# Different approaches in the production of simulated painting like effects in 3D computer graphics.

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Innovation Project

# Contents

# 1 Abstract

This Project sets out to examine different methods of producing simulated painted effects and also how these how these effects can be applied and combined in a coherent way to produce a visually stimulating animated sequence. This project will be presented as an animated sequence and in addition to this production report that documents the production of the animation in addition to the research undertaken. In particular in the concentration on Non-photorealistic rendering techniques that actually paint in a more traditional way by creating new surfaces unlike techniques that apply a simple post image filter that are applied to the rendered image or use a special surface shader on existing 3D scenes.

# 2 Introduction

The term 'Non-photorealistic Rendering' was first publicly used in 1994 by David Salesin and Georges Winkenbach's paper 'Computer-generated pen-and-ink illustration'[1] although the term is quite confusing in that the term photorealistic in computer graphics differs to the one used in traditional painting. The term refers to any work that is not rendered using normal rendering techniques also the movement of the raw paint as an image is constructed.

> "*It's What You Leave Out That Counts:*
> *Photorealism, like pornography, leaves nothing to the imagination. It presents the viewer with a world of objects complete with volume and texture, which is far more information than the viewer needs to get the point. Furthermore, unless great effort is devoted to every detail of modeling, shading, and lighting, much of that information will actually contradict the central idea, distracting the viewer…"* - Cassidy Curtis[2]

## *2.1 Style Development*

It was decided on that the medium of paint would be the chosen natural medium to emulate, in particular oil paint. To assist with the development of the style and approaches that were to be used in the computer generated simulation the following research was carried out into both existing work of existing traditional painters and in the generation of new traditional paintings.

### 2.1.1 Painting Influences

Influences for the style and approach of how to simulate painting were taken from various painters and painters of art moments which some of which are described here.

When most people think of a painting it is likely to be one painted by a member of the French impressionism art movement. The loose but still relatively true to the subjects form of the brush strokes lend themselves to have the potential to be emulated in non-photorealistic rendering quite well as in that most conventional programmed algorithms lack the intelligence and consciousness of the real human mind to create a more abstract piece. Also how

[1] http://portal.acm.org/citation.cfm?id=192184
[2] http://www.otherthings.com/uw/loose/sketch.html

**Figure 1 'The Seine at Argenteuil' painted by Claude Monet (lived. 1840 - 1926).[3]**

The expressive and fluid brushstrokes of painters such as the American abstract expressionists William De Koonings were also a large influence on the style and approach. The use of wide free flowing brushstrokes to form a expression of the paintings subject was something that was to be attempted to be included into the style of the project.

a) b)

**Figure 2 a) 'Woman 1' painted by William De Kooning[4]. b) "Lavender Mist" painted by Jackson Pollock (in 1950)[5].**

Another artist of the abstract expressionist movement was Jackson Pollock who is famed for his technique of action painting that has often been described as an 'event' of painting which has the

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[3] Image sourced from http://www.geocities.com/stranneby/frmain.htm (15/04/2007)
[4] Image sourced from http://www.safran-arts.com/42day/art/art4apr/art0424.html (15/04/2007)
[5] Image sourced from http://www.harley.com/art/abstract-art/pollock1.html (15-04-2007)

paint spontaneously being applied to a canvas, this spontaneous semi-randomness is something that it has been decided would be advantageous to be added to the style of the project.

### 2.1.2 Painting Experiments

To assist with the development of a style and approach to replicating real painting it was decided that the production of paintings to experiment with possible finishes and styles that could be adapted into the development of techniques to be used in computer graphic non-photorealistic aspects of the project would be advantageous. Following some of ideas researched and explored in the previous section the below paintings were produced.

The production of original traditional painting as it gave a real insight to the techniques and led to the approach and visual style that the effects developed towards and ultimately used in the final technology demonstration animation.

**Figure 3 A painting of a pair of shoes from life for the development of this project.**

**Figure 4 Paintings of housemates painted in the development of the project.**

# 3 Development

Here follows the areas that I researched and developed for use in the final animated piece, which include a approach of rendering existing 3D computer graphic scenes in a non-photorealistic way, also a ways to simulate the flow and movement of paint. This element of the project had the most time invested in it and the results produced and things learnt are the most important aspect of the project.

## *3.1 Non-Photorealistic scene rendering techniques*

This technique would be used in the majority of the animated demo and aims to simulate the look and feel of expressive painterly brushstrokes of a traditional painting painted in oil paints.

### 3.1.1 Development

Approaches of Non-Photorealistic rendering of a 3D scene can be split into two categories direct rendering or indirect rendering, these are explained below:

- Direct rendering: The application of non-photorealistic shaders to objects in the scene and/or the modification of the objects geometry.
- Indirect rendering: The rendering of control images of a scene that are then used to generate new 3D scenes or to be directly processed to create a final image.

