Consistent Media Model for Real-Time Scene Rendering

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Abstract

We present a consistent model for artistic media reproduction in 3D scene renderings and animations. Artistic media reproduction can be defined as a media model (such as brush, pencil, ink) and a support (such as canvas and papers). We create a surface grain according to the object geometry and apply it as additional material properties. Furthermore, we propose to use the abstraction of obtained results as an entry of a fractal surface reconstruction process that provides additional effects of traditional media such as brush stroke effects. Our model is fully implemented on GPU and the rendering process is strongly real-time.

1. Introduction

Creating animations using traditional media by hand is a tricky task; an artist paints or draws each frame independently and could not ensure a frame to frame coherence. To obtain a successful temporal coherent stylization, proposed methods should take into account the frame to frame coherence to avoid undesirable effects. Recently, Benard et al.[BBT11] have summarized the trade-offs proposed by various solutions concerning the temporal coherency problem. They have highlighted the conflicting nature of this issue and have stated that the solution is necessarily a compromise. Kass et al.[KP11] have proposed a solution based on Perlin noise filtered by depth and velocity fields and their consequent occlusion relationships. Remark that all coherent noise approaches provide a solution from noise space to object space and are sensitive to motion that causes extremely rapid changes. As we consider artistic media reproduction as a consistent support (such as canvas, papers) and a media model (such as brush, pencil, ink), we propose an artistic rendering style process (see figure 1) composed of : (1) a coherent stylization that maintains grain attachment on each object. The grain represented as one of the material properties produces a coherent stylization avoiding the *shower door* and popping effects (cf. section 2). Other additional material properties can be provided through : normal disruption, lighting disruption depending on the texture generation and variation of shape and orientation of the media grain. (2) a fractal model that produces artistic media such as visible brush strokes (see section 3). At the final step, images produced at different framework steps can be mixed.

2. Granularity, from object space to image space

By opposition to the previous noise approaches that first consider a noise and then its application on the 3D geometry, we propose an inverse approach : starting with the 3D object coordinates, our model computes the additional media as new space coordinates of procedural functions providing consistent time/space behavior. This approach does not suffer from problems related to sudden onset of geometry, disocclusion or rapid changes. The obtained surface grain is firstly attached to each object while maintaining an uniform aspect to the entire scene. These new material properties, representing the grain surface, would be generated using two types of data : a procedural noise function used to simulate the medium effect; one (a blend of) texture(s) given as an input of the pipeline and used to reproduce canvas. Thus, this leads us to compute the grain as a function related to a 3D coordinate that is strongly object-space dependent while taking into account the depth of the projective space.

This 3D coordinate depends on the vertex coordinate $\overrightarrow{\mathcal{V}}$, (to obtain a consistent grain surface during the movement) and the projective space, $\mathcal{P}$ (to have a grain continuity around the surface scene) and can be formulated as :

$$\overrightarrow{\mathcal{T}} = (x_t, y_t, z_t, w_t)^t = (x_v, y_v, z_e, 1)^t \times \mathcal{P}^t$$

where $\overrightarrow{\mathcal{V}}$ is the vertex homogeneous coordinates in the object space; z_e the z-axis component of $\overrightarrow{\mathcal{V}}_e = \mathcal{M} \times \mathcal{V}$ which expresses the vertex depth in the eye space ($\mathcal{M}$ the model-view matrix); $\mathcal{P}$ the projective space matrix. The vector $\overrightarrow{\mathcal{T}}$ varies with depth (z) and remains constant for other types of transformations (x and y) in projective space. So the noise parameters anchor a consistent noise to the object and adapt the noise frequency according to the depth variations.
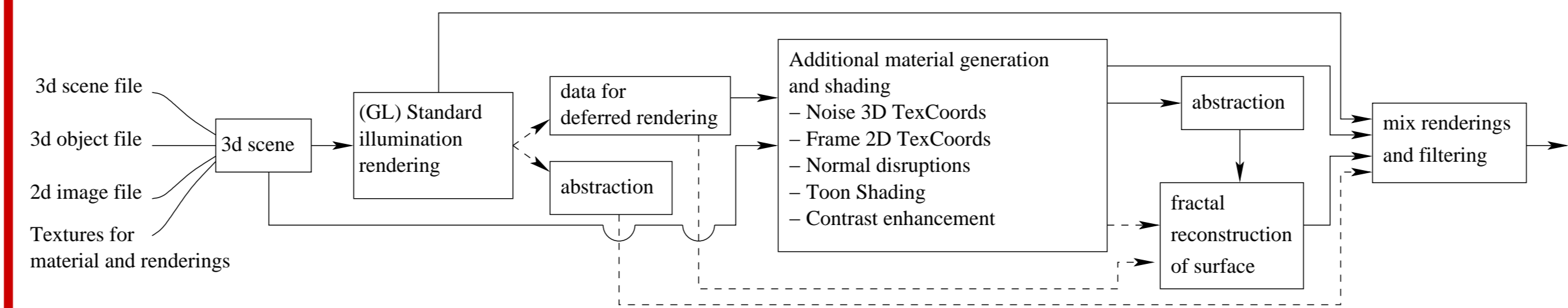

