

# Optimization of Character Gaze Behavior Animation using an Interactive Genetic Algorithm

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## Abstract

Character animation is required to appear as natural as human motion. Toward that goal, the approach that is followed is to ensure that the expression appears as natural as human expression by adding gaze behavior to the contextual situation and by adjusting the environment to the general behavior animation. However, a detailed understanding of some gaze control parameters is required for users to create the intended gaze behavior animation that is suitable for situations in which the gaze controller is used. It is difficult for beginners and users who are inexperienced in creating character animation to ensure that the user feels adequate because trial-and-error adjustments are required. In this paper, we propose a method for optimizing character gaze behavior animation by using an interactive genetic algorithm (IGA) based on the viewer's preference such as "where to gaze" and "how to gaze" without the need to manually set the gaze control parameters. We translate a character's gaze motion into parameters for the gaze controller. Furthermore, we obtain the optimized gaze target and control parameters such that the viewer experiences natural gaze animation when using the IGA. The experiment compared the viewer's impression of the method and the result they obtained by using manual creation with that obtained by the proposed method. The results confirmed that the proposed method enables the user to quickly and easily create gaze behavior animation of the same quality possible by using manual creation.

**Keywords:** character animation, gaze behavior, interactive genetic algorithm

## 1 Introduction

Character animation is required to appear as natural as human motion. Toward that goal, the approach that is followed is to ensure that the expression appears as natural as human expression by adding gaze behavior to the contextual situation and the environment to enhance the animation of general behavior.

Recently, the use of any 3DCG software enables gaze behavior animation to be created. This software has a gaze controller that rotates joints, such as the eyes, head, and chest, by specifying a gaze target for personal use. However, a detailed understanding of some gaze control parameters is required for users to create the intended gaze behavior animation that is suitable for situations in which the gaze controller is used. It is difficult for beginners and users with little experience to create character animation the user considers adequate because trial-and-error adjustments are required.

In this paper, we propose a method for optimizing the character gaze behavior animation based on the viewer's preference such as "where to gaze" and "how to gaze" without the need to manually set the gaze control parameters.

We translate a character's gaze motion into parameters for the gaze controller. In addition, we obtain the optimized gaze target and control parameters for the natural gaze animation the viewer felt when using the Interactive Genetic Algorithm

(IGA).

Our optimization system incorporates users' experience when watching a character animation. Then, suitable parameters are calculated for the gaze controller based on the viewer's preference. The user can use the system to create character gaze behavior animation based on their impression of the animation. Therefore, the animation the user would be expected to create would consist of both the intended animation and the animation that seems to be suitable for the scene although the latter is different from the initially envisioned animation.

## 2 Related Work

The behavior of turning one's gaze to a target is one of the important factors to consider when improving the expression of character animation [1].

Therefore, example-based [2, 3, 4, 5] and movement characteristic-based [6,7] gaze behavior controllers that rotate joints, such as the eyes, head, and chest, are proposed to adaptively turn one's gaze to arbitrary targets. Previously [8, 9], researchers were able to select a suitable gaze target based on cognitive features and generate gaze behavior consisting of turning one's gaze to the selected target in order to carry out an action based on the contextual situation and environment. In addition, a gaze controlled model was proposed [10] to stylize the gaze behavior animation of several characters.

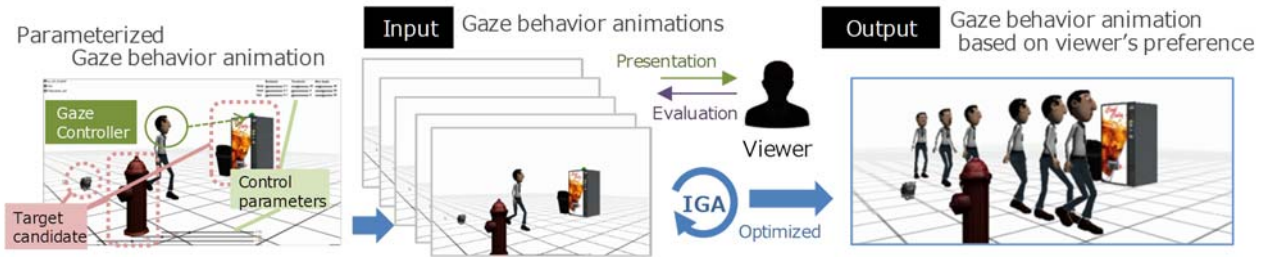


Figure 1: Overview of the proposed method.