For the development of the system the decision was to use the method of indirect rendering, this decision was made mainly based on the medium and style of painting that was trying to be emulated that is concerned with the creation of a lose representation of a image because of this using a direct rendering shader based system that are concerned with the shading of an area of a surface that is currently visible generally with simulated a pinhole camera with pixel by pixel independence. Using an indirect rendering approach this allowed the simulation to better replicate the real process of painting.

The plan is that hopefully by the use of new primitives to build up a new scene that represents the old one it will show the subject in a more naturalistic painted way that will hopefully provoke a sense of emotion more than the more static traditional surface shader based rendering.
This will be implemented by using a sequence of scripts written in the 'lua' scripting language with the use of the 'gd' image lua library and the 'Custard Cream' lua library from 'Biscuits GG tools' to extract information about a 3d sense rendered passes and then use this extrapolated data to construct a new separate scene.

The algorithms have been developed use the following rendered image passes that have been split into two standard four channel images for convenience and to save disk space:

Image 1:

- Beauty: A Fully Rendered colour pass using all the colour channels.

Image 2:

- du + dv: (Red) The combination of the estimate of the amount that the surface parameters u and v change from surface sample to sample.
- Object ID: (Green) An unique tone value that has been applied to each objects surface.
- Diffuse: (Blue) Just the diffuse pass isolated from the full beauty pass.
- Z-Depth: (Alpha) the position of the surface sample in z space.

The initial simple algorithm that was developed used just the 'du+dv' and the 'Object ID' information to create a simple 2D greyscale image, this algorithm can be described with the following sudo code:

```
function PaintStroke
        currentPixel equal random pixel
        if currentPixel is stroke starting pixel of  a previous stroke then
                return with out painting stroke
        if ObjectID at currentPixel is none then
                return with out painting stroke
        for random amount do
                for each pixel surrounding currentPixel do
                        if surrounding Pixel has not been picked before in stroke then
                                if this surrounding Pixel has the greatest value of 'du+dv' then
                                        draw pixel on output image at the pixels location at 40%
                                transparency
```

By using this algorithm a simple image depicting the edges and contours of a scene of objects can be created, a implemented example of this can be seen below.

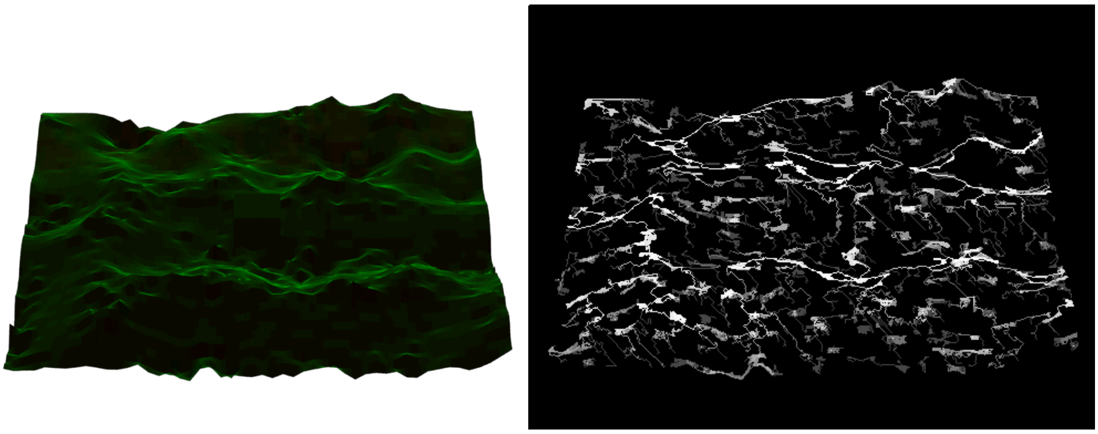


**Figure 5 The 'du+dv' pass of a scene and the image created when the initial 2D edge and contour extraction algorithm is applied.**

The next feature added to the algorithm was the ability to draw curves instead of just pixels; this was achieved by connecting the series of pixels to generate a curve, also to add a more fluid look to the image consecutive pixels that flowed in the same direction were ignored in the generation of curves. Catmull-Rom splines were selected as the curve type as they guarantee that the curve passes through the curves points and that they have a continuous smooth nature. To assist with future development the jump straight to 3D curves was made, because of this the 'Z-Depth' pass is now also used to specify a z location of the curve points.

