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Dynamic Behavioral Representation of 3D Objects by Insinuating Mass Spring System.

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ABSTRACT

Spring-Mass system is effectively utilized in computer animation for exploring the dynamic behaviors of the objects. Previously defined models are based on the continuous media mechanics where the mechanical behavior and kinematics were dealt with. Such methods require laborious descriptions of the boundary condition which is hardly compatible with other unpredictable conditions. In view of the downsides of the precious developed systems, a physical model is utilized to implement the spring mass damper. Here, a 3-dimensional model is synthesized which is a hyper elastic model that provides precise mechanical parameters for behavioral analysis. A robust controlling strategy for spring mass damper that often succumbs to external disturbances is presented. Furthermore, the system also generates the dynamic behavior that aids the study of motion of objects in animation.
Keywords: Spring mass damper system, physical based modeling, stiffness, elasticity, mass spring system.

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INTRODUCTION

The simulation of both 2-dimentional and 3-dimenaional objects can be accomplished pertaining to its environmental changes through the mass spring system. Moreover, it can be monitored and utilized for the deformation of the modelled soft bodies during its collision. The main aim of this work is to control the mass spring system in the 3-dimensional environment by delivering the 3D object's material details, its mass and its force.

Mass spring systems are extensively used in computer graphics to provide a way for synthesizing realistic motion that are physically truthful and convincing. The simulation of the physical body is provided by cogitating the mass all over the control points even though the actual mass is disseminated among the volume of the physical body. Here, the weight of the spring in the mass spring system is considered to be zero. Synthesizing and developing a computer generated models for animation is very much cumbersome. The mass spring system provides a simple methodology for synthesizing various soft object models such as cloth, fur, hair, liquids and so on. At each point of processing, the synthesized objects interacts with the respective environment and are subject to deformable as it changes its size, shape, surface points and position. Such kind of models necessitate parameters resembling stiffness constants and external forces that demonstrate motion of the synthesized objects. Here, a mass spring system is developed that exhibits more convincing 3D object behavior where speed, motion and stability of the object is maintained so that it is more visually authentic.

Mass spring system used Euler's methodology preciously that required large iteration phases in continuous media mechanism. Here, the known fast solver Runge-kutta method along with Hook's law is utilized and exploited to analyze and compute the standard mass spring system. Comparatively, Runge-kutta method requires less iteration when compared to the previous Euler's method. The illumination and shading of the 3D object provides the 3D environment where the illumination models are performed by computing the diffusion, ambient and specular lights whereas shading models are computed by a point light method.

RELATED WORKS

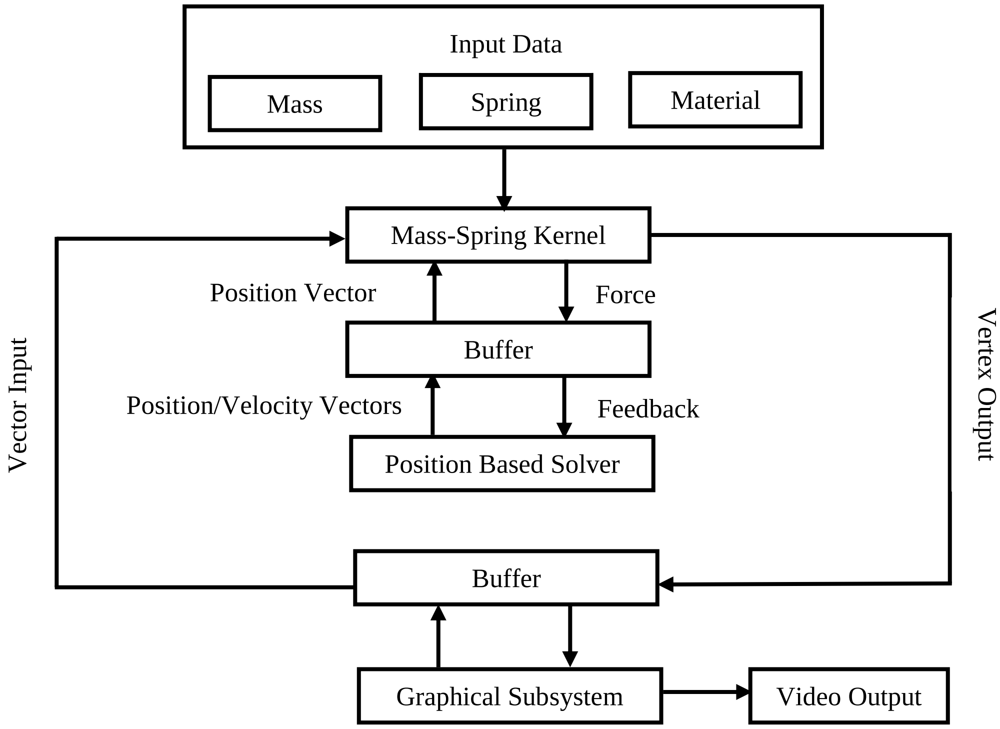
A discussion on the characteristics of nonlinear computational mechanics [1] is dealt with by the author. Also, the demonstration of different traits of nonlinear structural behavior is performed. Newton–Raphson iterative method elucidations are obtained by linearization aids in finding solutions to the nonlinear equilibrium calculations that occur in the finite element analysis. Prevention of collapse in the simulation of volumetric tetrahedra through a new altitude spring model [2] is proposed. A demonstration of hair behavior is accomplished where it considerably reduces the computational cost. A spring semi-implicit discretization is introduced in the multiple spatial dimension to showcase them as truly linear. Also, it is understood that it is very much stable without the requirement of Newton-Raphson iteration.

