Anticipating Impacts

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INTRODUCTION Recent years have produced several important papers on the topic of combining motion capture data with physical simulation to produce motion that is compelling and lifelike while also physically correct. This is especially important in motion sequences that include some degree of physical contact. In most of this work, however, the character generally appears to be oblivious to the impending contact. We present a novel approach for generating a humanlike response *in anticipation of* an approaching impact. To meet our goals, we model the incoming threat and associate it with actions that the character must take to prepare for impact. We then guide the character to perform these actions while obeying physical limits for balance and upholding characteristics taken from the character's current motion capture sequence (Figure 1).

ANTICIPATING A THREAT Our anticipation model is based on a set of rules, such as "block" and "turn away", gleaned from psychological studies of monkeys and humans [Cooke and Graziano 2003; King et al. 1965] . These rules are parameterized with attributes of the impending collision object, which we call the *threat*. The threat model includes its incoming direction, its relative size and its relative speed. Psychology researchers describe the anticipatory response (in monkeys) as involving two distinct components: a startle response and a sustained response. In our technique, we form a correspondence between the set of rules and the threat parameters to produce startle and sustained anticipation responses.

More specifically, our heuristic-based rules mimic four independent components of response found in the literature. They are combined to create unique target poses for the startle and sustained responses. The first rule makes the character *lean* or pull away from the threat. The lean magnitude is dependent upon the threat size and the lean is distributed across the pelvis and the joints associated with the spine. The second rule causes the character to *turn away* with the goal of orienting the face away from the threat. Here, we rotate the neck and possibly the spine (depending on the severity of the turn required) based on the threat size. Third, a *recoil* rule pulls the free (non-supporting) extremities in, towards the body, and 'buries' the head into the shoulders. Intuitively, the larger or more heavy the threat, the more the character recoils. Last, a *blocking* component moves the arms to intercept the threat using inverse kinematics (IK). The perceived size of the threat determines how far the character reaches away from the body to intercept the threat.

These rules may lead the character to a posture that is out of static balance. To manage this, our algorithm ensures that both feet are on the ground and then positions the projected center of mass (COM) to control balance. If a foot is not on the ground, it is placed at the nearest ground position (following a short look-ahead in time) and the center of support is computed. A numerical optimization adjusts the character's pelvis to move the COM toward a desired value, while maintaining the pose created by the rules. The desired COM is based on the center of support but is shifted slightly in the direction of the threat in order to brace for the impending impact.

More details about our balancing algorithm follow in the next section.

MOTION GENERATION Generating motion based on the response pose created by the rules requires careful consideration if the movement is to appear natural. Proper timing and balance are crucial. And in practice, we found that controlling the path trajectories, especially for the arms, was of particular importance.

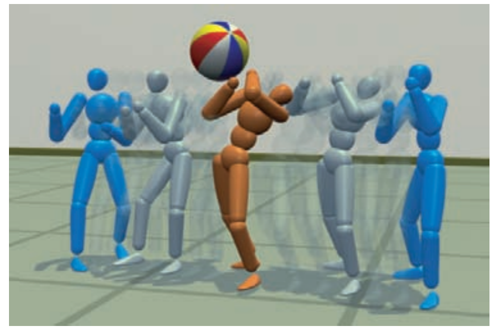

Figure 1: An example anticipation pose. The blue poses represent motion capture frames, grey poses represent interpolation frames, and the orange pose represents the character's pose at impact.

Our basic approach for this motion synthesis is to interpolate from a motion capture sequence to the target anticipation pose and back again (after the threat has been averted). We also include an intermediate "startle" pose (if the animator chooses) just following ($\sim 80ms$ after) the threat's appearance to give the character the sense of initially "becoming aware of the threat." This initial (unbalanced) version of the motion trajectory is computed by smoothly blending the joint angles of the character using spherical linear interpolation (slerp). We also found that using IK to guide the hand trajectories along straight-line paths led to more natural-looking motion.

Next, we once again adjust balance by modifying the unbalanced trajectory to control the projected COM. Our balancing algorithm treats the pelvis as the end effector of three IK chains rooted at the head and each foot and we perform a quasi-Newton based search that adjusts the position of the pelvis (root body) in order to achieve the desired COM.

Finally, we incorporate a version of Zordan et al.'s technique for dealing with unpredicted impacts through the use of a physical simulation which responds to impact forces and a smooth transition, generated by interpolating between motion capture postures and an active simulation [Zordan et al. 2005].

References

COOKE, D., AND GRAZIANO, M. 2003. Defensive movements evoked by air puff in monkeys. *Journal of Neurophysiology 90*, 1, 3317–3329.

KING, S., DYKEMAN, C., REDGRAVE, P., AND DEAN, P. 1965. Use of a distracting task to obtain defensive head movements to looming visual stimuli by human adults in a laboratory setting. *Perception 21*, 2, 245–259.

ZORDAN, V. B., MAJKOWSKA, A., CHIU, B., AND FAST, M. 2005. Dynamic response for motion capture animation. *ACM Trans. Graph. 24*, 3, 697–701.