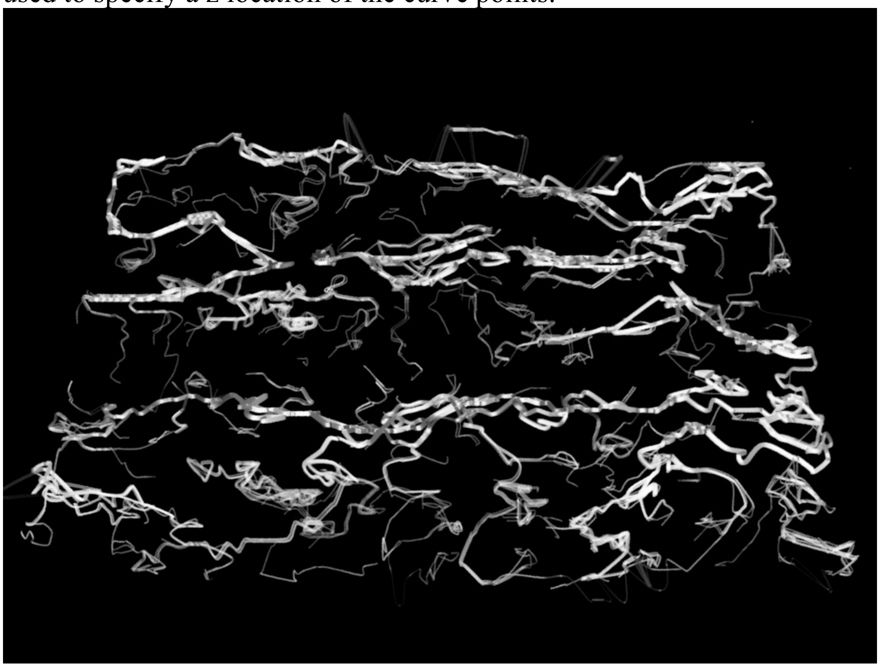


**Figure 6 Example of using 3D curves instead of the previous example on 2D pixels.**

Next colour was added to the curves by sampling the 'beauty' pass at the curves corresponding pixels. Also sampling the 'diffuse' pass and using that to determined half of 40% of the opacity value enhanced the opacity of the curves points.

**Figure 7 Example of coloured edge algorithm**

At this point it was felt that the edge and contour detection algorithm was satisfactory and the decision to adapt this approach to create an algorithm to create a fill for an object was made. To create the fill effect instead of using the selection of the greatest adjacent ‘du+dv’ sample value to the current one, the selection of the most similar ‘du+dv’ sample value to the current one was used instead.

**Figure 8 Example of the fill algorithm’s image overlay on the edge and contour algorithm’s image.**

After tweaking the variables of the script it was felt that the results were good and the decision to move on to applying the technique to an animated sequence was made. The decision to not pursue a technique of enhanced frame continuity was decided, as this would have required a great amount of research and development, also the result as they were seemed adequate and could be argued that were more expressive and natural than for example morphing curves. Also a third algorithm was developed at this stage to deal with shadows; this algorithm is simply a simplified and tweaked version of the fill algorithm.

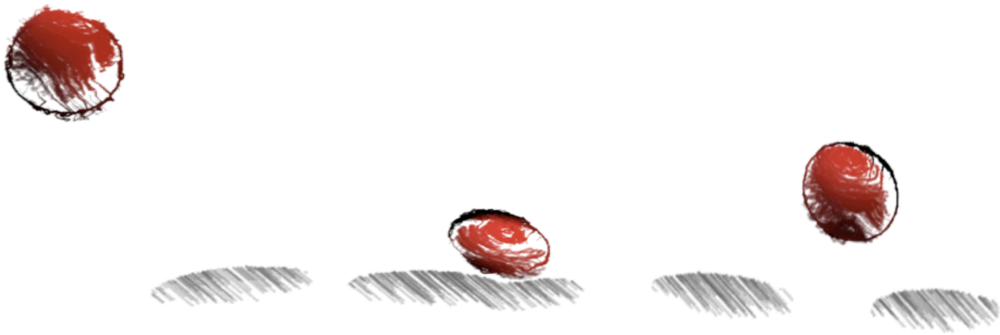
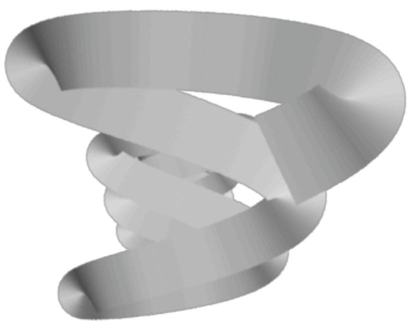
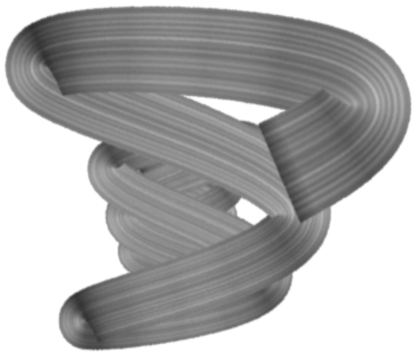


**Figure 9 Example bouncing ball animation created by overlaying the edge/contour, fill and shadow algorithm's renders.**

Although the previous test renders had the feeling of a naturally created sequence of images they seemed more similar to a pen or crayon than the intended fluid painterly look, to rectify this the use of 3D lighting and realistic shaders was used. A simple 'plastic' shader was applied to the edge contours algorithms curves and a similar but textured version was applied to the thicker fill algorithms curves. As shown below the addition of lighting and a simple texture enhances the look of a curve dramatically.



a)



b)

c)

**Figure 10 a) Simple 'plastic' 3D lit shader. b) Addition of a simple texture to the previous example. c) A real painted brush stroke.**

Next the new lighting and shaders were applied to the previous animated ball example. Also a thicker curve was used to simulate a wider brushstroke, which also allows the coverage of more area of the surface and therefore the need for fewer curves and therefore quicker simulation and rendering times.

