TraceMove: A Data-assisted Interface for Sketching 2D Character Animation

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Abstract: In this paper we present TraceMove, a system to help novice animators create 2D, hand-drawn, character animation. The system and interface assists not only in sketching the character properly but also in animating it. A database of image frames, from recorded videos of humans performing various motions, is used to provide pose silhouette suggestions as a static pose hint to the users as they draw the character. The user can trace and draw over the generated suggestions to create the sketch of the pose. Then the sketch of the next frame of the animation being drawn is automatically generated by the system as a moving pose hint. In order to do this, the user marks the skeleton of the character in a single sketched pose, and a motion capture database is used to predict the skeleton for the subsequent frame. The sketched pose is then deformed according to the predicted skeleton pose. Furthermore, the sketch generated by the system for any frame can always be edited by the animator. This lets novice artists and animators generate hand-drawn 2D animated characters with minimal effort.

1 INTRODUCTION

Creating hand-drawn 2D character animation requires a significant amount of skill. Sketching a character to convey a certain mood or idea is difficult for novice artists. An animation needs a series of such sketches and is even more difficult to create. It requires a lot of skill and effort to create an illusion of life (Thomas and Johnston, 1995) from sketches, which often detracts and frustrates novice animators.

In this paper, we present TraceMove, a system that provides hints to the animator as they draw the sketch of the character for every frame of the animation, thereby making the creation of the animation easier for novice animators. The hints provided are of two kinds. The first assists in the sketching of the static pose and is provided as a background silhouette image of the pose that the animator is trying to sketch at the current frame. This is predicted by the system based on the sketch strokes that the animator has drawn on the frame so far and a database of images containing humans in various poses. The animator can choose to follow these hints as much or as little as she wants. The second kind of hints are aimed at assisting the animator in sketching the next pose, once the current one is finished. Sketching characters in motion requires a sense of timing and rhythm of the movement (Williams, 2009), which is very hard to get for novice artists. Our system takes the help of motion capture data to predict the next sketched frame for the animator. She can draw over this prediction, modify it as she wishes and proceed. The two kinds of hints can be interleaved and used as desired on the same or different frames of the animation, thereby giving the animator a lot of flexibility and complete control during the creation process.

We will start with a discussion of the current literature available in this area in Section 2. We will follow this up with an overview of our system in Section 3. After this we present a detailed discussion of how we generate the static pose and moving pose hints, in Sections 3 and 4. We present sketch sequences generated using our system in Section 5. We conclude with a discussion of the limitations of the system and directions for future work in Section 6

2 RELATED WORK

Sketching is an art form that is ubiquitous in animation, painting and design. There have been many systems developed to make sketching accessible to novice users. The iCanDraw interface (Dixon et al., 2010) helps the user by providing step by step guidance to draw the human face using a reference image

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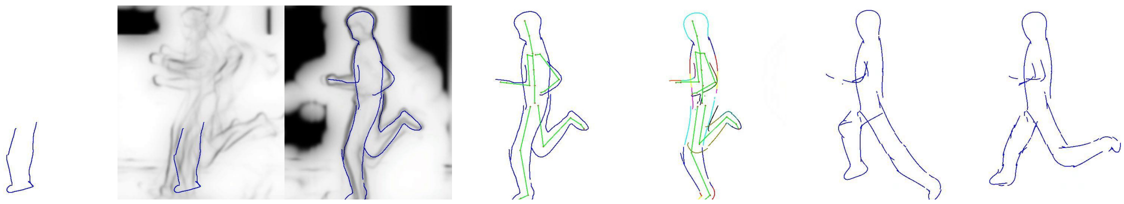


(a) (b) (c) (d) (e) (f) (g)

Figure 1: (a) The animator starts to sketch, (b) The static pose hint updates depending on the sketch, (c) The animator can follow it to complete the sketch, (d)-(e) The moving pose hint predicts the next frame from the current drawn sketch, (f)-(g) the animator can continue and easily complete the animation.

