Expressive Human Pose Deformation Based on the Rules of Attractive Poses

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Abstract. We propose a method of deforming a human pose based on the rules of attractive poses. In our previous research, we proposed an approach for obtaining the rules of attractive poses from a set of attractive poses with a specific style and another set of unattractive poses by creating a decision tree based on the low-level pose features. In this paper, we propose a heuristic kinematics-based pose deformation method based on the discovered rules of attractive poses. The rules can be applied to any input pose with any specified scale. We evaluated our method through a user experiment. The results show that our method can deform a pose to realize a specified style, although not all rules are applicable to all kinds of poses and an appropriate style and deformation scale must be selected by the user.

Keywords: Human pose · Attractive poses · Pose deformation

1 Introduction

Attractive poses of human characters often appear in various types of media content such as movies, animations, computer games, illustrations, comics, and action figures. The creators must design attractive poses that fall within a certain style and are novel and eye-catching. Because there are no specific definitions or rules of attractive poses, the creators must design them based on their experience and through trial and error. This is a difficult and time-consuming task.

In our previous research [1], we proposed an approach to obtain the rules of attractive poses from a set of attractive poses with a specific style and another set of unattractive poses by creating a decision tree based on the low-level pose features that are computed from the example poses. We implemented our approach for two kinds of attractive poses, Hero and JoJo standing poses, and successfully discovered the rules of these styles. We also developed a heuristic pose deformation method specialized for the discovered rules.

In this paper, we propose a method of deforming a human pose. We developed a heuristic kinematics-based pose deformation method based on the discovered rules of attractive poses. This method is generalized and can work with any rules based on our low-level pose features. The rules can be applied to any input pose with any specified scale. Using our system, a creator can interactively design

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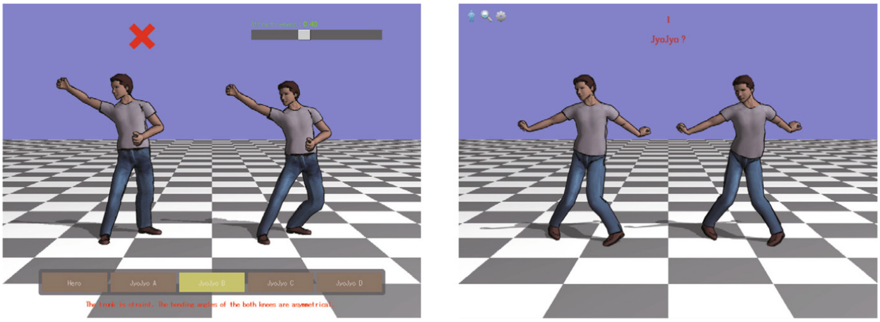
novel poses. We evaluated our method in a user experiment. The results show that our method can deform a pose to realize a specified style, although not all rules are applicable to all kinds of poses and an appropriate style and deformation scale must be selected by the user.

Attractiveness is an important factor in content creation. However, it is a difficult factor to evaluate. Although there are subjective evaluations for human motions [2], the specific rules of attractiveness are still unclear. In this research, we developed a pose deformation method based on the rules of attractive poses that we discovered in our previous work [1]. For pose deformation, we implemented a kinematics-based method. Although similar approaches have been used before [3,4], our method focuses on the pose features that appear in the discovered rules of attractive poses. High-level pose features have been introduced in previous studies [5]. However, such high-level features are only applicable to a specific range of poses. To handle a wide range of poses, many pose features would be required.

2 System Overview

We have developed a pose deformation method and system. Figure 1 shows screen shots of our system. The user can specify an input pose, a class of attractive poses, and a deformation ratio. The system deforms the input pose interactively. An input pose can be specified in several ways. The system has a user experiment mode that we implemented for our experiments. This mode is explained in Sect. 5.1.



(a) pose deformation mode (b) user experiment mode

Fig. 1. Developed pose deformation system. (a) The pose deformation mode allows the user to apply the rules of attractive poses to an input pose. The input pose is shown on the left side. The deformed (output) pose is shown on the right side. The class (style and category) of attractive poses is selected via the menu at the bottom. Whether the input pose satisfies the rules of the class is shown on the top left by a circle (yes) or a cross (no). The deformation scale is controlled by the slider on the top right. (b) The user experiment mode shows a randomly selected example pose and a deformed pose. The user is asked which pose has the indicated style.

