Interactive System for Creating Attractive Poses Using Pose Features and Statistical Models

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***Abstract*—Creating attractive poses is crucial in generating works of art. However, designing these poses is challenging because of a lack of clear definitions or rules for attractive poses. Thus the artist must design through experience and trial and error. In this study, we propose a system for creating new attractive poses based on a set of sample poses for a class of attractive poses. Pose features for some parts of the body, rather than the entire body, make the pose attractive. By combining such multiple sample pose features, the proposed method creates a novel attractive pose that is dissimilar to any of the sample poses. Using our system, a new attractive pose is created by interactively deforming based on the pose features of the sample poses. Our system constructs 2D latent spaces that map the sample poses for each pose feature for the user to find the pose feature to apply to the editing pose.**

***Index Terms*—Human pose, attractive poses, pose deformation**

I. Introduction

Creating attractive poses is crucial in generating works of art, such as comics, animation, and computer games. An attractive pose can enhance the impact of a scene. However, designing these poses is challenging because of a lack of clear definitions or rules for attractive poses. This causes the designers to rely on experience and go through trial and error. This difficulty highlights the need for new technologies that can support the creation of novel and appealing poses.

In this study, we propose an interactive system for creating new attractive poses based on a set of sample poses, to generate a specific class of attractive poses, such as the appearance of a hero character or a fighting pose.

There are pose features for some parts of the body, rather than the entire body, that make the pose attractive. By combining such multiple pose features, our method creates a novel attractive pose that contains such pose festures from the sample poses and is dissimilar to any of the sample poses. Using our system, the user can create an attractive pose by repeatedly deforming an initial pose based on the pose features calculated from sample poses. We introduced seven pose features: right arm, left arm, upper body, lower body, body orientation, limb positioning, and arm opening. Our system constructs 2D latent spaces that map each pose feature onto the sample poses, making it easier for users to find the pose features to apply to the editing pose. By choosing a point in one of the latent spaces, the corresponding pose features are computed and applied to the editing pose.

II. Related Works

Interactive pose deformation methods exist, as in [1] and [2]. These methods deform human poses based on predetermined rules for natural human poses. Oshita et al. proposed a method for deforming input poses based on rules discovered for attractive poses [3]. The rules for attractive poses are identified using decision trees that are obtained by learning a set of attractive and normal poses [4]. The decision trees thus obtained are used to deform the poses to generate attractive poses. However, this method requires a manual design of the deformation rules from the decision trees obtained, and multiple rules cannot be combined. The proposed method solves these problems by performing multiple pose feature-based deformations.

Previous studies have used statistical models to generate poses. Grochow et al. proposed a method for generating poses by using a Scaled Gaussian Process Latent Variable Model [5]. Shin et al. proposed a method for generating poses using Multidimensional Scaling [6]. As these statistical methods synthesize new poses by interpolating similar poses of the entire body, the range of poses that can be synthesized is limited. Our method solves this problem by applying multiple pose features for part of the entire body to generate a novel attractive pose.

III. System Overview

A. System architecture and pose generation procedure

In this study, an interactive system is proposed for creating new attractive poses based on a set of sample poses. As there are a variety of attractive poses, a single set of sample poses cannot handle all classes. Therefore, a set of sample poses for a specific type of attractive pose that the user wants to create must be provided. The system architecture is illustrated in Fig. 1. In the preprocessing step, the user provides a set of sample poses to the system (Fig. 1(a)). The system creates statistical models for the pose features of the right arm, left arm, upper body, lower body, body orientation, limb positioning, and arm opening (Fig. 1(b)). At runtime, the user provides an initial pose (Fig. 1(c)). For the initial pose, either a simple standing pose or a randomly chosen pose from a set of sample poses can be used. The user selects a source pose from one of the latent

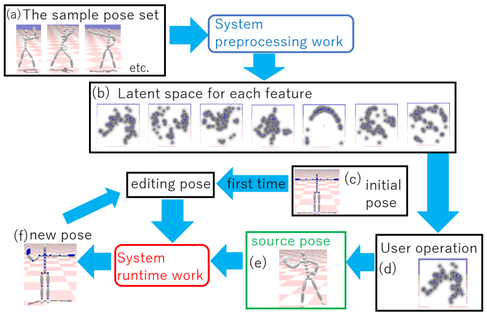

Fig. 1. System architecture depicting (a) (b) preprocessing; (b) to (f) runtime pose creation process.