and written instruction. Other systems try to match sketch strokes with images (Jacobs et al., 1995),(Chen et al., 2009) and then these can be used to guide the sketching. ShadowDraw (Lee et al., 2011) is a sketching system that presents a shadow image that is a blend of matching object images from a database. The user can use the shadow as a draw-over guide to create a sketch of that object. A part of our system is based on ShadowDraw, in which we generate the static pose hint using methods from that paper. A gesture based rapid 3D sketching system is presented in (Bae et al., 2009) which allows novice users to sketch designs for complex objects.

Sketch-based interfaces for modelling and animation are also an active topic of research in computer graphics. Sketches have been used for modelling 3D objects from sketches by novice users (Igarashi et al., 1999), from design sketches (Xu et al., 2014) or for creating layered additions to exiting 3D models (De Paoli and Singh, 2015). Sketches have also been used to pose 3D character models (Öztireli et al., 2013).

Sketches have also been used to drive 3D animation. The input to algorithm described in (Jain et al., 2009) is a set of hand-drawn frames. The method uses motion capture data to transfer the 2D animation to 3D, while maintaining the unique style of the input animation. In an earlier work, (Davis et al., 2003) takes user drawn stick figures as input, extracts best matched 3D skeleton poses for the input figures and generates a 3D animation. Inspired by traditional, hand-drawn animation, silhouette curves are used to stylize existing 3D animations by (Li et al., 2003). Motion Doodles (Thorne et al., 2004) is a system that takes a stick figure of character and a motion path as input, and finally animates the figure on the path. The LifeSketch system (Yang and Wünsche, 2010) also outputs 3D animation of 2D sketch given as an input by user. However, this work makes an assumption that object is blobby and all the parts of objects are visible. More recent work by (Levi and Gotsman, 2013) creates a 3D model of an articulated character from multiple sketches and then allows animation of the character in 3D.

In other prior work (Pan and Zhang, 2011) describe a skeleton driven 2d animation technique. The system is provided with one image and then the user sketches the skeleton for the subsequent frame. The system deforms the character according to the new position of the skeleton and creates animations automatically. However, this is very cumbersome because the user is required to draw the skeleton for all the frames and no help is provided for sketching the actual poses. Thus, we find that all prior work to our knowledge, either requires the sketch as input for the animation or provides no feedback assistance to the novice animator in creating the animation.

In contrast, our TraceMove system tries to help novice animators in sketching 2D animations. For this we not only help in the static pose sketches at individual frames but also predict sketched poses for subsequent frames. These hints allow the animator to create sketched 2D character animations very quickly.

3 SYSTEM OVERVIEW

An overview of the TraceMove system is shown in Figure 2. We start by pre-processing an image database of human poses at various stages of multiple motions to edge descriptors (Figure 2(a)). This is done only once for the entire database. Then the animator can start sketching and the static pose hint is updated, as required, based on the current sketch available to the system and the processed image database. The static pose hint is generated by blending the top ten edge figures from database that best match the sketched pose, in the edge descriptor space (Lee et al., 2011). This is shown in Figure 2(b)-(c). Once the animator is satisfied with the sketch (Figure 2(d)), it is passed on to the moving pose hint generation module.

We have also pre-processed motion capture data to obtain 2D projected motion capture data (Figure 2(e)). Now the animator draws a skeleton on