Given a human skeleton model, a pose is represented by the position and rotation of the pelvis and the rotations of all joints. We used a skeleton model with 16 joints and 15 segments. A skinned human model is used to display poses, as shown in Fig. 1. Our system provides several ways to input a pose such as the use of a mouse-based pose editing interface [1].

3 Rules of Attractive Poses

In this section, we briefly explain the rules of attractive poses for two kinds of example poses. For the details, the reader can refer to our previous work [1].

We define each type of attractive pose using examples. Given a set of attractive poses with a specific style and another set of unattractive poses, we determined rules with which to separate the two sets of poses by creating a decision tree. Our research focuses on the static standing poses of a male character with an average physique who does not hold any props. We also assume that the attractiveness of a pose is view independent and it does not change when the pose is mirrored (i.e., flipped horizontally).

3.1 Pose Features

We compute a large number of low-level pose features for each example pose (381 in total). Of them, a decision tree automatically chooses a few important features that are effective for separating attractive and unattractive poses.

We use simple pose features such as the positions and orientations of the body segments and joints that can be computed from the pose representation using forward kinematics. All pose features are represented by a (signed or unsigned) one-dimensional scalar value. Three-dimensional positions and rotations are divided into a combination of single variables.

As mentioned above, the attractiveness of a pose should not change when the pose is mirrored (i.e., flipped horizontally). Therefore, instead of using pose features from the right and left sides (limbs) of the pose, we use the average and absolute difference between values from the two sides. Additionally, as the horizontal position and direction of the pose do not affect the attractiveness of the pose, horizontal positions and angles are discarded. The pose features are categorized as follows.

1. Rotational angles of the center joints.
2. Rotational angles of the limb joints (the average and difference angles of the right and left side joints).
3. Relative orientation angles between the center body segments.
4. Orientation of the center body segments with respect to the ground.
5. Body segment heights.
6. Body segment distances.
7. Height of the center of mass.

3.2 Example Pose Sets

We implemented our approach for two styles of attractive poses: Hero and JoJo styles. We chose these two styles because they are well-known popular styles in Japanese culture and materials such as picture and illustration books about these styles are available.

We created 30 example attractive poses for each style based on example poses that are taken from the picture and illustration books. In addition, we created 30 examples of unattractive poses.

Hero poses (Fig. 2) are the first type of attractive pose used in this study. Suited action heroes in Japanese movies often appear in Hero poses. When a hero or heroine faces the villain during a fight scene, they often adopt strong and defiant poses. The example poses are chosen from a picture book [6] that is meant to provide examples for creators.

JoJo poses (Fig. 3) are the other type of attractive pose considered in this study. The JoJo standing poses appear in the comic series *JoJo's Bizarre Adventure* by Araki [7], which is famous and popular in Japanese culture. The JoJo standing poses have a unique style. They are often imitated in many other media as well. The example poses were chosen from an illustration book [8].

Unattractive poses (Fig. 4) are ordinary standing poses. They were chosen from various books [9,10]. Of the many possible example poses, we selected ordinary poses that are dissimilar to the Hero and JoJo poses.