A stable method to handle the post buckling instability is represented in the dynamic simulation without the preamble of a damping force is reported. A very convincing and realistic motion of cloths [3] in a uniform time frame is proposed and synthesized. An adaptable and robust model for geometrically complex deformable solid objects [4] is presented where it deliberates elastic and plastic deformations. A large amount of practical and efficient methods for numerical computing [5] is presented that aids in modelling and simulation. For constructing the differential equations, elasticity theory is employed [6] that models the non-rigid curvesbehavior, surfacesbehavior, and solidsbehavior as a time function. Basically, all these models are highly dynamic and the animation is generated by the solutions that are obtained by numerically computing their fundamental differential equations.

A cloth simulation system [7] that can steadily take huge time steps is described. The proposed system combines a new method for enforcing the constraints over individual cloth particles utilizing the implicit integration method. Rather than using the old-styled numerical analytical method, a geometric method [8] based on time integration is presented. The use of discrete variational principles to obtain robustness is reviewed. A general-purpose numerical method for time integration of Lagrangian dynamical systems [9] is presented. The applicability of the integrators for the simulation of non-linear elasticity is demonstrated with its implementation niceties. Behavioral and look of the clothing by the digital stand-ins to their human equivalents is presented through various methods. Novelty contributions helps in controlling the huge scale folding. Generation of cloth simulation [10] with many folds and wrinkles are the basic aim of the proposed techniques.

A variational integrator for certain highly oscillatory problems in mechanics [11] is derived and presented. To perform this, a new scheme to split the fast and slow potential forces is done based on Lagrangian action integral. An example-based method [12] for simulating complex elastic material behavior is proposed. By means of interpolation, the proposed system constructs a space of preferred deformations. The benefits of physics-based simulations to conventional animation pipelines [13] is analyzed and presented. The equations of motions are formulated in the deformation subspace. A rich physical motions to abrasive input animations created to demonstrate the efficacy of the proposed method. A novel technique that lets one to preserve energy [14] utilizing the time integration method is proposed. The user chooses his own preferred time integration scheme with respect to aesthetics and further apply the proposed method to conserve the energy desired.

An approach that neglects the velocity layer [15] and simultaneously works on the respective positions is presented. Controllability is the prime advantage of the position oriented scheme. A unified dynamic solver [16] which is a standalone library that models all matters such as meshes, points, curves and solids. A new method to adapt the stiff characteristics of textiles inspired from dynamic inverse procedures [17] is presented. A method to acquire very low strain along the warp and weft direction using Constrained Lagrangian Mechanics and a novel fast projection method [18] is proposed. A new methodology, Continuum-based Strain Limiting (CSL) [19] is presented to restrict the deformations in the physically based cloth simulations. A fast strain-limiting methodology [20] that permits stiff non-compliant materials to be simulated efficiently is proposed. In comparison with other techniques, the propose method is efficient in terms of implementation and usage.