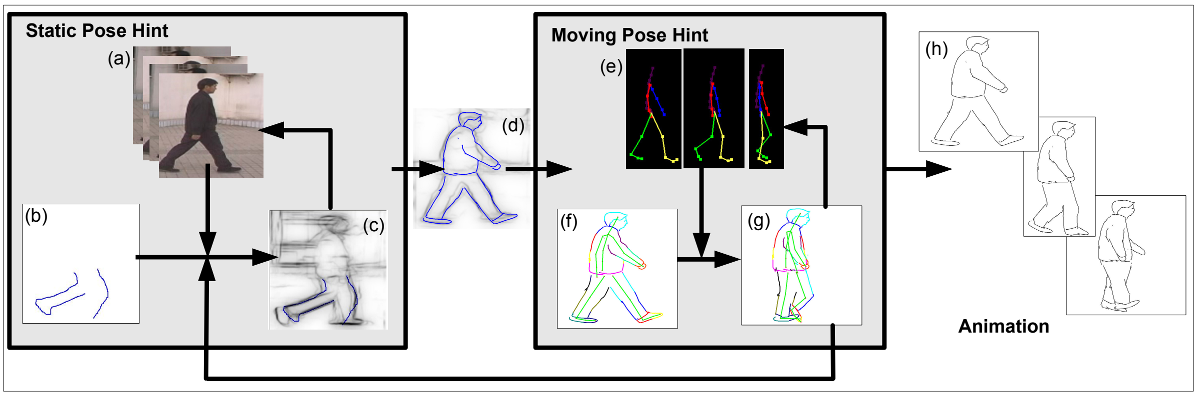


Figure 2: Overview of the TraceMove System.

the sketch by clicking joint positions on the sketch (Figure 2(f)). This has to be done only for one pose for the entire animation. The order of clicking is shown to the animator and automatically establishes joint correspondences to the skeleton hierarchy used in the motion capture. The skeleton on the sketch is used to identify a best matching pose from the motion capture data, and the subsequent poses to the best matching pose, are used to find corresponding subsequent poses for the skeleton on the sketch, and by consequence of the sketch itself (Figure 2(g)). At this point, the animator can choose to manually edit the predicted sketched pose, again with the help of the static pose hint or without it. This process is repeated to get sketches for all the frames of the animation.

It should be noted that the animator can choose to ignore the static and moving pose hints completely at any stage, or use them at any stage in the creation process. So the system does not stifle the freedom of the animator, but provides enough help to the novice animator to be able to create convincing sketched character animations.

The static pose hint generation module of our system is based on ShadowDraw (Lee et al., 2011). Our static pose hint is like the shadow image generated in that work. We have implemented our system from scratch and have made some changes to the original ShadowDraw idea which improve the quality of the generated hint.

The first part of the static pose hint generation module involves processing a database of figures of human in various poses during a motion. For walking people, we used the CASIA Gait Database (Wang et al., 2003). For other motions, we created our own database by recording videos of various motions on 6 different users. We used the frames of these videos as figures in our database, In total the combined database has 3052 frames for 6 different kinds of motion. Example images from the database can be seen in Figure 3. The database is processed offline, in a pre-processing step to generate a database of patch-features from the edge figures of the figures in the original database. These descriptors are then used to generate the static pose hint while the user sketches.

Figure 3: Example images from the image database.

3.1 Generating the Database of Patch-features

The original figures in the database are converted to edge figures, post cropping and size normalization. We use (Dollr and Zitnick, 2013) to extract long edges from the figures. This is important because it is found that while sketching it is natural to draw the long edges first. So we need an algorithm that can prioritize long edges. ShadowDraw (Lee et al., 2011) uses the work presented in (Bhat et al., 2010) for extracting edges. Our implementation of the same gave either faint or very thick edges, so we used the different method mentioned above.

This is followed by dividing the edge image into overlapping patches and computing a BICE descriptor for each patch (Zitnick, 2010). We want to match the user's sketch to the figures in the database, in descriptor space. However, computing a match directly on the descriptor is expensive so it is converted to a sequence of k values, each generated by applying k different min-hash functions to the descriptor of the patch. Each sequence of these k values is a patch-feature. This is repeated n times, using a different set k hash functions each time, to get n patch-features for each patch descriptor. Therefore while matching, a potential input patch has to match multiple instances of the same descriptor to be considered a good match. This reduces both false positives and false negatives. We have used $k = 3$ and $n = 20$. We store the patch-features with a reference to the original image to which they belong, and the patch location coordinates in the original image in another database.