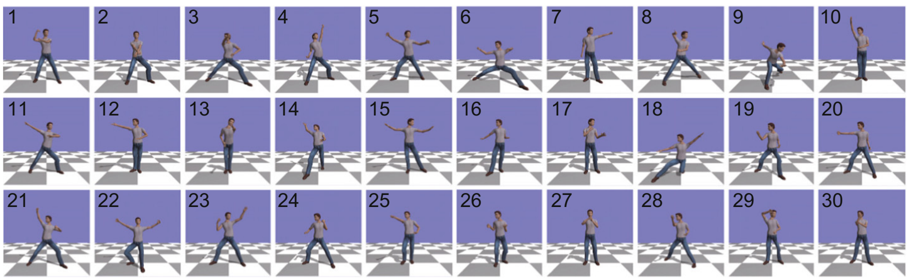


Fig. 2. Examples of attractive Hero poses

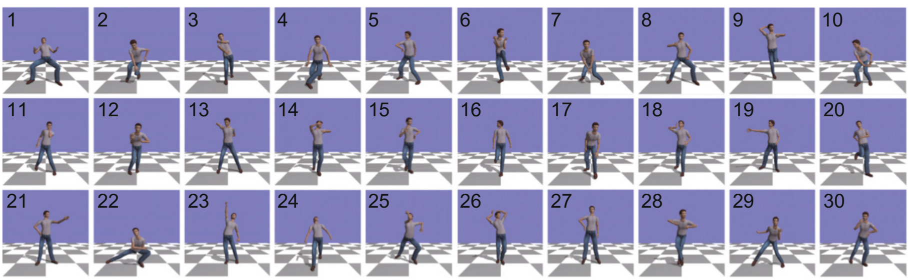


Fig. 3. Examples of attractive JoJo poses

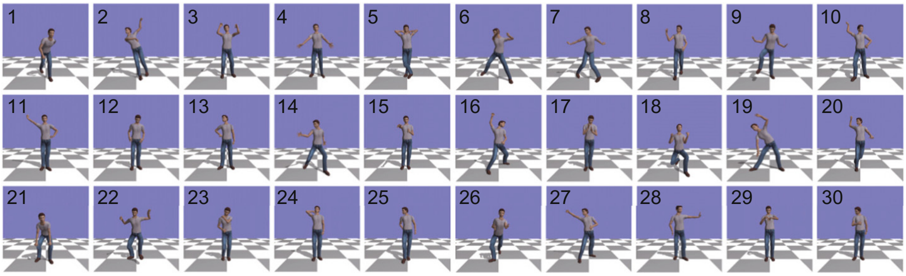


Fig. 4. Examples of unattractive poses

3.3 Discovered Rules of Attractive Poses

Decision trees are a non-parametric supervised learning method used for classification [11,12]. The results are represented as simple trees, which are visible and easy interpreted. By changing a parameter that determines the processing condition, different trees with similar accuracies can be generated. We chose a decision tree that contains fewer pose features and conditions and provides intuitive rules. Some styles have more than one category of poses. The rules for five classes (style and category) were obtained as follows.

Hero Poses. Almost all of the Hero poses can be categorized into one cluster with conditions as follows.

Hero pose: The bending angle of head with respect to the neck should be between −0.045 and 0.15. If the bending angle is between 0.15 and 0.045, the absolute value of the horizontal angles of the head with respect to the trunk and waist should be less than 0.11 and 0.77, respectively. In short, when both the bending and orientation angles of the head are small (i.e., the head is facing forward), the pose is considered to be a good pose.

JoJo Poses. JoJo poses are categorized into four clusters as follows.

JoJo pose A: When the bending angle of the trunk with respect to the ground is less than −0.063 (i.e., bent backward), the bending angle of the head with respect to the pelvis should be should be less than 0.22. In short, when the trunk is bent backward, the bending angle of the head should be straight. Typical poses in this category are poses 1 and 24 in Fig. 3.

JoJo pose B: When the bending angle of the trunk with respect to the ground is between −0.063 and 0.46 (i.e., straight), the absolute value of the difference between the bending angles of the left and right knees should be larger than 0.59. In short, when the trunk is straight, the bending angles of the knees should be asymmetrical. Typical poses are poses 9 and 16 in Fig. 3.

JoJo pose C: When the bending angle of the trunk with respect to the ground is between −0.063 and 0.46 (i.e., straight) and the absolute value of the difference between the bending angles of the left and right knees is smaller than 0.59, the absolute value of the horizontal orientation of the neck with respect to the trunk should be between 0.0078 and 0.01. In short, when the trunk is straight, the head should be facing forward. Typical poses are poses 11 and 26 in Fig. 3.

JoJo pose D: When the bending angle of the trunk with respect to the ground is larger than 0.46 (i.e., bent forward), the absolute value of the difference between the bending angles of the left and right elbows should be larger than 0.15. In short, when the trunk is bent backward, the bending angles of the elbows should be asymmetrical. Typical poses are poses 12 and 29 in Fig. 3.

4 Pose Deformation

We developed a pose deformation method based on the discovered rules of attractive poses. The rules can be applied to any input pose with any specified scale. We defined pose deformation parameters based on the pose features that are used in the rules. Using these parameters, an input pose can be deformed using a heuristic kinematics-based method.