SYSTEM ARCHITECTURE

Figure 1: Overall architecture of the mass spring system.

The overall architecture of the mass spring system is illustrated in Figure 1.The mass data, spring data, and material data is given to the system as the input. From the processed input data, the position, velocity and orientation of the 3D object is determined. Finally, the motion or the movement of the object is visualized as an animated video sequence.

Spring motion module

The input parameter such as the object's position(x), velocity (v), mass (m), spring length (l) and spring stiffness (k) are considered and given as input to the mass spring system. When the mass is applied over the string, the respective force acts in the reverse path and successively stretches the spring. The force of the spring is assessed and calculated by the following equation.

$$F_{spring} = -k * stretch \qquad (1)$$

When the coordinate system is adjusted to the object's positon (x), the string is stretched. Then the force of the spring is estimated by utilizing the equation.

$$F_{spring} = -k * x \qquad (2)$$

The frictional force is an additional force, when applied over the spring the velocity and the movement of the system is reduced where the total force is reduced to zero. The final total force can be estimated and calculated by the following equation.

$$F = F_{spring} + F_{damping} = -kx - bv \qquad (3)$$

The motion of the object can be calculated by the following equation.

$$F = ma \qquad (4)$$

The equation of the object's motion acceleration can be assessed by the equation,

$$a = x'' \qquad (5)$$

Therefore, the equation for the motion of the object (4) and the equation for the acceleration (5) are coalesced to form the differential equation,

$$x'' = {}^{k}/_{m}x - {}^{b}/_{m}y \qquad (6)$$

The above equation (6) gives the spring motion of the object at every time interval.

Runge-kutta integration

The popular Runge-kutta method is utilized for solving the x and y values of the spring motion in the equation (6). For implementing the spring motion in Runge-kutta method the second order differential equation is converted to first order differential equation, $x'' = v'$. Therefore the spring motion equation(6) can be expressed as

$$x' = vv^1 = -{}^{k}/_{m}x - {}^{b}/_{m}y \qquad (7)$$

Initially, according to Runge-kutta method, the simulation starts by retrieving the object position (x), the initial value (v) at the time t=0. The fourth order Runge-kutta integration equations is calculated and are given as follows.

$$F_1 = h \cdot f(t, x) \qquad (8)$$

$$F_2 = h \cdot f(t + \frac{h}{2}, x + \frac{F1}{2}) \qquad (9)$$

$$F_2 = h \cdot f(t + \frac{h}{2}, x + \frac{F2}{2}) \qquad (10)$$

$$F_2 = h \cdot f(t + \frac{h}{2}, x + \frac{F2}{2}) \qquad (11)$$

Here in the above equations, h is the interval and t is the time. The x variable can be calculated as

$$x(t+h) = x(t) + \frac{1}{6}(F_1 + 2F_2 + 2F_3 + F_4) \qquad (12)$$

Similarly the v value is calculated as the value of x.

Vector allocation

Initially, the object in movement is considered as zero. The analytical distance at a particular time is calculated utilizing the following equation.

$$x(t) = x_0 \cos\left(\sqrt{k/mt}\right. \qquad (13)$$

Where x_0 is the initial position of the block with respect to t = time.

The oscillation repeats in a particular period of time. The period is calculated where the oscillation repeats using the time,(t) and the frequency (f),

$$t = 2\pi\sqrt{m/k} \qquad (14)$$
$$f = \frac{1}{2\pi}\sqrt{k/m} \qquad (15)$$

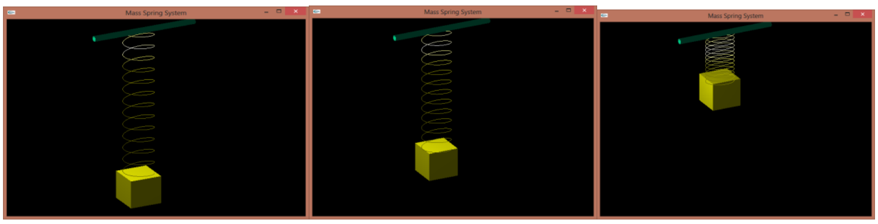
Based on the x value at time t, the vectors in the 3D are calculated by adding the distance to the coordinates of the vectors at each and every interval of time.