Recently, it became possible to use a gaze controller on any 3DCG software for personal use [11].

However, setting the control parameters manually requires time, effort, and a trial-and-error approach to create the ideal gaze animation.

The use of an interactive genetic algorithm (IGA) is a method of interactive evolutionary computing that generates an optimized solution based on the user's subjectivity. The IGA method is based on the genetic algorithm (GA), in which the population is evaluated by the user. IGA has been applied to research in the field of computer graphics [12].

We previously proposed an optimization method based on IGA for gaze behavior animation [13]. In this research, we focused on gaze behavior that turns one's gaze to the intended target beforehand.

Therefore, in this paper, we propose a method that supports the creation of character gaze behavior animation including the subject of selecting a suitable gaze target from multiple candidate targets.

### 3 Our Approach

Our approach involves generating the gaze behavior animation in the scene by evaluating the appropriateness of the character animation based on the viewer's preference. Figure 1 shows an overview of the proposed method.

The method accepts the population of the gaze behavior animation as its input. The initial gaze behaviors are generated by adding the rotation of the eye, head, and chest for any one

of the gaze targets to the general behavior animation by the gaze controller. The gaze behavior controller used in this research is able to rotate the joints toward the target by the parameters of the point of gaze, time of rotation, and the amount of rotation.

Therefore, the gaze behavior in the population is represented by the control parameters, which are optimized by using an IGA based on the user's subjectivity.

As a result, we obtain the optimized parameters for the natural gaze behavior animation the viewer felt to be adequate.

### 4 Parameterized Gaze Behavior

In this work, we define gaze behavior as a sequence consisting of the following three actions: (i) switching one's gaze to, (ii) keeping one's gaze, and (iii) removing one's gaze from. In our proposed method, we use the gaze controller to generate gaze behavior animation. The gaze controller adds gaze behavior to a contextual situation and to the environment within which the general behavior animation occurs.

The gaze controller described in this paper extends the existing controller [1][2] by reference to the asset in Unity [3], which is the 3DCG development environment.

The point gaze  $target_j$  is represented by three-dimensional coordinates  $(p_x, p_y, p_z)$  in the object coordinate system. The temporal parameters are the switching start time  $t_{start}$ , keeping start time  $t_{in}$ , keeping end time  $t_{out}$ , and removing end time  $t_{end}$ . Figure 2 shows the relationship of the rotation of the head to

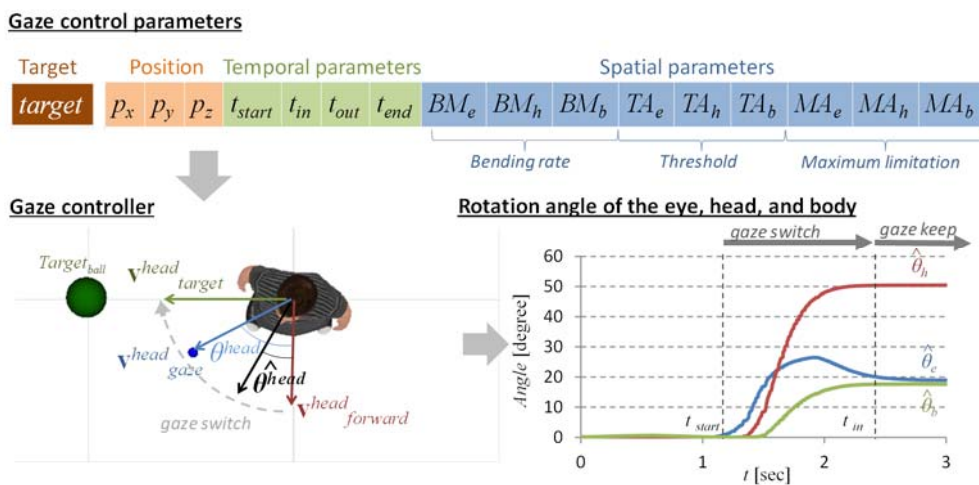


Figure 2: Gaze behavior controller and control parameters.