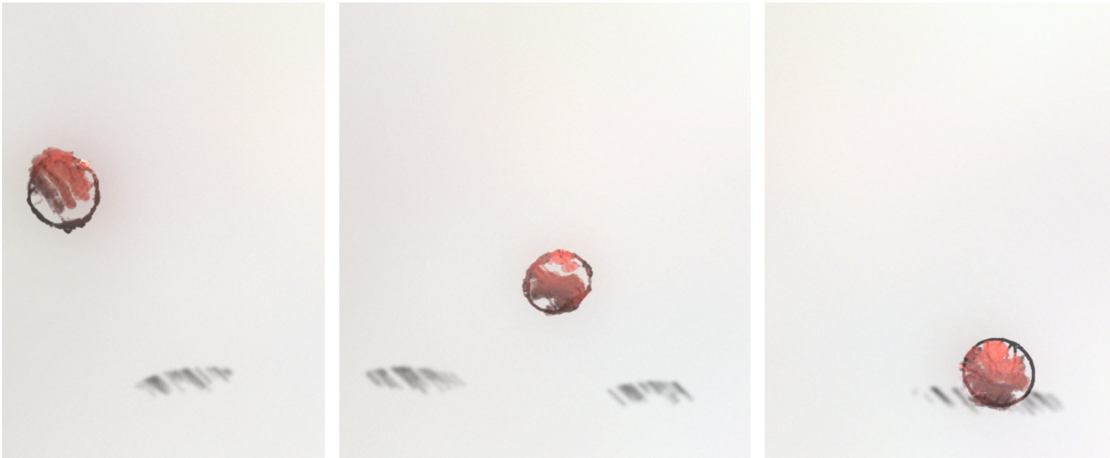


**Figure 11 Example of the previous animated ball sequence with new lighting and shaders with additional paper like background.**

### 3.1.2 Conclusion

The non-photorealist rendering effect is probably has been the most effective element of project. It has managed to capture the general feel of the proposed style that was researched, with the final implementation of the effect being comparable in quality to many professionally created effects.

## *3.2 Close-up paint like effects*

In addition to a conventional non-photorealistic effect as described previously I also wanted to experiment with particle based painting effects with the original intention to blend between both effects.

For this effect the intention was to explore the fluid nature of paint but also retaining it's solid nature that differences it from thinner liquid such as water. For these experiments a previous written simple particle system in Biscuits was used as a base and additional effects were created on this framework.

### 3.2.1 Development

It started by adding the ability of infinite plane collision to add a floor, also the use of blobbys rendering effect which also are known as metaballs were used to simulate a more sticky liquid like effect.

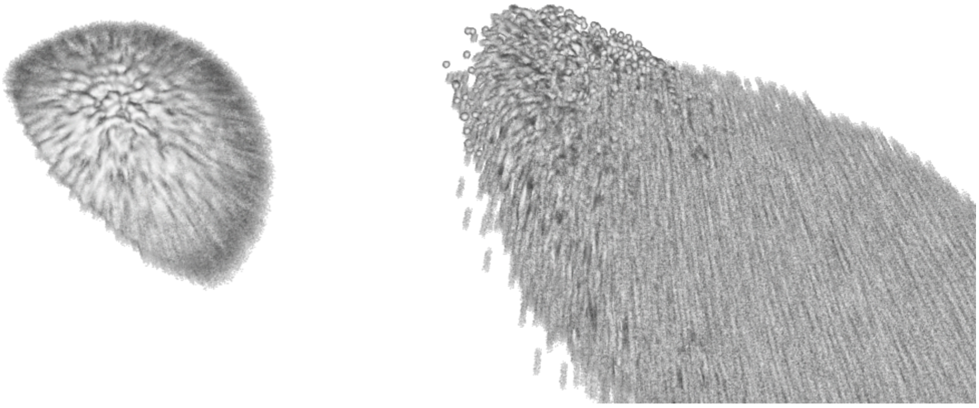


**Figure 12 Example of particle explosion with (slightly broken) floor collisions rendered with blobby effect.**

This floor collision was refined and instead of the particles exploding from a point they were set to pour from a point to simulate paint pouring on a surface.