Graphical solution

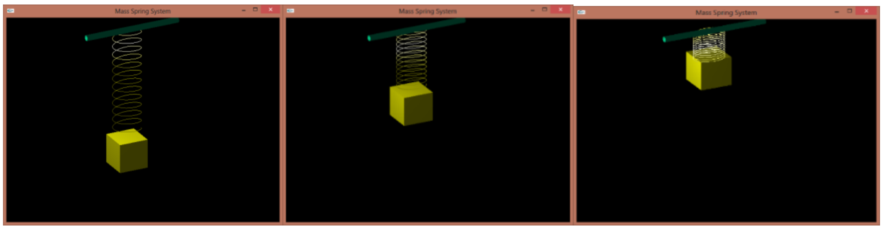
The 3D cube and spring are created by giving the angle of projection and view point with specific coordinates determining the volume and area to be placed in the display window. At every particular interval of time the vectors are updated based on the previous vectors so that the motion can be seen with varying force due to the damping constant.

RESULT

The synthesized 3D mass spring system consists of a cube and a spring where the cube is attached to the spring. Here, in the synthesized model, certain mass is applied to the cube and a stiffness constant is applied to the spring. The forward and backward motion or the movement of the cube depends upon the force applied, weight applied and the stiffness applied over the spring. When the force is applied over the cube, the spring reduces its elongation according to the environmental friction. This motion provides the realistic display of the animation sequence. During the objects motion or movement, the intensity of light projected on to the system also changes thereby creating shadows on the cube. In the below Figure. 2, the cube with different shades can be seen at different position by varying different levels of darkness. An ambient light source is provided to the environment so as to maintain the light intensity all over the environment. This reflects the light sources several times from different surfaces. The specular light is applied for providing shininess to the object. The diffusion light is used for the reflection of the dull surfaces. Here in synthesizing the 3D environment, different illumination models are utilized for the emulation of realism. Figure 2. shows the sequence of motion of the synthesized object.



(a) (b) (c)



(d) (e) (f)

Figure 2: (a), (b), (c), (d), (e), (f): Sequence of synthesized object in motion

Statistical analysis

Figure 3. shows the variation in the distance of the object when the force is of 75 Newton, spring stiffness is of 0.05 and the mass of 45 kg is applied on the string with different time intervals. The vertices of the object are calculated according to the displacement. Suppose, initially the distance of the cube from the origin is 8 then in the next millisecond, the position of the body decreases to 7.9972 reducing 0.0075 distance as shown in the graph. The time is considered in milliseconds and the distance is 10e-2 of the graphical value. By the next second the value again decreases to 0.024 to the previous values. The variation in distance appears when there is change in mass, force and the spring stiffness constant. When the force and mass increases the speed of the motion of the cube also increases creating larger displacement.

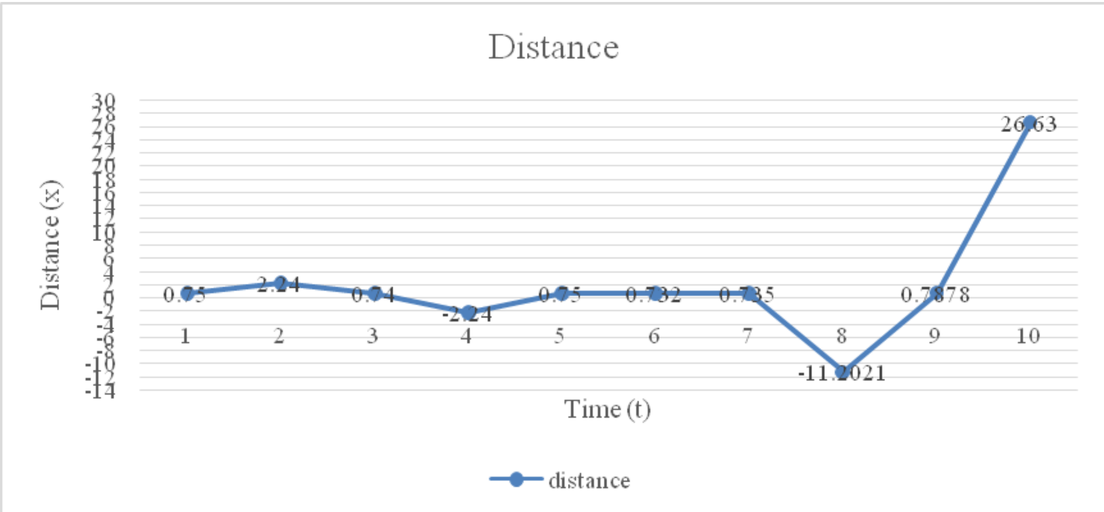


Fig. 3: Distance(x) at different intervals of time(t)