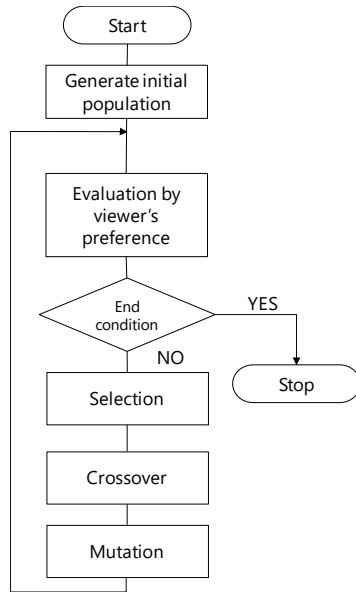


Figure 3: Flowchart of a GA.

each vector, where

$\mathbf{v}_{forward}^i$  is the forward vector and  $\mathbf{v}_{gaze}^i$  is the gaze vector of joint  $i$  of the character coordinate system. The horizontal and vertical angles  $\theta_h^i$  and  $\theta_v^i$ , respectively, are defined as the angle between  $\mathbf{v}_{forward}^i$  and  $\mathbf{v}_{gaze}^i$ . The rotation angle of joint  $i$   $\hat{\theta}^i = (\hat{\theta}_v^i, \hat{\theta}_h^i)$  is represented as follows:

$$\hat{\theta}^i = BM_i \theta^i, \quad (1)$$

subject to  $TA_i \leq \theta^i, \hat{\theta}^i \leq MA_i$ ,  $i = eye, head, chest$ .

Here,  $BM_i$  is the blending rate,  $TA_i$  is the threshold angle at which each of these begins to bend and  $MA_i$  is the maximum angle limitation of joint  $i$ .

Therefore, gaze behavior against an arbitrary target  $j$  is represented as  $g = \{target_j, p_x, p_y, p_z, t_{start}, t_{in}, t_{out}, t_{end}, BM_e, BM_h, BM_b, TA_e, TA_h, TA_b, MA_e, MA_h, MA_b\}$ .

## 5 Optimized Gaze Animation using IGA

IGA is a method based on a genetic algorithm (GA), except that the population is evaluated by the user based on their subjectivity. In our work, the chromosome is the gaze control parameters  $g$ .

The following steps (1) to (7) are performed according to the procedure of a GA (Figure 3).

(1) Generating initial population

The chromosome is the gaze control parameters  $g$ .  $g$  is composed of the index of a gaze target and 16 real-valued parameters. Figure 2 shows the chromosome encoding of  $g$ .

The number of chromosomes in the population is eight to relieve the burden on the viewer. The number of each gaze target occupying the initial population is set equally because the gaze target is also optimized.

(2) Animation presentation

The gaze behavior character animation as a chromosome is displayed to a viewer. The two animations to be compared are displayed side-by-side to enable paired comparison to be evaluated in the evaluation phase.

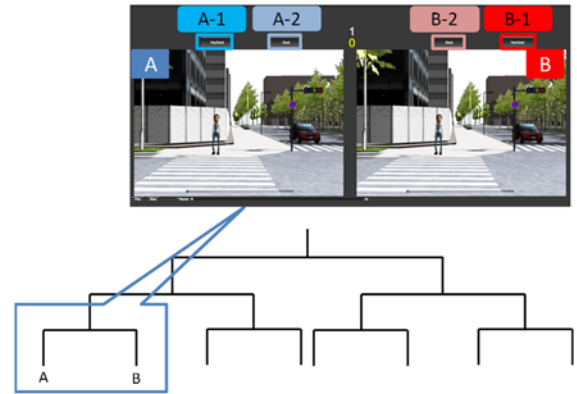


Figure 4: Paired comparison tournament method.