4.1 Adjusting Pose Features

The target values of the pose features are determined according to the selected style and category and the specified scale of attractiveness. As the scale increases, each target pose value approaches to the desirable range and value in the discovered rules. When the scale is between 0.0 and 0.5, it is linearly interpolated from the initial value, which is computed from the initial pose to the threshold using the discovered rules. When the scale is between 0.5 and 1.0, it is linearly interpolated from the threshold to an extreme value that is manually specified in advance. If the rules define a feature range, the center of the range is used as the extreme value.

4.2 Pose Deformation

Given an input pose and desired pose features, the input pose is deformed through the following three steps.

Step 1. Deformation of the upper-body pose. Joint rotations of the upper-body joints and the pelvis are computed. Joint rotations, segment orientations, and segment positions can be controlled by one or a few joint rotations. When the pose feature is mapped to a single joint rotation, the joint rotation is determined according to the desired pose feature value. When the pose feature is mapped to multiple joint rotations, the rotations of these joints are computed according to the desired pose feature value and the weights of joints that are manually defined in a way similar to [13]. The head orientation, for example, can be controlled by rotations of the neck, trunk, and pelvis. When there are multiple conditions that control the same joint, the order of conditions must be determined manually.

Step 2. Balance correction control. Deformation of the upper-body pose may result in an unbalanced pose. The lower body pose is controlled through the position of the pelvis. All joint rotations on both legs are computed using inverse kinematics [14] so that the positions of both feet are kept. The horizontal (two-dimensional) position of the pelvis is computed to keep the balance so that the horizontal position of the center of mass remains in the same place after deformation of the upper-body pose.

Step 3. Deformation of the lower-body pose. The lower body pose is controlled via the lateral (one-dimensional) position of the pelvis under the constraints of balance and foot position. The lateral axis is determined according to the positions of the two feet. Balance can be maintained as long as the pelvis moves along the lateral axis. The target lateral position is linearly interpolated between the initial value and foot position.

The pose features contain the rotations of the lower-body joints. However, it is not possible to simply change them, because such pose deformation breaks the constraints of contact between the feet and ground. We therefore control them by moving the pelvis along the lateral axis; e.g., the difference between the bending angles of the two knees is controlled. When the pelvis is moved over the right foot, the right knee is bent and the left knee is extended. Note that the required pose feature may not be satisfied depending on the input pose. When the two feet are close to each other, for example, there is little room in which to control the lateral pelvis position without moving the foot positions. This is a limitation of our method.

5 Experimental Results and Discussion

5.1 User Experiment

We conducted a short user experiment to evaluate the effectiveness of our pose deformation method and the discovered rules of attractive Hero and JoJo poses. We evaluated whether the subjects could recognize that the poses deformed using our method have the intended styles compared with the original poses. Nine university students participated in the experiment. The participants were moderately familiar with Japanese subcultures including Hero and JoJo, although they were not content creators. Before the user experiment, images of example poses of Hero and JoJo (Figs. 2 and 3) were presented to each participant so that they could grasp the features of these styles. During the experiment, our system randomly chose an example pose from the set of 30 ordinary poses, a class of attractive poses from five classes (style and category), and a deformation scale from 0.5 or 1.0. There were thus 300 combinations (patterns). The system showed the original example pose and the deformed pose for a random placement as shown in Fig. 1(b). The participant was then asked to choose which pose has the indicated style compared with the other pose. The participant could change the viewing orientation of the pose using a mouse. Each participant went through 300 trials, which took about 30 min.

5.2 Results and Discussion

We measured whether the participants chose the deformed pose correctly for each pattern of example pose, class and deformation scale. Because this is a two-choice question, the ratio of correct answers should be around 50%, if our pose deformation method is ineffective. The results are shown in Fig. 5. High accuracy ratios exceeding 70% were obtained for 24.66% of patterns. This demonstrates that our method can realize the intended style successfully on many patterns. Meanwhile, a low accuracy ratio less than 30% was obtained for 14.0% of patterns. This shows that the combination of an input pose and a class is important, in that some combinations could have negative effects. However, this is not a problem in practice for our system. As the user can choose the class and deformation scale interactively, they can avoid such ineffective combinations.

Examples of successful and unsuccessful patterns are shown in Figs. 6 and 7, respectively. We analyzed some unsuccessful examples to see why our deformation method had negative effects. One reason that we found was the problem of incomplete rules of attractive poses. For example, in Fig. 7(g), the head faces down in the deformed pose, whereas Hero poses are expected to have the head facing forward. This is because our rules of Hero poses happened to be based on the local neck rotations and keep it straight. When the body faces down, the head faces down too. This kind of problem should be avoided by refining the decision trees.