FIGURE 1: Artistic rendering pipeline including the grain surface generation and the fractal surface reconstruction.
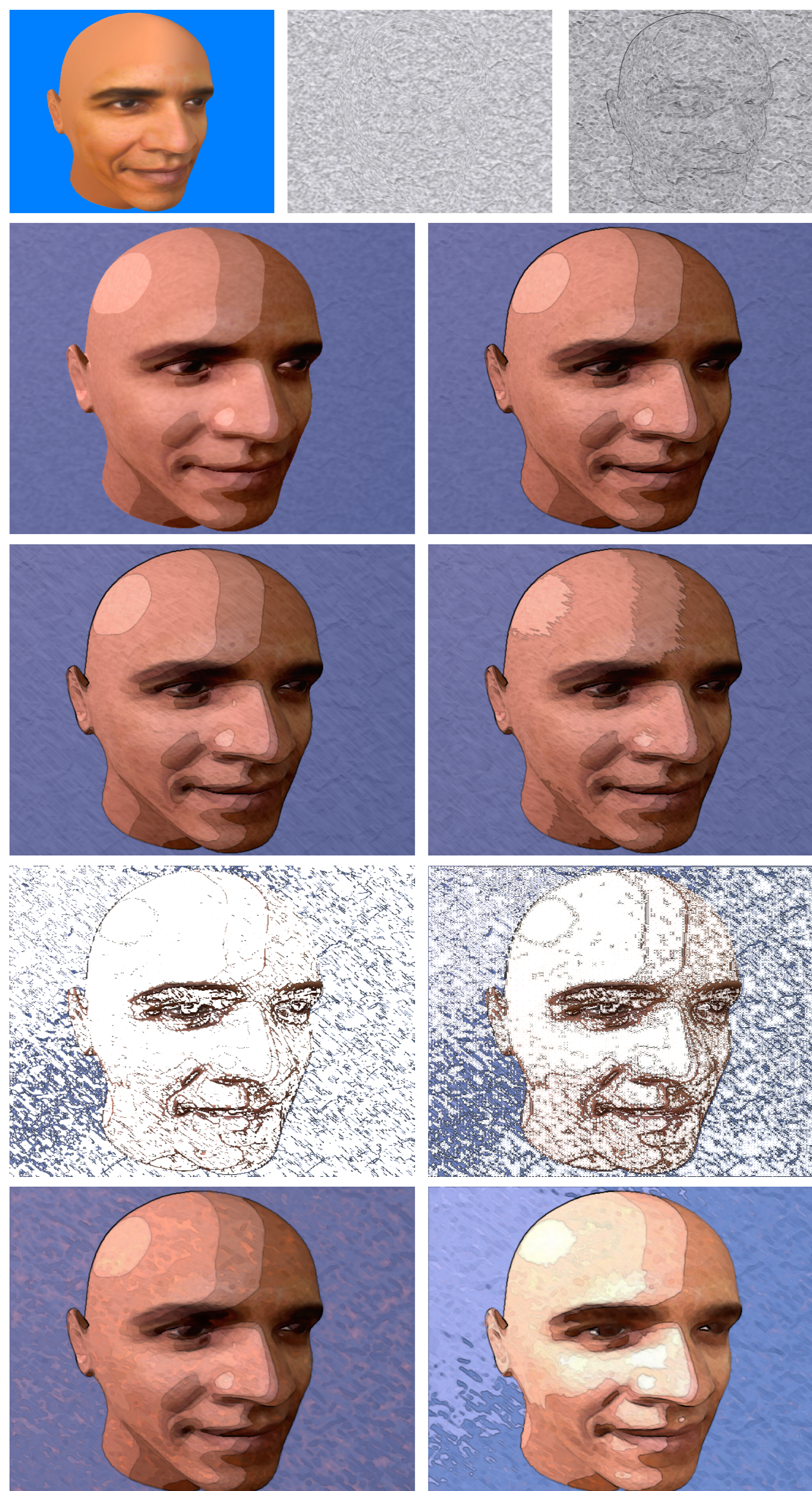