(3) Evaluation by viewer's preference

A viewer evaluates gaze animations by using the paired comparison tournament method. Each chromosome in the population is placed in the first round of the tournament and presented by two chromosomes in accordance with the tournament (Figure 4).

The viewer compares the two animations displayed as a chromosome to decide which is more suitable. There are four evaluation buttons in the evaluation UI (Figure 4). The viewer presses the evaluation button according to the evaluation scale as follows.

- In the case of “animation A is clearly more suitable than animation B”, the viewer presses the A-1 button.
- In the case of “animation A is more suitable than animation B”, the viewer presses the A-2 button.
- In the case of “animation B is more suitable than animation A”, the viewer presses the B-2 button.
- In the case of “animation B is clearly more suitable than animation A”, the viewer presses the B-1 button.

In this way each animation is awarded an evaluation value as a chromosome depending on the match result between the two competing animations and the result of the tournament.

The evaluation value of animation  $k$  is  $e_k$ . The evaluation value of the champion of the tournament is  $e_{champion}$ .

There is a winner for each individual in the tournament except for the champion. The evaluation value  $e_k$  of the individual  $k$  is obtained by subtracting an arbitrary value from the evaluation value  $e_{victory}$  of the winning individual.

$$e_k = e_{victory} - e_{result} \quad (2)$$

$$e_{result} = \begin{cases} e_{wide} & (\text{clearly more suitable}) \\ e_{narrow} & (\text{more suitable}) \end{cases} \quad (3)$$

$$\text{subject to } e_{victory}, e_{wide}, e_{narrow} \in \mathbb{N}, \\ e_{narrow} < e_{wide} < e_{victory}.$$

Figure 5 shows an example of the calculated evaluation value of each individual. The individual #7 is the champion of the tournament; thus, the evaluation value of this individual is  $e_{champion}$ .

Each evaluation value of individuals #0, #4, and #6 that lose directly to individual #7 is obtained by subtracting the value  $e_{result}$  (based on the user's evaluation) from  $e_{champion}$ . Further,

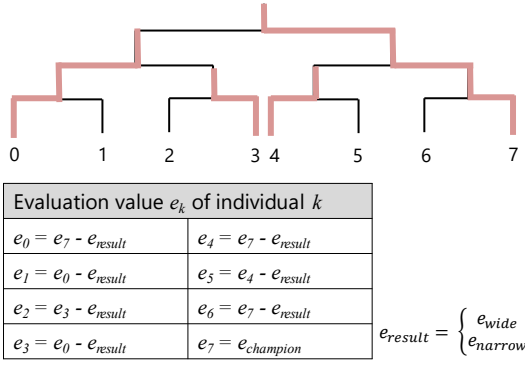


Figure 5: Example of the calculated evaluation value.

each evaluation value of individuals #1, #2, #3, and #5 is obtained by subtracting the value  $e_{result}$  based on the user's evaluation from the evaluation value  $e_{victory}$  of each winning individual.

#### (4) Selection

The chromosomes of the crossover target are selected by the ranking selection method and the elite selection method based on the evaluation value.

#### (5) Crossover

The gaze control parameters  $g$  that are used as a chromosome are composed of the index of a gaze target and 16 real-valued control parameters. The crossover of the 16 real-valued control parameters is operated by the unimodal normal distribution crossover (UNDX) [21].

The crossover of the gaze target is operated by the probabilistic approach based on the evaluation value.

The selection probability  $Pr^j$  of the gaze target  $target_j$  is represented as follows:

$$Pr^j = g_j / \sum g, \quad (2)$$

$$g_j = \sum_{k=0}^n e_k / n, \quad (3)$$

where  $g_j$  is the sum of the evaluation value of the chromosome that has the gaze target  $target_j$ .  $e_k$  is the evaluation value of the target.