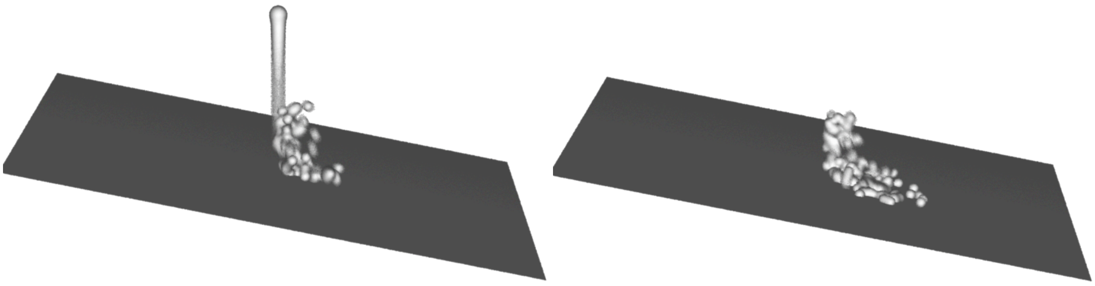


**Figure 13 Example of simple particle collision with floor plane.**

Next the particle amount was increased to create a more dense spacing and the impression of a finer liquid.

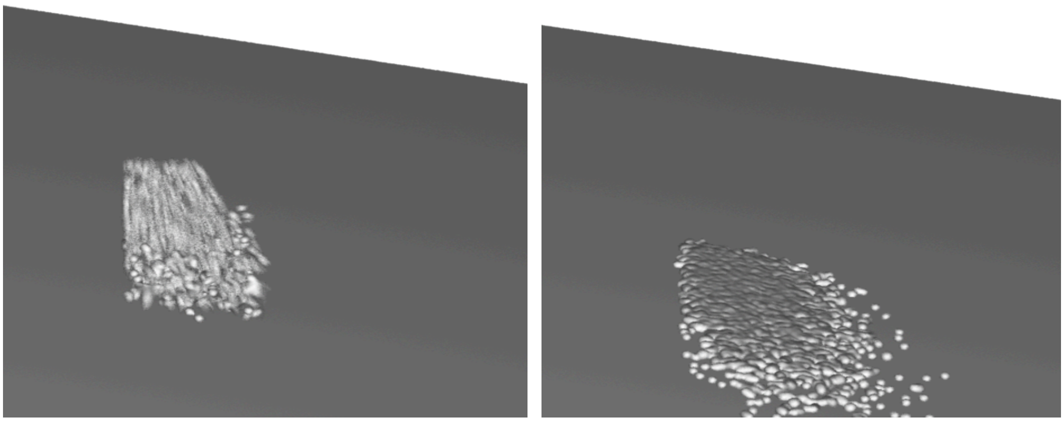


**Figure 14 Example of simple floor collision with increased amount of particles.**

Next to add a more realistic stacking like effect sphere to sphere intersection with simple point based physics were added to simulate paint building up on it's self.

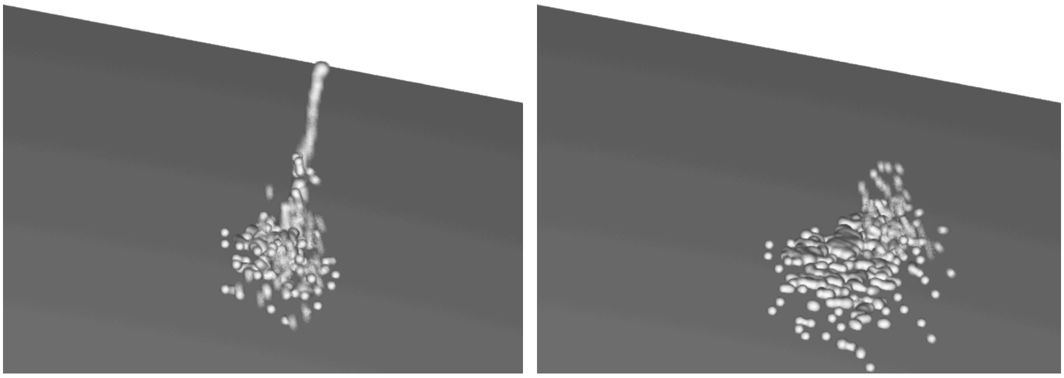


**Figure 15 Example of simple sphere to sphere collision to add a stacked depth like effect.**

Now that the basic particle effects were implemented more exotic ideas could be tried. Collecting points together and using these points to create curves to simulate congealed flecks of paint was the first experiment, although this created a interesting stylistic result it's realism wasn't that great.