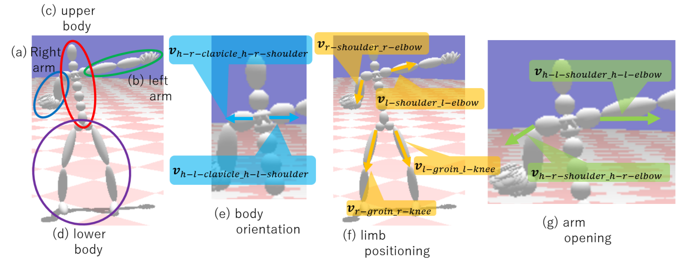

Fig. 2. Pose features.

spaces Figs. 1(d) and (e). The system deforms the editing pose by applying the pose features of the source pose (Fig. 1(f)). The user can repeat this process until a satisfactory attractive pose is generated.

B. Pose Representation

Given a human skeletal model with n joints, the pose P is represented by $P = \{\boldsymbol{p}_r, \boldsymbol{R}_r, \boldsymbol{R}_0, ..., \boldsymbol{R}_{n-1}\}$, where $\boldsymbol{p}_r$ is the waist position; $\boldsymbol{R}_r$ is the waist rotation in a 3×3 matrix; and $\boldsymbol{R}_i$ is the rotational matrix for all joints. Index i represents the joint number. The positions and rotations are represented using a reference coordinate system. The center and orientation of the reference coordinate system are defined based on the horizontal position and orientation of the hips in the upright position. Although our method can handle any skeletal model with an arbitrary number of joints, it must include the primary joints used for computing pose features: the shoulder, elbow, wrist, clavicle, neck, spine, groin, knee, and ankle. Also, necessitating the preparation of sample poses with the same number of joints and body segments having the same skeleton length as that of the pose that the user wants to generate.

IV. Pose Feature

Seven pose features were introduced $Q = \{\boldsymbol{q}_{right\_arm}, \boldsymbol{q}_{left\_arm}, \boldsymbol{q}_{upper\_body}, \boldsymbol{q}_{lower\_body}, \boldsymbol{q}_{body\_ori}, \boldsymbol{q}_{limb\_positioning}, \boldsymbol{q}_{arm\_opening}\}$. A set of pose features Q was computed from pose P. The first four pose features represent the joint rotations of the body parts, whereas the other three represent the spatial aspects of the pose. Based on our observation of attractive poses, pose features for some parts of the body, rather than the entire body, make the pose attractive. By combining the pose features obtained from the sample poses, our method generates a novel attractive pose that contains pose features from sample poses and is dissimilar to any of the sample poses.

The pose feature for joint rotations contain rotations of multiple joints. The rotation of each joint is represented using a unit quaternion. A unit quaternion $\boldsymbol{r}_i$ is a four-dimensional vector that represents a rotation. For example, $\boldsymbol{q}_{right\_arm} \in \boldsymbol{R}^{12}$ involves the rotations of the right shoulder, elbow, and wrist, as shown in Fig. 2(a). Similarly, $\boldsymbol{q}_{left\_arm} \in \boldsymbol{R}^{12}$ involves the rotations of the left shoulder, elbow, and wrist (Fig. 2(b)); $\boldsymbol{q}_{upper\_body} \in \boldsymbol{R}^{32}$ involves the rotations of the spine, neck, and clavicle (Fig. 2(c)). $\boldsymbol{q}_{lower\_body} \in \boldsymbol{R}^{28}$ involves rotations of the groin, knee, and ankle (Fig. 2(d)). We introduced these pose features because distinguishable features for the right arm, left arm, trunk, and lower body parts are often observed in an attractive pose. As pointed out in [1] and [2], a body line based on the trunk is important for human poses. Although each arm can have individual pose features, the legs must be treated together to maintain contact with the ground and balance the body. Therefore, the legs were handled together as part of the lower body.