The gaze target of each chromosome of the next generation is operated according to the selection probability  $Pr^j$ .

#### (6) Mutation

The new real-valued parameters are generated by the mutation of uniform random numbers in the range in which the value is valid

#### (7) End condition

The solution search is terminated after a maximum of 10 generations to relieve the burden on the viewer.

The gaze target and the control parameter are calculated according to the above procedure based on the viewer's preference, and the suitable gaze behavior animation that the viewer felt is generated by these parameters.

## 6 Experiment

### 6.1 Overview

We demonstrated the effectiveness of the proposed method by comparing the impression of the method and result between the manual creation (named HAND) (Figure 6) and the creation by the proposed method (named IGA) (Figure 7).



Figure 6: UI for the manual creation (named HAND).



Figure 7: UI for the proposed method (named IGA).

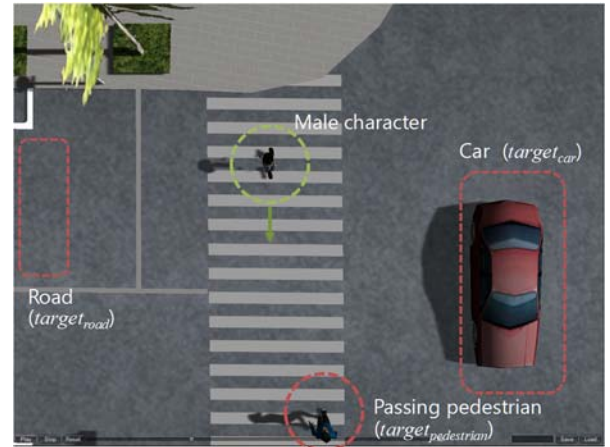


Figure 8: Animation scenario.

The animation scenario consists of a male character who gazes at one of the targets selected from among multiple target candidates when he uses the pedestrian crossing (Figure 8). The target candidate is located to the right of the direction of travel of the road, and the direction of movement of the car and the passing pedestrian. The evaluator selects one of the gaze targets and creates the suitable gaze behavior animation. The evaluators are 20 students in their 20s who have little experience in creating character animation.

### 6.2 Experimental procedure

The experiment was carried out in the following steps.

- (1) Creating the animation by HAND or IGA.
- (2) Creating the animation by IGA or HAND.
- (3) Evaluating each result.

The 10 evaluators created by HAND in step (1) and IGA in

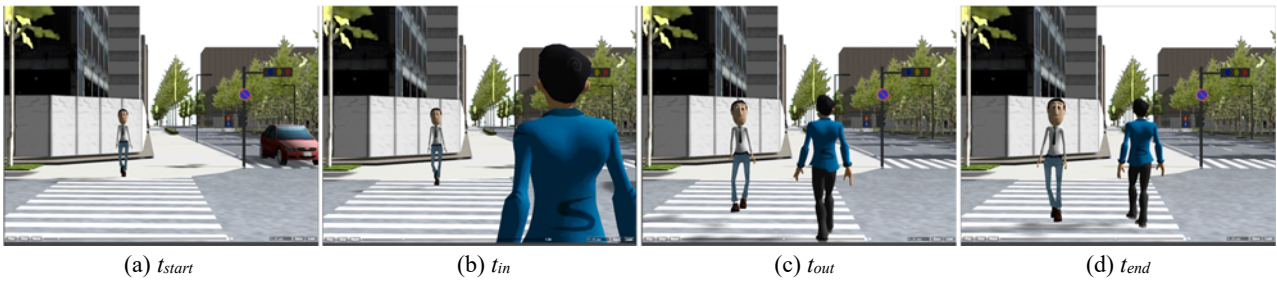


Figure 9: Animation created using IGA (section 6.3.1).