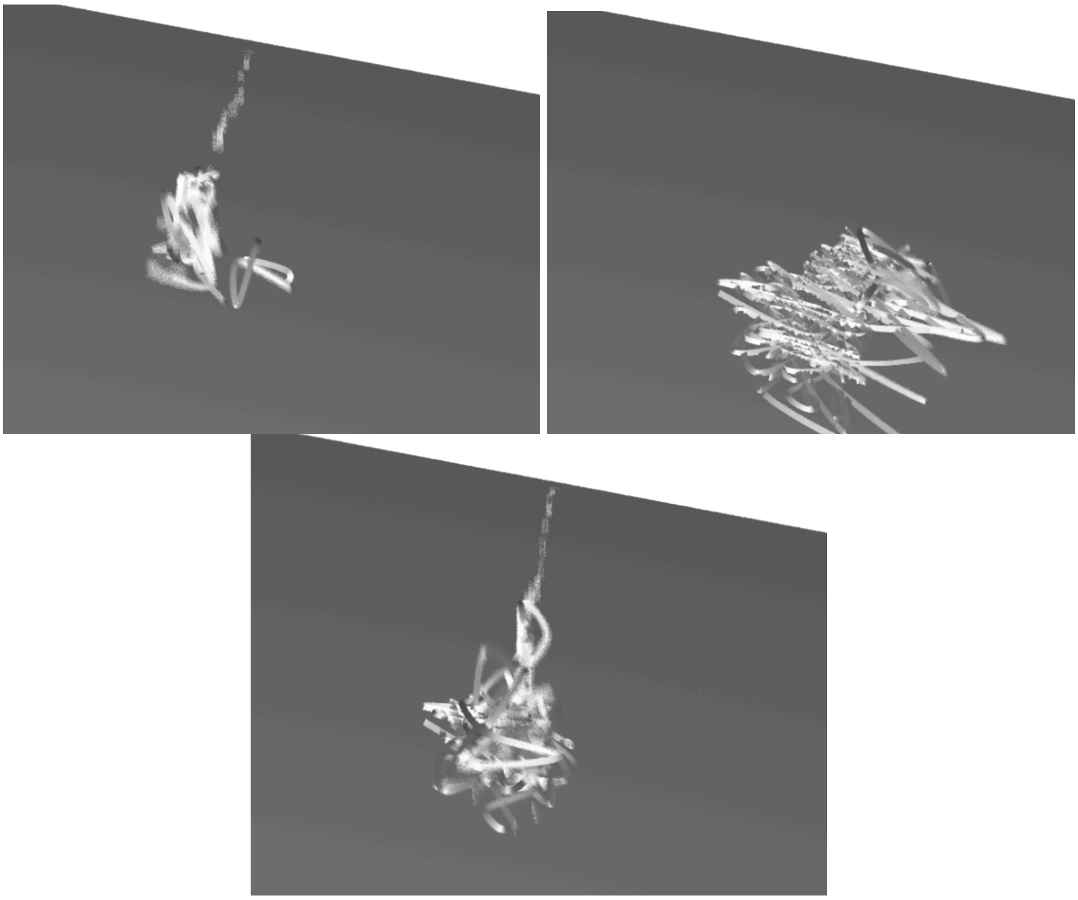


**Figure 16 Examples of using collections of particles to form curves.**

These curves were converted to meatballs by sampling the curves along their length then using these points to create particles with there radius varied that are then converted to metaballs.

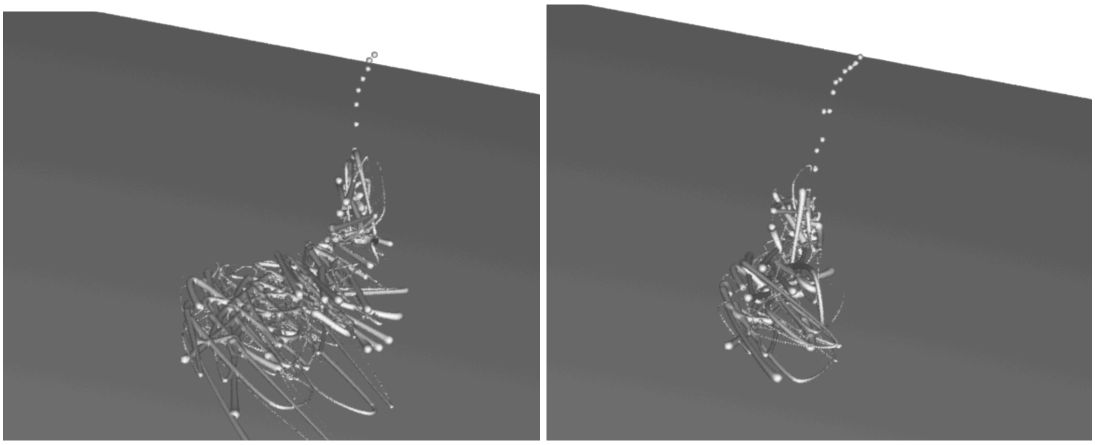


**Figure 17 Example of converting curves to strings of metaballs (no motion blur)**

These ‘strings’ of metaballs were then tweaked and motion blur added. Additional ordinary metaballs were then added to bulk up the effect.