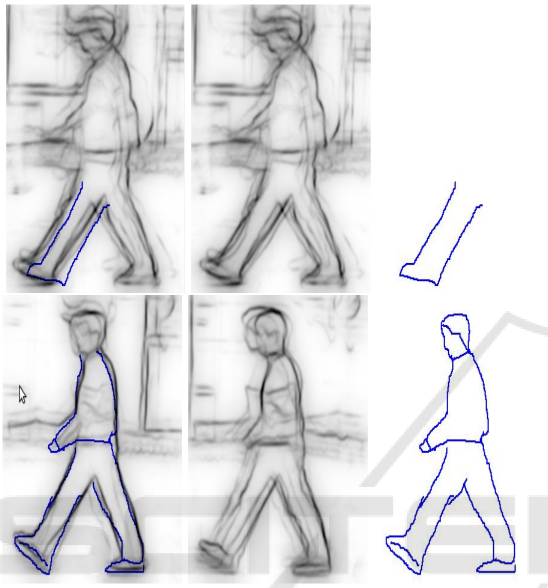


Figure 4: First column shows the drawn sketch overlaid on the static pose hint, second and third columns show the static pose hint and the drawn sketch separately.

3.2 Generating the Static Pose Hint

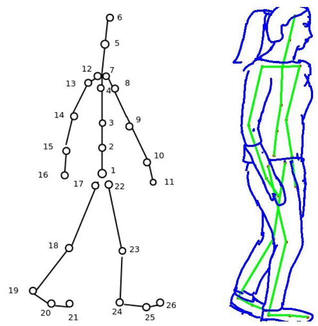
As soon as the animator finishes sketching a stroke, an image of the canvas is converted to patch-features and only patches containing the strokes are matched to the database created in the previous section. Top 10 figures from which maximum number of patch-features match the patch-features from the input sketch are aligned and blended. This blended image is then multiplied with its own blurred version to strengthen edges that match in position between them and weaken others. This forms the static pose hint image. It is displayed on the drawing area, underlying the animator's sketch, and can be updated in real-time as the animator sketches. We have, however, found this to be distracting during use. So we give the animator an option of updating and displaying the static pose hint on the canvas at the push of a button, instead of updating it continuously on sketching. The last updated static pose hint is displayed on the side in a smaller window so that the animator still has a reference for the pose being sketched but the drawing area is not obstructed by it. An example of the static pose hint is shown in Figure 4

4 MOVING POSE HINT

After successfully drawing the character in a particular pose, the animator now wants to sketch the pose in the next frame of the animation. The moving pose hint is meant to help with this. We start with a database of motion capture clips. This database currently has 6 different kinds of motions and a total of 625 frames. We project the 3D motion capture data to 2D, using a camera that projects the root node of the motion capture skeleton to the origin of the image coordinate system. We fix other camera parameters to give us desired projections of the motions being processed. It should be noted that we can only generate moving pose hints if the sketch of the character is from the a viewpoint that is close to the camera viewpoint used to generate the 2D projections of the motion capture data. The creation of the 2D projected motion capture database is a pre-processing step and has to be performed only once.

4.1 Skeleton Matching

The animator marks the skeleton on the sketch of the current pose by clicking the joint positions on the sketch. The joints have to be clicked in a particular order that is shown in the interface during the clicking (as shown in Figure 5(a)). This has to be done only once for a single sketched pose of the entire animation and is very simple to do. The ordered clicking automatically sets up correspondence between the user marked skeleton and the motion capture skeleton.



(a) (b)

Figure 5: (a) Order in which the skeleton nodes have to marked by the user, (b) Joint nodes for left arm have to marked even when it is occluded.

The animator has to mark the entire skeleton even if a part of the body is occluded in the current sketch.