FIGURE 2: original model; noise application; adding contours; noise material and toon shading; 2 noise variations with contours and toon shading; normal perturbation; abstraction of output considered as initial constraints of the MCMD method; result after the 1st MCMD sub-process (constraints forwarded to their ancestors); result after the 2nd MCMD sub-process (reconstruction); result produced using noise additional material, normal perturbation (using the luminance of the object textures) and median filter.

The vector $\overrightarrow{\mathcal{T}}$, used as parameter of the procedural noise function, is also used to compute the texture coordinates. As we use 2D textures, we provide a consistent transformation that computes, for each vertex, its 2D texture coordinates. By analogy with environment cube mapping, we project the coordinates of the vertex normal $\overrightarrow{\mathcal{N}}$ onto one of the six cube faces and store the result in $\overrightarrow{\mathcal{C}}$. This projection guaranties that one of the $\overrightarrow{\mathcal{C}}$ coordinates always corresponds to one of the six planes. We use this coordinate to select which one is not used in the vector $\overrightarrow{\mathcal{T}}$. Thus, the remaining coordinates of $\overrightarrow{\mathcal{T}}$ help us to maintain the consistence of each object texturing while adapting the overall texture frequency according to each object depth.

3. Fractal Surface Reconstruction

In[BB10], Belhadj et al. have suggested that various painting effects can be realized with a fractal reconstruction model applied to characteristics expressed as heightmap data with a quite reasonable time computation for an interactive reconstruction (i.e. ~2fps). An abstraction step is used to extract scene characteristics expressed as a heightmap (using a standard illumination rendering, abstracting images consist in computing contours and segmentation). Then the fractal reconstruction model produces an image that preserves and disseminates the given characteristics. We propose to adapt this fractal reconstruction algorithm (i.e. the two sub-process of the presented algorithm : MCMD) through a simplification of the first sub-process and a full GPU implementation of the entire algorithm to obtain real-time reconstruction. Our new algorithm is 35 times faster than the original one. As each sub-process tree walking is stored as a texture, parallel computations can be done in GPU at each tree level.

Thus, for the first sub-process, from a parent node point of view, we just need to know that a constraint exists for a child and thus the parent should consider its color in the original image as a constraint. So the algorithm consists in looking for a given fragment where the color is flagged to unknown if one of its children has a color (see figure 2). For the second sub-process (see figure 2), it can be resumed to a midpoint displacement where some of the children nodes have a known color (constraint). In this process and for each coordinate, we should determine when the coordinate value must be computed regarding to the subdivision order.

4. Results, discussion and conclusion

The figure 2 presents an overview of possible results produced by our model. Video available as additional media shows a more than 1M polygons scene is rendered in real-time at a 800x600 resolution on an Intel Bi-Xeon 2.7 Ghz and an nVidia Quadro FX 3800; here, temporal coherence is maintained during displacements while a *resampling effect* appears only for very high depth variations between two consecutive frames. Using, the surface fractal reconstruction process, this effect tends to disappear.

We have proposed a consistent model for artistic media reproduction in 3D scenes and animations. Our consistent and coherent grain generation is a compromise and we favor the temporal continuity and the coherence of motion. To provide traditional media such as visible brush stroke effects, we have also proposed a full GPU implementation of a new fractal surface reconstruction process as one of the possible complementary material properties.

References

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