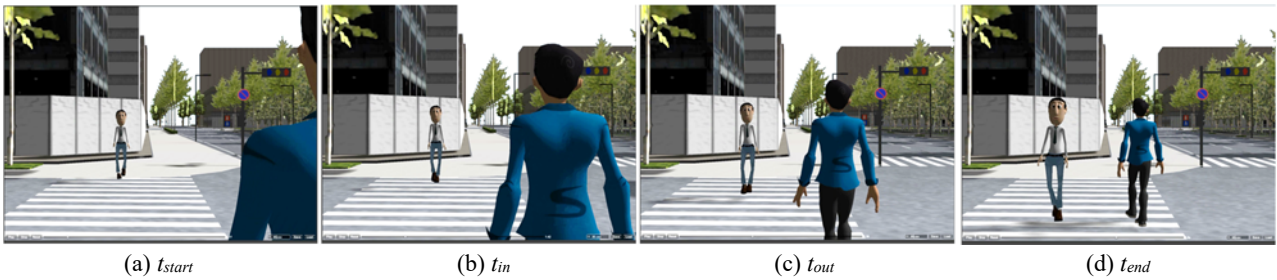


Figure 10: Animation created using HAND (section 6.3.1).

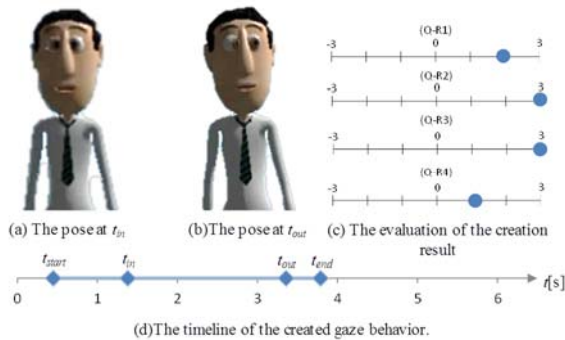


Figure 11: Evaluation result of IGA (section 6.3.1).

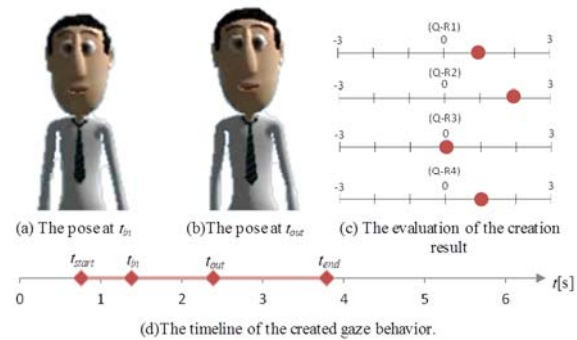


Figure 12: Evaluation result of HAND (section 6.3.1).

step (2). The another 10 evaluators created by IGA in step (1) and HAND in step (2). The evaluators answer the questionnaire about the creation method after the creation in the creating step of (1) and (2). The evaluators answer the questionnaire about the creation results in step (3) on the day after creating it in step (2). At that time, each created animation was displayed to the evaluator.

The questionnaire items about the creation method are: Q-S1 “ease of creation work” and Q-S2 “operability”. The questionnaire items about the creation result are Q-R1 “the impression of the animation”, Q-R2 “adequacy of gaze target”, Q-R3 “adequacy of gaze motion” and Q-R4 “adequacy of the timing of gaze behavior”. The evaluator rates questionnaire on a scale of -3 to 3 for each item.

### 6.3 Result

#### 6.3.1 The result of creating gaze behavior to the same gaze target under both conditions in

Figure 11 and 12 show the result of created gaze behavior animation by an evaluator. The gaze behavior animations to the same gaze target are created for both conditions (Figure 9 and 10).

A little rotation of the eye and the head of the character at the

end time of keeping his gaze  $t_{out}$  is confirmed in IGA condition (Figure 11(b)) On the other hand, none of the joints of the character is hardly rotating at  $t_{out}$  for the HAND condition (Figure 12(b)). The evaluator awarded a higher rating to the animation created in IGA than to the animation created in HAND for the evaluation of each result in items other than Q-R4.