For example, as shown in Figure 5(b), one arm of the character may be occluded but all the skeleton nodes for that limb have to marked approximately.

After the skeleton is marked on the sketch, its bones are re-scaled to match the bone length of the skeleton in the motion capture database. This is necessary because the bone lengths of the motion capture skeleton are fixed, while bone lengths of the sketch skeleton can vary with the sketch. Therefore, we determine scale factors needed to scale the sketched skeleton bones appropriately. If S_i is the scale factor for i^{th} bone, L_i^{sketch} and L_i^{mocap} are bone lengths of i^{th} bones of the skeleton on the sketch and in the motion capture database, respectively.

$$S_i = \frac{L_i^{mocap}}{L_i^{sketch}} \tag{1}$$

This scale factor is applied to each bone of skeleton on the sketch. We also calculate the inverse scale factor, $IS_i = 1/S_i$ that is used later in our calculations.

After scaling the skeleton on the sketch, the system searches for the best matching frame in the motion capture data such that the pose of the skeleton in that frame best matches the sketched pose. This is done by minimizing, over all frames, a distance metric that sums the Euclidean distance between the corresponding root-centred joint coordinates of the sketch and motion capture skeleton joints.

$$D_t = \min_t \{\sum_k dist(C_k^{sketch}, C_k^{mocap}, t_k)\} \tag{2}$$

Here D_t is the minimum value of distance metric, C_k^{sketch} is the coordinate of the k^{th} joint of the sketched skeleton with the root of the skeleton as the origin, and the C_k^{mocap} is the similar coordinate of the corresponding joint of the skeleton in the motion capture data and t iterates over all the frames of the database. Now we can predict the next pose for the sketch from the pose of the skeleton that follows the best matching skeleton in the motion capture data. This predicted sketch is the motion pose hint. But before we can do that we need to be able to deform the sketched pose using the skeleton. This requires us to rig the sketch with the sketched skeleton.

4.2 Rigging

In order to facilitate rigging, every sketch stroke is internally converted to a Bézier curve. Rigging is computed automatically by the system on the basis of distance of the curve points from skeleton bones. Every curve point is associated with at least one skeleton bone. Curve points near a skeleton joint are associated to both bones at the joint. Weights are assigned to the curve points by inverse weighting them by their distance from the bone.

Due to ambiguity of 2D projection, there are cases where automatic rigging incorrectly associates curves with skeleton bones. This causes erroneous deformation of the sketch when the skeleton moves. In such cases, animator can correct this simply by going to manual rig mode and selecting the curve that need to be re-associated and the bone with which it needs to be associated by clicking on it. This will detach the curve from its initial bone and re-associate it to the new bone.

Figure 6(a) shows an incorrect automatic rigging output. Curves associated with different skeleton bones are of different colour. The curves of the torso get wrongly associated to an arm and move backwards as the arm swings back in a subsequent frame in Figure 6(b), as indicated by the red arrows. Figure 6(c)-6(d) shows the corrected rigging in the initial frame and how it stays in position correctly in the generated sketch for the following frame, as indicated by the green arrows.

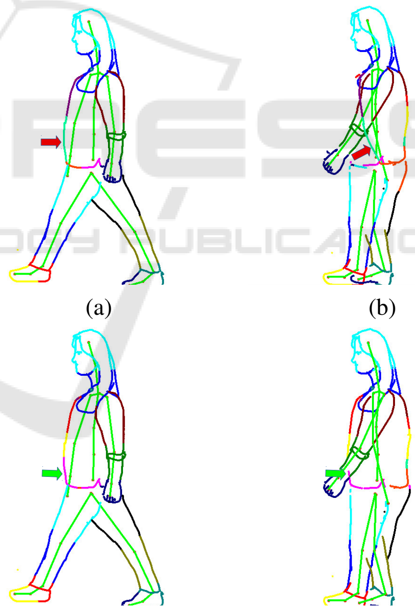


Figure 6: (a), (b) Automatic Rigging, (c), (d) Corrected Rigging.