The $\boldsymbol{q}_{body\_ori}$, $\boldsymbol{q}_{limb\_positioning}$, and $\boldsymbol{q}_{arm\_opening}$ features focus on the spatial relationships of the joints; $\boldsymbol{q}_{body\_ori}$ denotes body orientation in the horizontal plane; $\boldsymbol{q}_{limb\_positioning}$ represents the directions of the arms and legs; and $\boldsymbol{q}_{arm\_opening}$ represents the horizontal spread of the arms. The spatial relationship between the two joints is represented by the vector $\boldsymbol{v}_{base\_target}$ from the position of the base joint $\boldsymbol{p}_{base}$ to the position of the target joint $\boldsymbol{p}_{target}$. The position of joints $\boldsymbol{p}_i$ represents the position of each joint and is computed from a pose using forward kinematics. For example, $\boldsymbol{q}_{body\_ori}$ is defined by four vectors representing spatial relationships; $\boldsymbol{q}_{body\_ori} = (\boldsymbol{v}_{h-r-clavicle\_h-r-shoulder}, \boldsymbol{v}_{h-l-clavicle\_h-l-shoulder}) \in \boldsymbol{R}^4$ represents a combination of the two-dimensional vector $\boldsymbol{v}_{h-r-clavicle\_h-r-shoulder}$ from the right clavicle $\boldsymbol{p}_{h-r-clavicle}$ to the right shoulder $\boldsymbol{p}_{h-r-shoulder}$ and the two-dimensional vector $\boldsymbol{v}_{h-l-clavicle\_h-l-shoulder}$ from the left clavicle $\boldsymbol{p}_{h-l-clavicle}$ to the left shoulder $\boldsymbol{p}_{h-l-shoulder}$ in the horizontal plane. Label h denotes the joint position in the horizontal plane. Labels r and l represent the joints in the right and left arms, respectively. These two vectors represent the twist of the upper body, which is an important feature of attractive poses. Other pose features for joint positions are represented in the same manner. $\boldsymbol{q}_{limb\_positioning} = (\boldsymbol{v}_{r-shoulder\_r-elbow}, \boldsymbol{v}_{l-shoulder\_l-elbow}, \boldsymbol{v}_{r-groin\_r-knee}, \boldsymbol{v}_{l-groin\_l-knee}, \boldsymbol{r}_{r-knee}, \boldsymbol{r}_{l-knee}, \boldsymbol{r}_{r-ankle}, \boldsymbol{r}_{l-ankle}) \in \boldsymbol{R}^{28}$ represent the orientations of four limbs (Fig. 2(f)). We introduced this pose feature because the combination of the directions of the four limbs is important for attractive pose features. Knee and ankle rotations are also included in this pose feature to avoid losing contact with the ground and body balance when this pose feature is applied during deformation. $\boldsymbol{q}_{arm\_opening} = (\boldsymbol{v}_{h-r-shoulder\_h-r-elbow}, \boldsymbol{v}_{h-l-shoulder\_h-l-elbow}) \in \boldsymbol{R}^4$ represent the horizontal orientations of the arms (Fig. 2(g)). The degree of the horizontal angle between the arms is an important feature for attractive poses.

V. Statistical Models for Pose Features

A statistical model was constructed for each pose feature by mapping all sample poses onto a two-dimensional latent space. For the statistical model, the multidimensional scaling method was used in a manner similar to that in [6]. To apply this method, the distances between all pairs of samples are required. We defined the distance between two poses using the pose feature vectors described in Section III. The distance between two poses P_j and P_k with respect to pose feature e is computed by Eq. 1 using the pose feature vectors $\boldsymbol{q}_{ej}$ and $\boldsymbol{q}_{ek}$. The indices j and k represent the sample pose number, and the index e represents the pose feature.

$$d_{ejk} = ||\boldsymbol{q}_{ej} - \boldsymbol{q}_{ek}|| \tag{1}$$

Given a point in latent space, pose P_s is synthesized by interpolating the nearby sample poses using blending weights based on the distance between the given position and position of each sample pose in latent space. Nearby sample poses were selected based on a distance threshold. The blending weights w are calculated by applying a Gaussian function to distance a.

$$w = e^{-4a^2} \tag{2}$$

The blending weights were normalized. The position of the waist $\boldsymbol{p}_{s\_r}$ was calculated using the weighted average. The rotations of the joints $\boldsymbol{R}_{s\_i}$ and waist $\boldsymbol{R}_{s\_r}$ were calculated by linear interpolation of the logarithmic vectors.