These results are attributed to the failure of the evaluator to specify suitable gaze control parameters when using HAND but who succeeds in using appropriate gaze control parameters when using IGA to create suitable gaze behavior.

#### 6.3.2 Result of creating gaze behavior for different gaze targets under both conditions

Figure 15 and 16 show the result of the created gaze animations of the different gaze targets under both conditions. The gaze target of the animation in IGA (Figure 13) is the car, and the gaze target in HAND (Figure 14) is the right side of the direction of movement of the road.

The character follows the car with his eyes when the car passes him in Figure 13. The character ensures that cars are not approaching from the right side before entering the pedestrian crossing in Figure 14.

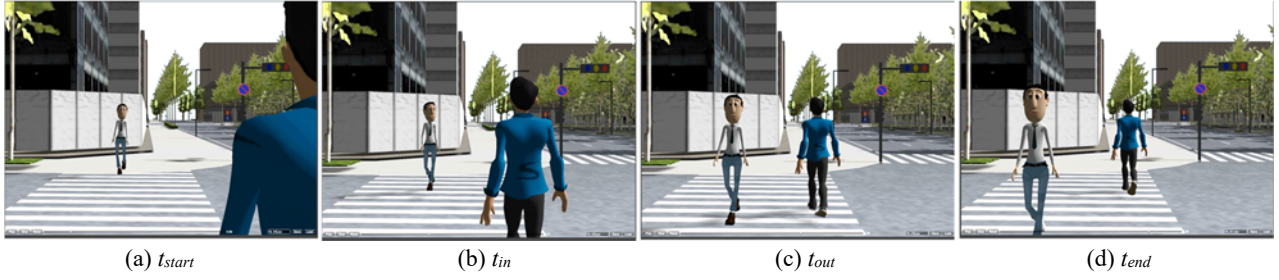


Figure 13: The created animation using IGA in section 6.3.2.

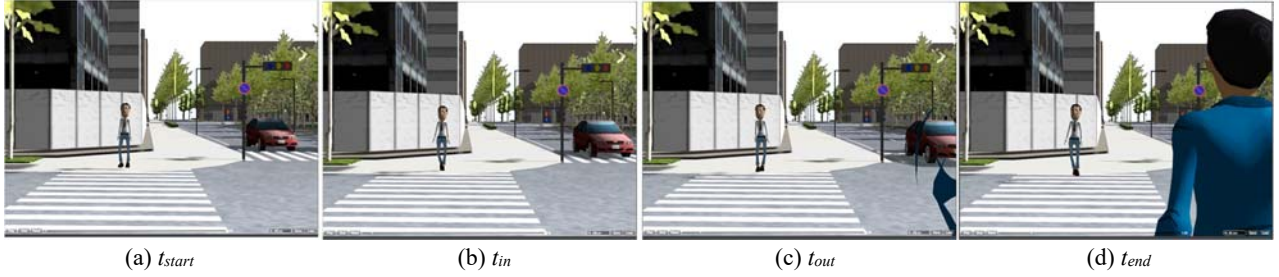


Figure 14: The created animation using HAND in section 6.3.2.

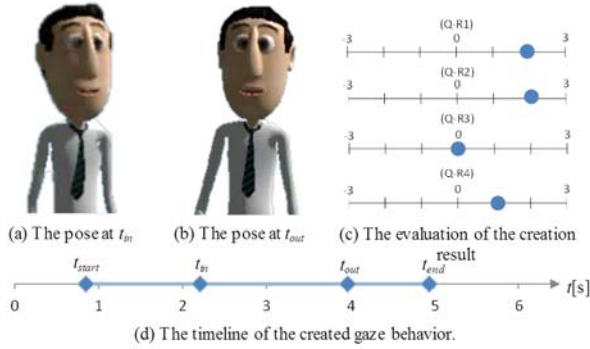


Figure 15: Evaluation result of IGA (section 6.3.2).