4.3 Binding Matrix Calculation

The curves are defined in screen space and skeleton joints are defined in their own local frame. The curve associated with a particular bone need to be defined in the same frame as that of the bone so that all the transformation that are applied to joint, when applied to curve will move the curve along with the bone. To define the curve points in the joint space with which they are associated we need to find the binding matrix for all the skeleton joints. This binding matrix, B when multiplied to the curve points, transfer them to the joint local coordinate frame, with Y-axis along the bone, X- axis perpendicular to the bone and parent node as the origin. The binding matrix for the k^{th} joint is calculated as

$$B_k = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & -J_k x, \\ 0 & 1 & -J_k y \\ 0 & 0 & 1 \end{bmatrix} \quad (3)$$

Here

$$\begin{aligned} L_{k+1} &= J_{k+1} - J_k \\ D &= \sqrt{(L_{k+1}x)^2 + (L_{k+1}y)^2} \\ \cos\theta &= L_{k+1}y/D \\ \sin\theta &= L_{k+1}x/D \end{aligned}$$

J_{k+1} is the coordinate of $k+1^{th}$ joint and L_{k+1} is its coordinates with respect to its parent, i.e., k^{th} joint. Now, for curve associated with k^{th} joint, the binding matrix is the product of a rotation matrix and a translation matrix. First, the translation matrix is applied to the curve which will bring the k^{th} joint to the origin and then rotation matrix is applied to align the bone with the Y-axis as shown in Figure 7.

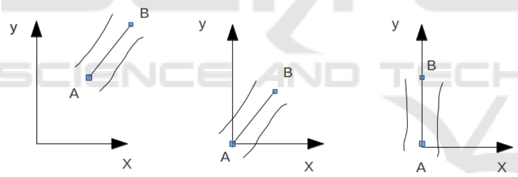


Figure 7: (a) A bone and the associated curve, (b) Translated to origin (c) Rotated so that bone lies along Y-axis.

4.4 Generating the Moving Pose Hint

We have found the frame from the motion capture database that best matches the sketched skeleton. We also know the pose of the skeleton in the frame that follows the best frame in the motion capture data. The system now finds the translation difference in coordinates for these two frames in the motion capture database and applies that difference to the current sketched skeleton, after inverse scaling it to drawn skeleton. This is done using Algorithm 1.

Here T_k is the translation difference for k^{th} joint. J_k^{t+1} and J_k^t are the 2D coordinates of k^{th} joint for next frame and current frame of the motion capture skeleton respectively. Note that the translation difference is calculated by taking parent joint node as origin. Sim ilarly in the subsequent step, when applying this difference to sketched skeleton joint J_{k+1}, its parent joint J_k is shifted to origin. After applying the difference to the $(k+1)^{th}$ joint, the k^{th} joint is shifted back to its new position that is calculated after applying the translation difference to it. The coordinates given by the J^{t+1}'s are the new predicted position of the joints of the sketched skeleton in the next frame.

Algorithm 1: Generate Next Sketch Skeleton.

for every joint k of the motion capture skeleton in frames t and $t+1$ **do**
  $T_k = (G_{k+1}^{t+1} - G_k^{t+1}) - (G_{k+1}^t - G_k^t)$
end for
for every bone i of the sketched skeleton between joints J_{k+1} and J_k **do**
  $J_{k+1}^{t+1} = (J_{k+1}^t - J_k^t) + IS_i \cdot T_k + J_k^{t+1}$
end for

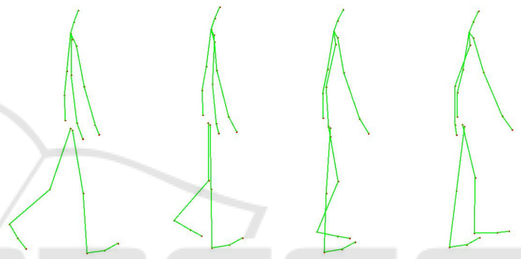
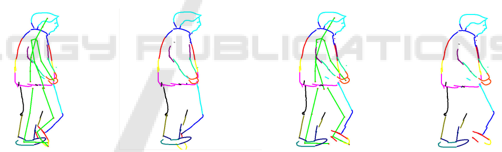


Figure 8: First frame is the drawn skeleton, rest of the frames are generated using Algorithm 1.



