will be regarded as being different. However, if we compare the two signals after our normalization, the match is 4 out of 5.

We had two methods for slicing controller signals. In the first method, we sliced every 15 frames. We had tried several values and this value gave the best result. Too small values made the normalization meaningless, while too large values put more than one signals in the same frame, making the result unreliable. In the second method, we performed the slicing every time the signal of the ghost AI or the player movie changed values, based on the assumption that matching signals should occur in the same frame time period as its counterpart. With the second method, we always had one signal per slicing window. We also gave score if there were some similarity between controller signals. For example, if the ghost AI was pressing down-forward and the player was pressing forward only, we gave similarity score of 0.5 (50%) to the ghost AI.

4.2 Result

The result of our experiment is illustrated in figure 7 and table 2. *Player_Player%* is the similarity (in percentage) between each player's own movie and his actual control when re-playing the situation in the movie. *Ghost AI_Player%* compares each ghost AI with its corresponding player's re-play. *Delta*% is the difference between the two comparisons. Table 2 displays the overall statistical summary. *Delta A* and *Delta B* indicate delta percentage points between the result of [player's own movie vs. player] and [ghost AI vs. player]. *Score* is the score that the players evaluate their ghosts' similarity to their fighting styles based on their feelings.

Both signal slicing methods gave similar results. But the second method gave less matching percentage points. This is likely because the number of signals after the normalization was less than in the first method. With many long signals in play, such as idle signals, the first method scored better because it did not compress long signals into one signal. For the first method, the average similarity between ghosts and the players is 26.33%. This may seem small. But if we look at the comparison between the players and their own movies, the similarity is only 34.96%. The ghosts' performances were therefore very close to players' performances (75.31% close). Some ghosts even scored better than their corresponding players.

An average satisfactory score given by players is 72.2%, which is good. The players thought that the ghosts sometimes performed more attacks and fewer defenses than their creators. Some players could not distinguish between their ghosts and their own movies while semi-playing. (We did not tell the players which engine was really controlling the characters).

5. CONCLUSION AND FUTURE WORK

We propose a method and concept for creating ghost AI without having to know game source code. We used AI-TEM, an emulator based testbed to provide a commercial game testing environment. Our concept for ghost AI creation is general for all fighting games. Using SFZ3, which is a very well respected commercial game, with its basic systems being used in almost all fighting games, our findings are guaranteed to be applicable to other commercial games.

Our method produces good results. Ghost AIs display their creators' playing styles even when the training time is short. The two-minute average training time we used is equal to a match time in an average fighting game.

For future experiment we are interested in exploring techniques for ghost AI in team based fighting games, where characters can cooperate. Another interesting future work is developing AI that can adapt and counter an opponent's play style.

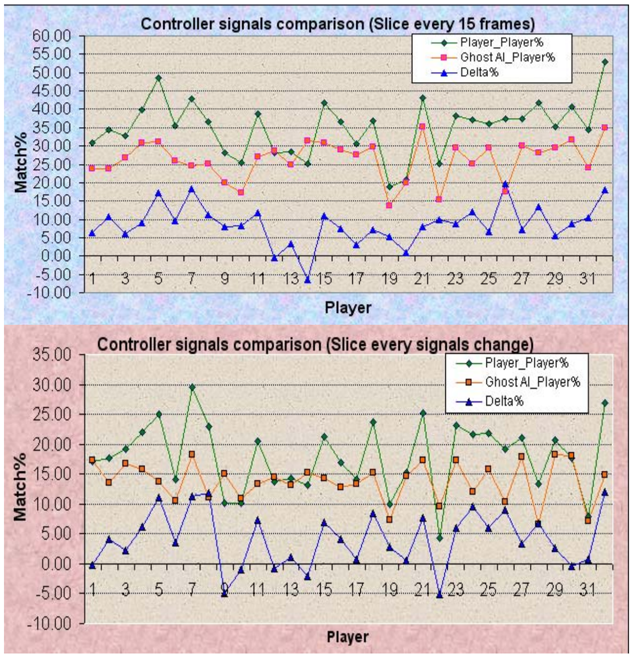

Figure 7: Players vs. Movies and Players vs. Ghosts.

Table 2: Summary Result of Experiment. A: Slice Every 15 Frames, B: Slice Every Time When Signal Change.

Summary	Player_ Player A	Ghost AI_ Player A	Delta A	Player_ Player B	Ghost AI_ Player B	Delta B	Score
Min	18.81	13.6	-6.45	4.37	6.54	-5.18	44
Max	52.84	35.18	19.82	29.51	18.27	12.03	90
Average	34.96	26.33	8.62	17.93	13.81	4.12	72.2

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