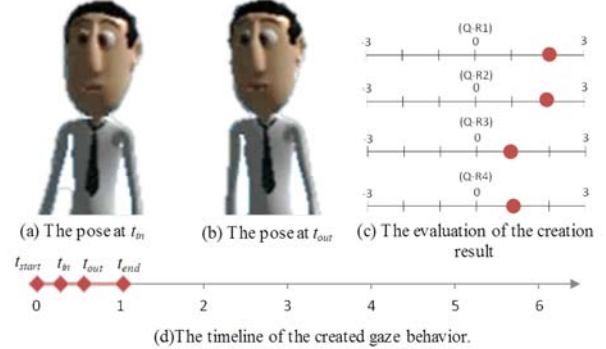


Figure 16: Evaluation result of HAND (section 6.3.2).

The evaluator rates the animation that is created in HAND higher than the animation that is created in IGA at Q-R3. However, the evaluation values at Q-R1, Q-R2, and Q-R4 are the same. We received a comment from the evaluator, “I felt that directing the gaze behavior to the car is also natural in the production process using IGA UI.” Therefore, a suitable gaze behavior animation for different gaze targets of his own plan can be created using IGA.

#### 6.4 Evaluation result

The average score and standard deviation of the evaluation value of the creation method are shown in Figure 17. The average score and standard deviation of the evaluation value of the creation result are shown in Figure 18.

We evaluated each item by the Wilcoxon signed-rank test. Q-S1 “ease of creation work” and Q-S2 “operability” both of which are questionnaire items about the creation method differ significantly between IGA and HAND. However, Q-R1 to 4, which are questionnaire items about the creation result do not differ significantly between IGA and HAND.

The average time of the creation in IGA and HAND is 7.5 minutes and 10.5 minutes, respectively. The creation time of both conditions exhibited a weak positive correlation with  $r =$

0.23.

Therefore, the user is considered to have the ability to quickly and easily create gaze behavior animation by using IGA of a quality that equals that of using HAND.

## 7 Conclusion

In this paper, we propose a method for creating character gaze behavior animation based on the viewer’s preference such as “where to gaze” and “how to gaze”.

We translated a character’s gaze motion into parameters for the gaze controller, after which we obtained the optimized gaze target and control parameters for the natural gaze animation the viewer felt when using the Interactive Genetic Algorithm (IGA).

The result of the animation created by users who have little experience creating a character animation indicated that our proposed method enables the user to create gaze behavior animation quickly and easily.

However, the gaze behavior animation created using IGA depends on the initial gaze behaviors in the population. In future, setting up the population based on the user’s preferences would need to be considered.

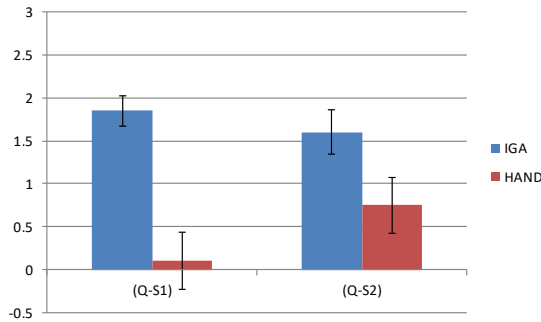


Figure 17: Evaluation value of each creation method.

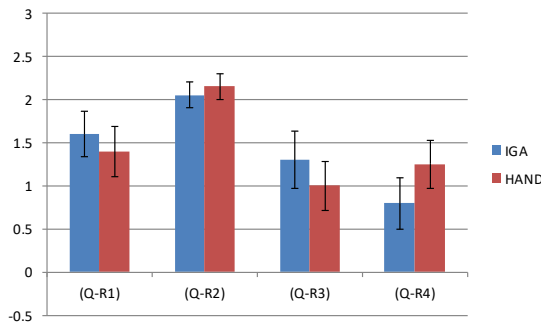


Figure 18: Evaluation value of each creation result.

## Acknowledgment

This work was supported by JSPS Grant-in-Aid for Young Scientists (B) Grant Number JP26730143.

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