A Ragdoll-less Approach to Physical Animations of Characters in Vehicles

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Figure 1: The character's body moves forward by our method when a car collides into a wall

ABSTRACT

Recently the use of vehicles has increased in importance for many games. This is not only for open-world games, where the use of vehicles are a crucial element of world traversal, but also for scenario based games where the use of vehicles adds a more varied game-play experience. In many of these games, however, the characters inside the vehicles lack the animations to connect their motion to that of the vehicle. The use of a few poses or small number of animations makes in-vehicle characters too rigid and is particularly noticeable in open vehicles or those with excessive motion such as tractors, speedboats or motorbikes. This can break the connection the player has to the vehicle experience. To solve this problem, several games have used a method to control a ragdoll with physical parameters to follow the input poses [Fuller and Nilsson 2010] [Mach 2017]. However, this solution has several complications regarding controllability and stability when simulating a ragdoll and a vehicle at the same time.
I would like to introduce a new approach using particle-based dynamics rather than using a ragdoll. We present two methods: a particle-based approach to physical movement (see Figure 1) and modifying goal positions to generate plausible target poses (see Figure 3).

CCS CONCEPTS

• Computing methodologies → Computer Graphics → Animation → Procedural animation

KEYWORDS

Procedural animation, Character animation, Physics-based

SIGGRAPH'19 Talks, July 28 – August 01, 2019, Los Angeles, CA, USA
ACM 978-1-4503-6317-4/19/07.
10.1145/3306307.3328146

ACM Reference format:

Hyojong Shin, Mark Leadbeater and Ben Merrick. 2019. A Ragdoll-less Approach to Physical Animations of Characters in Vehicles. In *Proceedings of SIGGRAPH'19 Talks. Los Angeles, CA, USA, July 28 – August 01, 2019*, 2 pages. https://doi.org/10.1145/3306307.3328146

1 Particle-based Animation

1.1 Time Integration

We conduct this phase after finishing physics simulation steps including vehicle simulation so that we can get exact goal positions for the character. Our approach uses particle-based methods to simplify each body's movement. It considers each bone as a particle and changes its position by applying velocities.
[Müller 2005] introduced a stable and robust way to integrate positions. However, it is designed for elastic objects so we add a damping coefficient on the velocity calculation to give natural movement.

$$\mathbf{v}_i(t+\Delta t) = \alpha \frac{\mathbf{g}_i(t) - \mathbf{x}_i(t)}{\boldsymbol{h}} + (1-\alpha)\mathbf{v}_i(t) + \Delta t \frac{\boldsymbol{f}_{ext}}{m_i} \tag{1}$$

$$\mathbf{x}_i(t+\Delta t) = \mathbf{x}_i(t) + h\mathbf{v}_i(t+\Delta t) \tag{2}$$

where $\mathbf{g}_i$ is the goal position of particle i, $\boldsymbol{f}_{ext}$ is the external force and α is the parameter to control stiffness. We use $(1-\alpha)$ for the damping value for controllability and natural movement. If α is 1.0, the character will be 100% stiff and it is completely the same as the authored animations. If α is 0.0, then the character follows the basic physics laws without a restoration force. This is easy to control stiffness and gives a more natural motion for the human body because particles eventually follow input animations with any α value that is greater than zero while the vehicle is at constant velocity.

1.2 Strain limiting

Section 1.1 shows stretches between particles, as they do not have constraints yet. [Rungjiratananon et al. 2010] introduced how to handle strain limiting and collisions to simulate hairs with the same time-integration method. The human body also has similar length constraints but it is not as simple as hair chains because the human body is consisted of multi-chains connecting spine, arms and legs. Besides, it also needs to adjust closed-loop constraints for clavicles and pelvis-thigh bones. To solve these issues, we adopted the fast converging particle IK method for human-like models [Aristidou et al. 2016]. Results are shown in Figure 1. This also allows characters to move their hips freely from the seat while running on rough terrain (see Figure 2).

Figure 2: Hip movement by multi-chain method

1.3 Oscillation removing

When stopping a vehicle, fluctuation can occur around goal positions and it does not look like a human. We increase stiffness with a Gaussian function only when the vehicle's acceleration is small. This can allow characters to maintain their good posture without oscillation while undergoing small accelerations.

2 Goal Positions

While the above technique gives us plausible physical reactions to the vehicle motion it still relies on authored animations to get full response of the character in the second phase of the characters motion. Basic reference animations when the vehicle moves on slopes or uneven terrain lack the connectivity to the vehicle, as humans try to react to local forces and gravity. Animation blending can solve this issue and [Fuller and Nilsson 2010] used parametric blending with 6 animations in 2-dimensional blend space to generate target reference animations. However, the number of animations will increase drastically in 3-dimeonsial space and those animations need making for many different situations. In reality, modern open world games provide hundreds of vehicles so it is hard to create those animations for each vehicle. For those reasons, many games often use a limited set of animations or poses across all vehicles. To tackle this issue we consider a procedural approach to adapt animations to the character's balance conditions and use the method based on Full-body IK solution considering the character's center of mass condition [Rabbani and Kry 2016].

$$\boldsymbol{J_b} = \left(\frac{\partial r_j(\theta)}{\partial \theta}\right) \quad (3)$$

where $\boldsymbol{r_j}$ is the position vector of the joint j and $\boldsymbol{J_b}$ is the body Jacobian matrix for IK positions.

Figure 3: Character balancing. [Left to right] Reference pose, leaning forward, left and right on each different slopes.

We adopted velocity-based forms with linear momentum theory for COM condition shown in [Kajita 2003] instead of partial derivative expression.

$$\boldsymbol{P_j} = \boldsymbol{\omega_j} \times (\boldsymbol{c_j} - \boldsymbol{r_j}) m_j \quad (4)$$

$$\boldsymbol{\omega_j} = \boldsymbol{a_j}\dot{\theta} \quad (5)$$

$$\boldsymbol{J_c} = (\boldsymbol{P_j}) \quad (6)$$

where $\boldsymbol{a_j}$, $\boldsymbol{c_j}$, m_j and $\boldsymbol{J_c}$ are the rotation axis vector of the joint j, center of mass, mass of all link structure driven by the joint j and Jacobian matrix for COM respectively.

$$\begin{pmatrix} \dot{\boldsymbol{r}} \\ \boldsymbol{M}\dot{\boldsymbol{C}} \end{pmatrix} = \begin{pmatrix} \boldsymbol{J_b} \\ \boldsymbol{J_c} \end{pmatrix} \dot{\boldsymbol{\theta}} \quad (7)$$

where $\boldsymbol{M}$ is the total mass of whole body and $\dot{\boldsymbol{C}}$ = Cr – C. Cr is the reference position for COM, often chosen as the center of the support zone or the closest point to the support. C is the current COM of the character. We solve it with Jacobian Pseudo-Inverse to satisfy both the IK conditions and the COM condition at the same time as far as possible. In addition, we use the projected COM position onto the horizontal plane so that it eliminates 1-dimension to increase stability. Characters change their poses depending on terrain geometry. Results are shown both in and out of vehicles (see Figure 3).

ACKNOWLEDGMENTS

We thank the teams at Ubisoft for their support of this project.

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