Automatic expressive deformations for implying and stylizing motion

Abstract  Three-dimensional computer animation often struggles to compete with the flexibility and expressiveness commonly found in traditional animation, particularly when rendered non-photorealistically. We present an animation tool that takes skeleton-driven 3D computer animations and generates expressive deformations to the character geometry. The technique is based upon the cartooning and animation concepts of “lines of action” and “lines of motion” and automatically infuses computer animations with some of the expressiveness displayed by traditional animation. Motion and pose-based expressive deformations are generated from the motion data and the character geometry is warped along each limb’s individual line of motion. The effect of this subtle, yet significant, warping is twofold: geometric inter-frame consistency is increased which helps create visually smoother animated sequences, and the warped geometry provides a novel solution to the problem of implied motion in non-photorealistic imagery. Object-space and image-space versions of the algorithm have been implemented and are presented.

Keywords  Expressive deformations · Cartoon animation · Non-photorealistic rendering · Stylizing motion · Implied motion

1 Introduction

Traditional animators have always had a rather flexible view of bone structure. An understanding of anatomy is crucial but of paramount importance are the fundamental principles of traditional animation [11, 22], which maintain that bones are there to be squashed and stretched, and joints can be broken [26] if it makes for a more appealing image or dynamic motion. As a result, the limbs of hand-crafted animated characters (both pencil and computer-generated) are often distorted to accentuate a motion or imply an emotion (see Figs. 1 and 2). Our aim is to automatically mimic these distortions in order to imply motion in static images, increase inter-frame coherency and to imbue 3D character animations with a degree of the expressiveness and fluidity found in traditional animation.

Commonly seen in 2D animation, the primary cause of these distortions is the use of what animators and cartoonists refer to as “motion lines” and “action lines” [2, 4, 6, 7, 12, 25]. Action lines are the basis for rhythm, simplicity, and directness in animation [2]. As can be seen in Fig. 3, these two types of line are closely related and are typically drawn as smooth curves or arcs. They are used by artists as a visual aid to add dynamism and maintain consistency of motion between frames. It is far easier to animate a few curves and have a character follow them than it is to animate every joint. The action line is often thought of as an extension of the spine and, in traditional animation, indicates the overall pose and direction of a character. Closely related to action lines, motion lines indicate the direction of the most accentuated movement of the pose [7]. When applied to the motion of humanoid characters, these motion lines usually define the motion of the limbs and,
whether consciously or subconsciously, often lead to the distortion of these limbs in the final illustration (see Figs. 2 and 3).

However, these distortions are by no means an undesirable by-product. Action and motion lines are primarily an animation device but the distortions they cause in traditional animation have the effect of implying motion and increasing inter-frame coherency. This is particularly useful in traditional hand-drawn animation which is prone to suffering from temporal aliasing artefacts such as strobing caused by reduced frame rates.

In computer graphics, the standard method of reducing these stroboscopic effects and also of implying motion in static images, is to use motion blur. Although suitable in many cases, motion blur is often not applicable in non-photorealistic animations. The blurring effects of motion blur could remove many of the image artefacts that make up a particular non-photorealistic rendering (NPR) style. For example, the strong contour lines that form the distinctive illustrative style synonymous with cartoon images would be lost (or their impact certainly reduced) if they were blurred. Likewise, many NPR shading styles such as hatching and stippling would become flat grey areas if subjected to motion blur. In these cases the illusion of speed would be at the cost of the visual style itself and so alternative methods need to be used.

Traditional cartoonists and animators have developed many visual cues and techniques to convey the motion of objects without the need for blurring.

These include speed lines, after-images, jagged distortions and the deformation of objects (see Fig. 4). As can be seen in Fig. 4, to show an object is travelling quickly it is often warped. These deformations not only imply