(a) (b) (c) (d)

Figure 9: (a) Current frame with skeleton,(b) Current frame without skeleton, (c) Next Frame with skeleton, (d) Next Frame without skeleton.

We find the transformation matrix from the current sketch skeleton to the next generated sketched skeleton for every skeleton joint. We apply this transformation matrix and the binding matrix to every curve associated with a particular joint, to generate the moving pose hint. This is illustrated in Figure 9.

4.5 Depth Adjustment

Since a sketch is 2D, some of the curves that were visible before may go behind the body and they will still be visible. For correct occlusion handling, these have to be erased via manual editing. While some new curves that were occluded before may be visible in the new frame. The animator will have to draw them. For this purpose, she can take help of the static pose hint

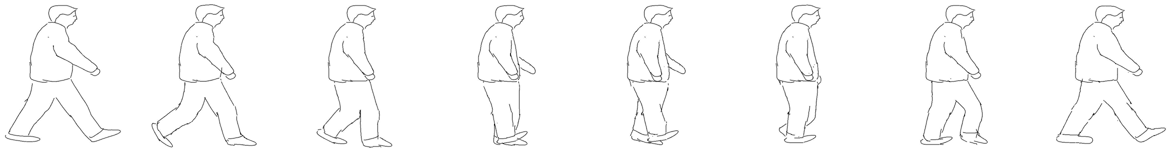


Figure 11: Frames from walk animation.

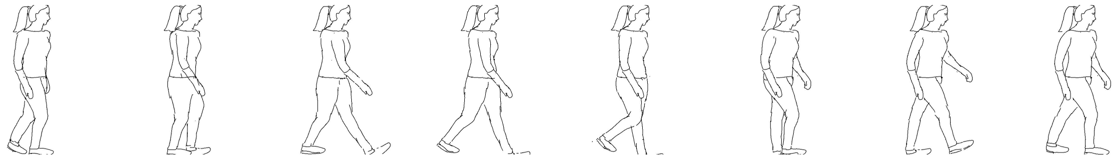


Figure 12: Frames from another walk animation with a different character.

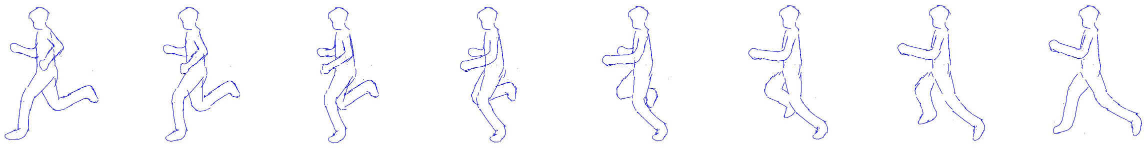


Figure 13: Frames from a run animation.

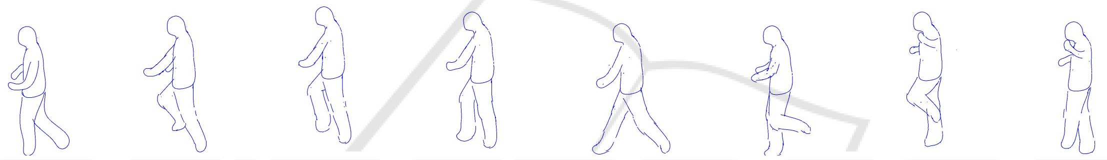
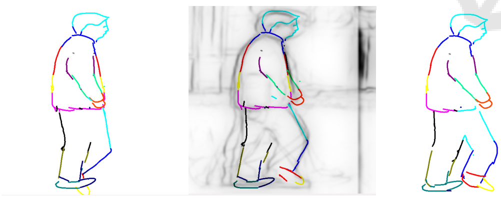


Figure 14: Frames from a skipping animation.

again, if required. This is shown in Figure 10. The newly drawn curves get automatically attached to the skeleton via automatic rigging.