Figure. 4, shows the velocity graph which varies according to the direction of force and distance at different time intervals. Velocity of the object depends on the spring stiffness constant as the stiffness of the spring increases the velocity decreases due to the rigid nature of the string. Due to the stiffness of the string movement in the spring is restricted which had shown the effect on the velocity. The below figure shows increase and decrease in velocity at every millisecond as it moves up and down. The velocity of the system decreases as the time increases as we see in the real system due the external forces. The property can also be found our system developed.

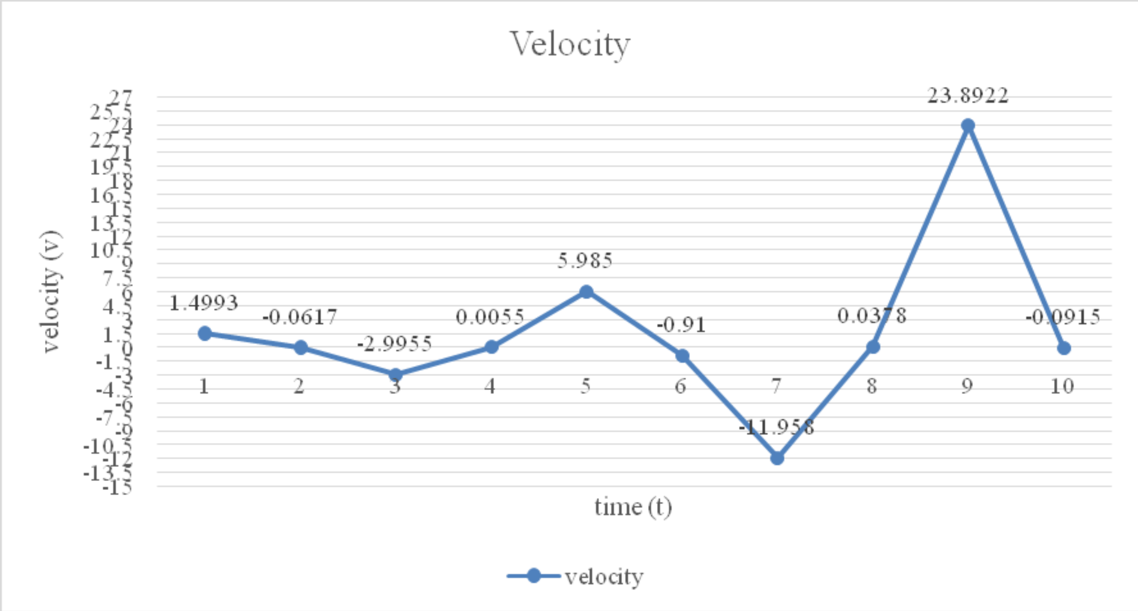


Fig. 4: Velocity (v) at different intervals of time(t)

CONCLUSION

Wide range of applications has been provided for deformable models, many parameters like representation, simulation, topological are taken into consideration for developing a physical model. A physically accurate simulation can be achieved by using the mass spring model and by using simple analytical expression the spring coefficients are initialized. The proposed method can be efficiently used for implementing of the soft body models and can be effectively used in the real time applications. This is used to develop those objects having the deformations and can be applied to the homogeneous and isotropic materials.

Previously, for modeling the physical dynamics the Euler's approach is used for the numerical integration. In the proposed work, the Runge-kutta method is utilized to increase the speed of calculation and accuracy. The advantages of the developed model is that, it presents a realistic motion in 3D and also enhances the motion of the system. The motion of the system depends on the force of spring and mass of the object in 3D. It includes the shadows, also possess illumination models like ambient, diffuse and specular. A 3D cube with spring is modeled using the mass spring system and this modeling can be used for any applications involving soft body objects for simulation. Point light has been used for creating the illumination and shadow of the object.