Another reason that we found was the problem of local pose deformation. As our deformation method only deals with a small part of the pose without considering the full body, infeasible poses may be produced. In Fig. 7(h), for

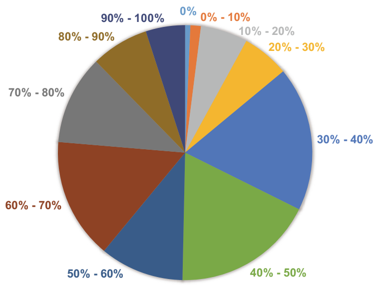


Fig. 5. Results of our user experiment. A histogram of all 300 patterns based on the ratios of answers that correctly chose the deformed pose matches the indicated style over the original pose.

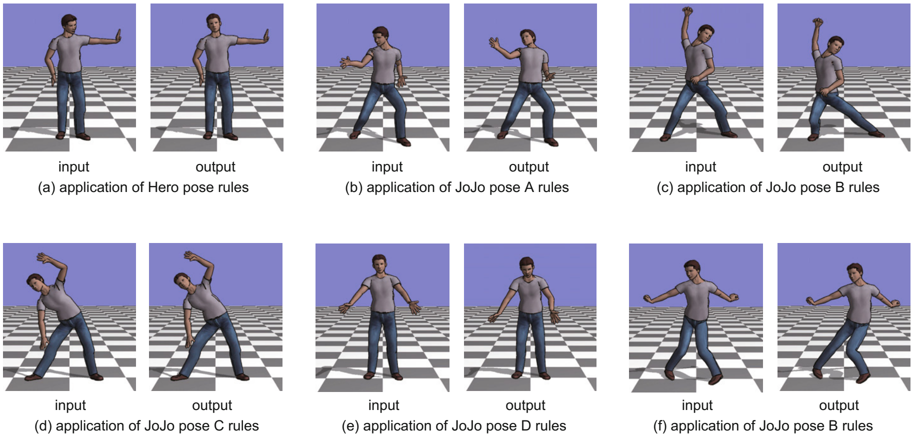


Fig. 6. Examples of successful pose deformation. Rules of the selected type and category are applied to the input.

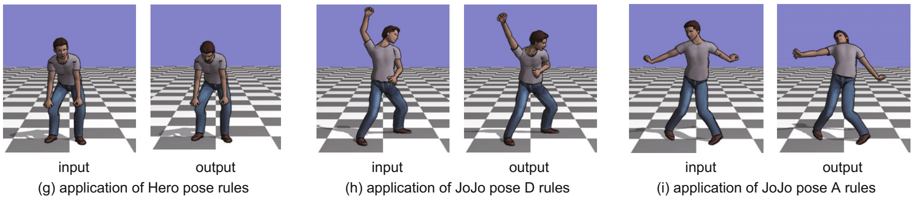


Fig. 7. Examples of unsuccessful pose deformation.

example, the deformation method extends the right arm and bends the left arm without considering shoulder rotations and collisions. As a result, the right arm pose looks infeasible and the left arm penetrates into the body. In Fig. 7(i), the upper body is too bent and the resulting pose looks infeasible. As explained in Sect. 4.1, we set extreme motion feature values manually. By setting smaller extreme values, such a problem does not happen. However, some poses may need higher extreme values. As mentioned above, this is not a problem in practice, as the user can interactively control the deformation scale to avoid deformation parameters that are too large and infeasible poses.

We successfully applied our approach to small numbers of example Hero and JoJo poses. Our pose deformation should be applicable to other rules for different kinds of attractive poses as long as the rules are described according to the low-level pose features. We are planning to implement our approach to a wider range of attractive poses. Introducing more advanced pose features is also a possible future direction of research. However, pose deformation becomes a difficult problem, because human poses have more degrees of freedom and it is hard to make a reasonable pose on the basis of a small number of pose features.

6 Conclusion

We developed a heuristic kinematics-based pose deformation method based on the discovered rules of attractive poses. We evaluated our method through a user experiment. The results show that our method can deform a pose to realize a specified style. Although we still need to experiment on different types of attractive poses, we believe that our approach is promising and can be an effective way to create novel attractive poses.

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