VI. Pose Feature-Based Pose Deformation Method

The user chooses a point from the latent space of pose features to synthesize the source pose P_a. Based on the source pose P_a and editing pose P_c, our system outputs a new deformed pose P_n by deforming the editing pose P_c based on the specified pose features of the source pose P_a.

To apply the pose features using joint rotations, including $\boldsymbol{q}_{right\_arm}$, $\boldsymbol{q}_{left\_arm}$, $\boldsymbol{q}_{upper\_body}$, and $\boldsymbol{q}_{lower\_body}$, the joint rotations of the pose feature vector are simply applied to the editing pose P_c.

The deformations were applied based on the pose features of the joint positions, including $\boldsymbol{q}_{body\_ori}$, $\boldsymbol{q}_{limb\_positioning}$, $\boldsymbol{q}_{arm\_opening}$, using inverse kinematics. The position of the target joint was computed based on the position of the base joint and the vector from the pose features.

$$\boldsymbol{p}_{n\_target} = \boldsymbol{p}_{c\_base} + \boldsymbol{v}_{a\_base\_target} \tag{3}$$

The joint rotation $\boldsymbol{R}_{n\_base}$ was computed using inverse kinematics to satisfy the new target position $\boldsymbol{p}_{n\_target}$. For example, to apply the pose feature vector of the arm opening about the right arm, the new pose's positions of the right elbow $\boldsymbol{p}_{n\_h-r-elbow}$ are computed from the editing pose's joint positions of $\boldsymbol{p}_{c\_h-r-shoulder}$ and feature's vector $\boldsymbol{v}_{a\_h-r-shoulder\_h-r-elbow}$, as shown in Fig. 3.

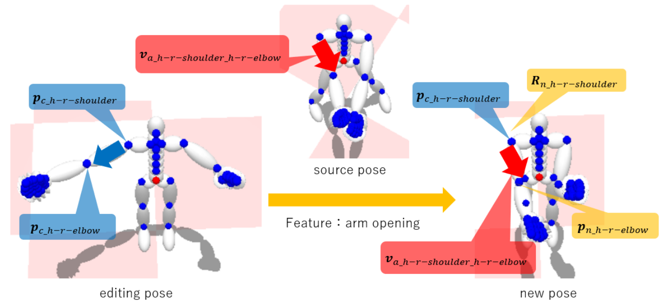

Fig. 3. Pose deformation for the arm opening pose feature's vector about right arm.

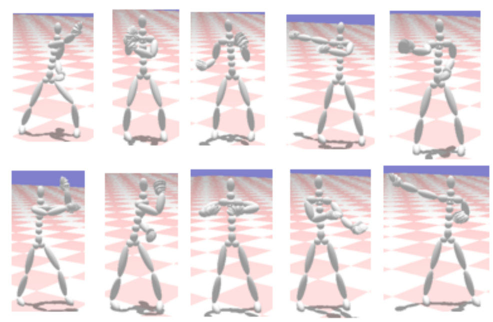

Fig. 4. Examples of a set of attractive sample poses set in the experiment.

VII. Experimental Results and Discussion

A. User experiment

A user experiment was conducted to evaluate the quality of the poses generated by our system, to assess the effectiveness of the pose features. The participants were ten university students familiar with the Japanese subculture. For the two tasks, the subjects were asked to read a certain page from two comic books, [7] and [8], and come up with two poses of the main character using our system described on the next page. We conducted the same experiment using a conventional modeling system, Blender, to compare the differences in the evaluation of poses created with and without the use of our system. The subjects were divided into Groups A and B. Group A created poses using our system and the conventional system (Blender), whereas Group B created poses using Blender and our system.