REFERENCES

[1] Bonet, Javier, and Richard D. Wood. Nonlinear continuum mechanics for finite element analysis. Cambridge university press, 1997.
[2] Selle, A., Lentine, M., &Fedkiw, R. (2008). A mass spring model for hair simulation. ACM Transactions on Graphics (TOG), 27(3), 64.
[3] Choi, K. J., &Ko, H. S. (2005, July). Stable but responsive cloth. In ACM SIGGRAPH 2005 Courses (p. 1). ACM.
[4] Teschner, M., Heidelberger, B., Muller, M., & Gross, M. (2004, June). A versatile and robust model for geometrically complex deformable solids. In Computer Graphics International, 2004. Proceedings (pp. 312-319). IEEE.
[5] Seiler, M. C., & Seiler, F. A. (1989). Numerical recipes in C: the art of scientific computing. Risk Analysis, 9(3), 415-416.
[6] Terzopoulos, D., Platt, J., Barr, A., & Fleischer, K. (1987, August). Elastically deformable models. In ACM Siggraph Computer Graphics (Vol. 21, No. 4, pp. 205-214). ACM.

[7] Baraff, D., &Witkin, A. (1998, July). Large steps in cloth simulation. In Proceedings of the 25th annual conference on Computer graphics and interactive techniques (pp. 43-54). ACM.
[8] Stern, A., &Desbrun, M. (2006, July). Discrete geometric mechanics for variational time integrators. In ACM SIGGRAPH 2006 Courses (pp. 75-80). ACM.
[9] Kharevych, L., Yang, W., Tong, Y., Kanso, E., Marsden, J. E., Schröder, P., &Desbrun, M. (2006, September). Geometric, variational integrators for computer animation. In Proceedings of the 2006 ACM SIGGRAPH/Eurographics symposium on Computer animation (pp. 43-51). Eurographics Association.
[10] Bridson, R., Marino, S., &Fedkiw, R. (2003, July). Simulation of clothing with folds and wrinkles. In Proceedings of the 2003 ACM SIGGRAPH/Eurographics symposium on Computer animation (pp. 28-36). Eurographics Association.
[11] Stern, A., &Grinspun, E. (2009). Implicit-explicit variational integration of highly oscillatory problems. Multiscale Modeling & Simulation, 7(4), 1779-1794.
[12] Martin, S., Thomaszewski, B., Grinspun, E., & Gross, M. (2011, August). Example-based elastic materials. In ACM Transactions on Graphics (TOG) (Vol. 30, No. 4, p. 72). ACM.
[13] Hahn, F., Martin, S., Thomaszewski, B., Sumner, R., Coros, S., & Gross, M. (2012). Rig-space physics. ACM transactions on graphics (TOG), 31(4), 72.
[14] Su, J., Sheth, R., &Fedkiw, R. (2013). Energy conservation for the simulation of deformable bodies. IEEE transactions on visualization and computer graphics, 19(2), 189-200.
[15] Müller, M., Heidelberger, B., Hennix, M., & Ratcliff, J. (2007). Position based dynamics. Journal of Visual Communication and Image Representation, 18(2), 109-118.
[16] Stam, J. (2009, August). Nucleus: Towards a unified dynamics solver for computer graphics. In Computer-Aided Design and Computer Graphics, 2009. CAD/Graphics' 09. 11th IEEE International Conference on (pp. 1-11). IEEE.
[17] Provot, X. (1995, May). Deformation constraints in a mass-spring model to describe rigid cloth behaviour. In Graphics interface (pp. 147-147). Canadian Information Processing Society.
[18] Goldenthal, R., Harmon, D., Fattal, R., Bercovier, M., &Grinspun, E. (2007). Efficient simulation of inextensible cloth. ACM Transactions on Graphics (TOG), 26(3), 49.
[19] Thomaszewski, B., Pabst, S., &Straßer, W. (2009, April). Continuum-based Strain Limiting. In Computer Graphics Forum (Vol. 28, No. 2, pp. 569-576). Blackwell Publishing Ltd.
[20] Wang, H., O'Brien, J., &Ramamoorthi, R. (2010, December). Multi-resolution isotropic strain limiting. In ACM Transactions on Graphics (TOG) (Vol. 29, No. 6, p. 156). ACM.