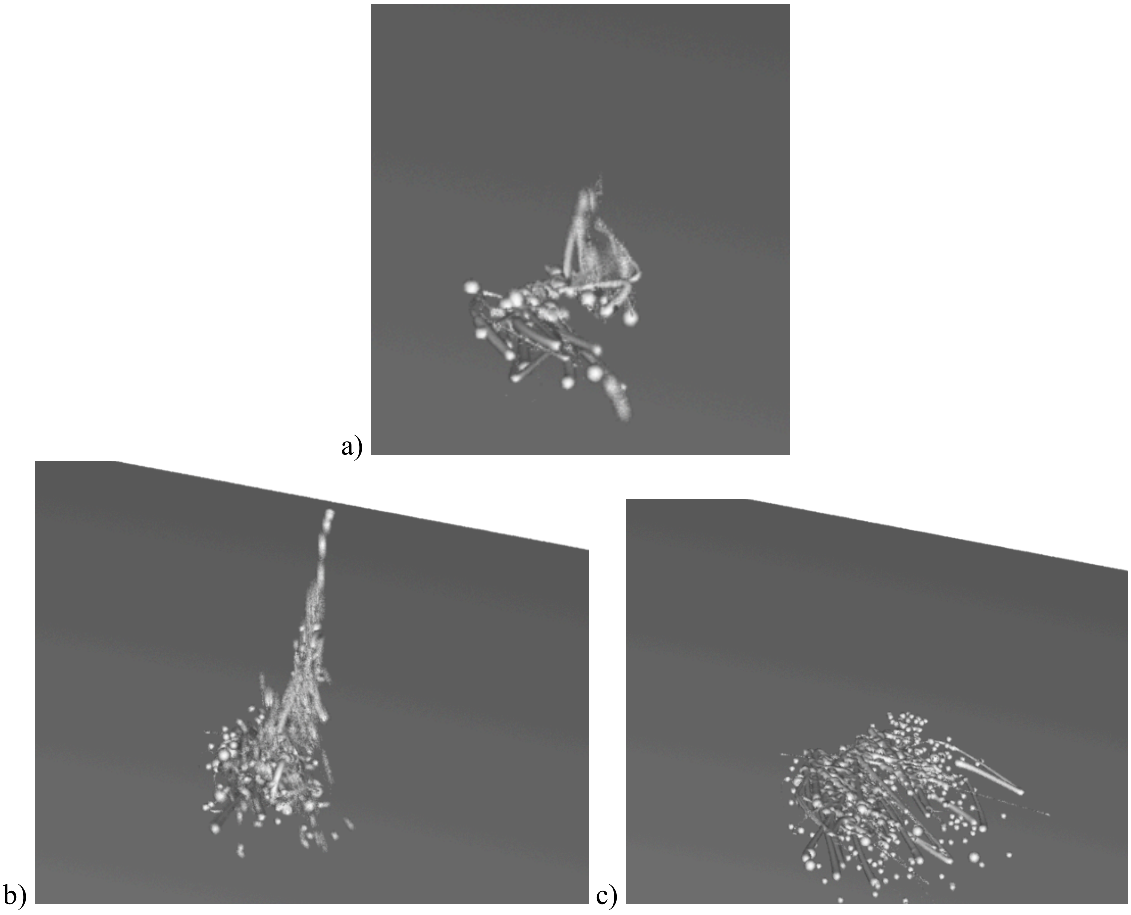



**Figure 18 a) Example of motion blurred metaball strings. b) & c) Examples of a mixture of metaball strings and particles.**

Unfortunately time was becoming short at this point and development was shifted back to the non-photorealistic effects. In the following images the developed effects are shown with more sophisticated lighting with ray-traced shadows.