(a) (b) (c)

Figure 10: (a) First frame, (b) Next frame without depth adjustment, (c) Next frame with depth adjustment.

5 RESULTS

We present examples of seven sketched animations generated using our TraceMove system for various kinds of motion. These were all created by two novice animators who had no prior experience in hand-drawn figure animation. The actual animations can be seen in the supplementary video submitted with this paper.

6 CONCLUSION

We have presented a system to assist novice animators in sketching 2D character animations. The system generates a static pose hint to help in the sketching of a particular pose of a character in a frame of the animation and also generates a moving pose hint that helps sketch the subsequent frame of the animation, given the current frame. Both these hints are generated with the help of pre-processed, stored databases of images and motion capture data.

The current system has certain limitations. The sketches for which the moving hint can be generated must be from a viewpoint that is close to the one used in generating the 2D projected motion capture database. This can be overcome by automatic viewpoint detection on the sketch and then using the corresponding view of the 3D motion capture data at run-time. Also, during the entire sketch animation that can be generated by the system, the camera orientation relative to the character cannot change much. The hint generation modules cannot work across viewpoint changes. A view-dependent hint generation method can possibly be used to alleviate this problem.

We also want to test the system with more novice

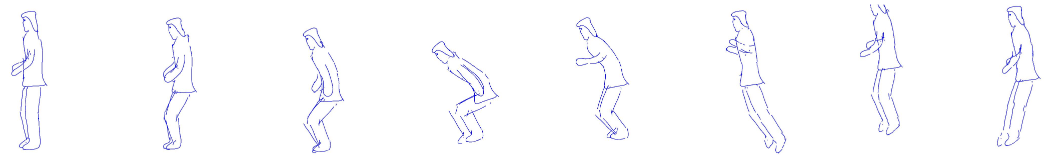


Figure 15: Frames from a jump animation.

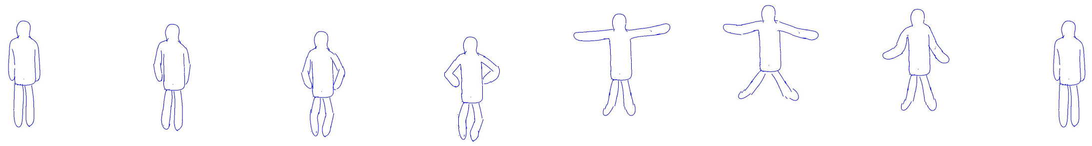


Figure 16: Frames from a different jumping animation.

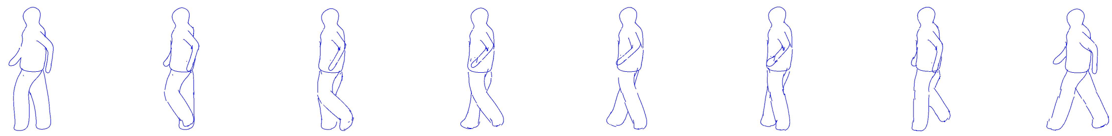


Figure 17: Frames from a backward walk animation.

animators and also, expert animators, to understand the efficacy of our interaction paradigms. This would require a thorough user study. We currently have no way to measure the aesthetic quality of the generated animation, but the novice animators who have used our system agree that it made the task of creating the animation easier for them and gave them a handle on a skill that they would have otherwise struggled to master. We want to use this positive feedback to further improve our system and make it more intuitive and natural to use.

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