The set of sample poses in the experiment included 56 attractive poses from the Kamen Rider series [9], as shown in Fig. 4. These poses were taken as a superhero character transformed from a person into a superhero. We chose this attractive pose because they match the two scenes of the comic books used in our experiment. Sample poses were created from

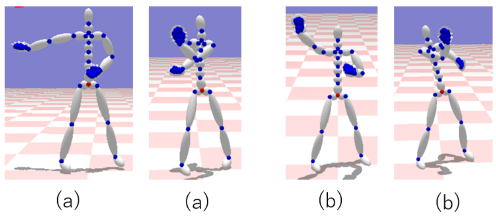

Fig. 5. Examples of attractive poses created by our system. (a) poses for the first task. (b) poses for the second task.

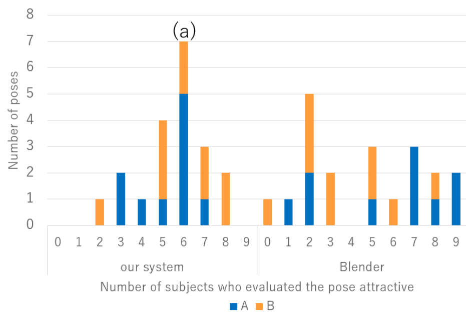

Fig. 6. Results show the number of subjects who evaluated each pose attractive.

the poses that an actor performed, selecting poses using an acceleration-based motion-capture system.

After the pose-creation tasks, the subjects evaluated the attractiveness of the poses created by others. A post-experiment questionnaire was used to assess the effectiveness of the pose features. The participants were asked to rate on a five-point scale whether the pose feature set was effective in generating attractive poses.

B. Evaluation results of created pose

The poses created by the participants using the proposed system are shown in Fig. 5. A histogram of the number of subjects who evaluated each attractive pose is shown in Fig. 6. The horizontal axis represents the number of participants who evaluated the created pose attractive. The vertical axis indicates the number of poses created in each bin. The blue bar shows the number of poses created by Group A, and the orange bar shows the number of poses created by Group B. For example, in Fig. 6(a), five Group A poses and two Group B poses were judged to be attractive by six subjects. The scatter in the ratings of the poses created by the two groups suggests that there is no difference in the order of pose creation. Fig. 6 shows that more than a majority of the subjects who evaluated the created poses using our system found them more attractive than the poses created using the conventional system. The subjects in Group A created an attractive pose using not only our system but also Blender, possibly because they reproduced the attractive poses created by our system using Blender.

C. Evaluation results of pose features used in pose generation

Table I lists the results of the questionnaire on the evaluation of pose features administered to the test subjects. Ten participants were asked to rate the effectiveness of the set-pose features on a five-point scale. The results show that the subjects consider some spatial pose features, such as limb positioning and arm-opening features, as not effective. This is because these pose features change the pose drastically and invalidate the pose created by the user. However, there have been cases of creating attractive poses using these features.

TABLE I
AVERAGE AND STANDARD DEVIATION OF FIVE-POINT EVALUATION SHOWING THE EFFECT OF POSE FEATURES. AVG REPRESENTS AVERAGE. SD REPRESENTS STANDARD DEVIATION.

	right arm	left arm	upper body	lower body	body orientation	limb positioning	arm opening
AVG	3.8	3.8	3.1	4.0	3.1	2.7	2.0
SD	0.75	0.75	0.94	1.1	1.2	1.3	0.63

D. Discussion

Our experiments show that users of our system can create attractive poses using our pose features although some pose features are used less than others. To create attractive poses, pose features must be designed carefully. Instead of designing new pose features manually based on observation, we automatically extract useful sets of pose feature combinations for different body parts using machine learning techniques.

VIII. Conclusion

In this study, we proposed an interactive system for creating new attractive poses based on a set of sample poses for a class of attractive poses. Our experiments demonstrated the effectiveness of our approach. The addition of new effective pose features using machine-learning techniques will be our future work.

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