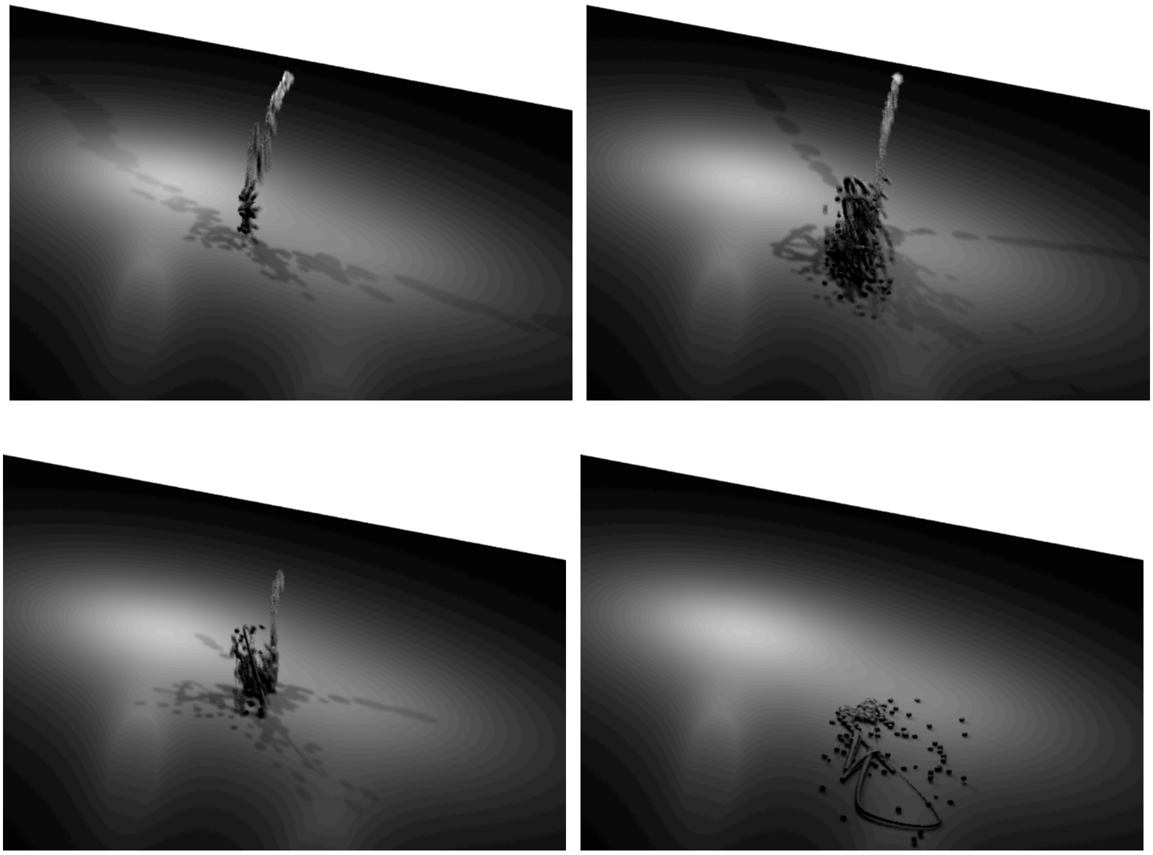


**Figure 19 Examples of pouring paint like liquid on a surface.**

### 3.2.2 Conclusion

Although some interesting effects were achieved such as the metaball strings that might prove interesting to develop further such as adding mid string collisions, also developing the ability to set goal locations would have been useful. Although the particle system falls down because of lack of optimization in the sphere-to-sphere collision that means that large-scale simulations would be very slow and the implementation of a tree sorted data structure such as a kdTree or ocTree would have been quite a large undertaking.
As a learning experience this element of the project as been very interesting and educational covering physics and maths problems that would occur often in production of similar effects.

# 4 Animation

The objective of creating the animation was to test and demonstrate that the above developed effects could be used in a real production environment, by doing this it is hoped that a more complete understanding of what would be needed of the developed systems to be useful in producing the effects on a larger scale was developed. Also it is hoped that in the production of an animation the developed effects can be shown in a more comprehensive than a simple demo animated example and advertise the effects in a more fun and interesting way.

## *4.1 Outline*

The animation will mainly be a sequence of abstract elements set to music with additional elements that represent the imagery described in the music. It has been decided that the animation should last no longer than 1 minute 30 seconds as that the production of additional elements would cause the overall quality to suffer due to the production time limits.

## 4.2 Production

The following sections are a scene by scene break down of how each scene was created and why they were used and finally a summary and analysis of the how the animation turned out.

### 4.2.1 Scene 1: Moving line

The first shot is the simplest but one of the most effective and consists of a painted line moving up and down in sync to the music, although this is a simple base image this was enriched with the non-photorealistic effects described earlier and additional 2D effects added in post to create a surprisingly striking animated sequence. This shot is used as a gradual introduction to the rendering techniques as not to overwhelm the viewer as they might miss subtle the details in a more complex shot to begin with.

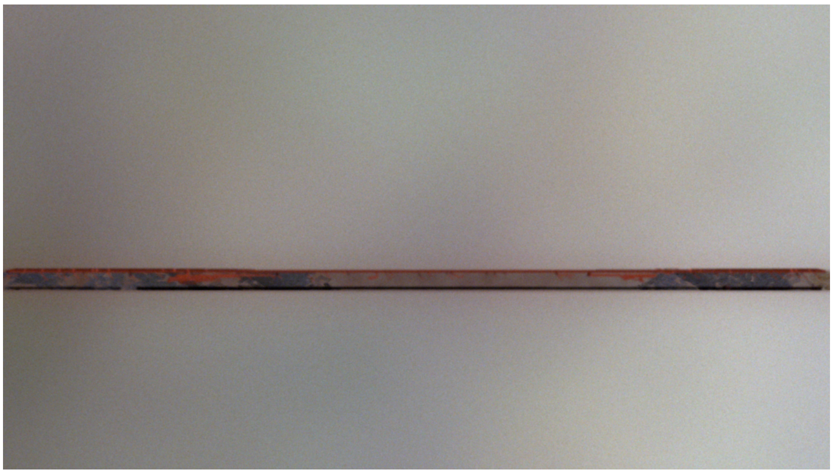


**Figure 20 An example frame from the first shot of the animated piece, it shows an animated line rendered with non-photorealistic rendering techniques and additional effects.**

### 4.2.2 Scene 2: Kaleidoscope lines

This shot continues the visual style of the previous shot using a long animated curve that is duplicated eight times and converted to tube surfaces. Although this technique of creation is simple it could be seen as very successful. Like the previous shot it is relatively simple, and continues the striking graphic style and being that it uses more complex shapes than the previous, it is hoped that it will give the viewer the sense that something more visually complex and exciting is to come.

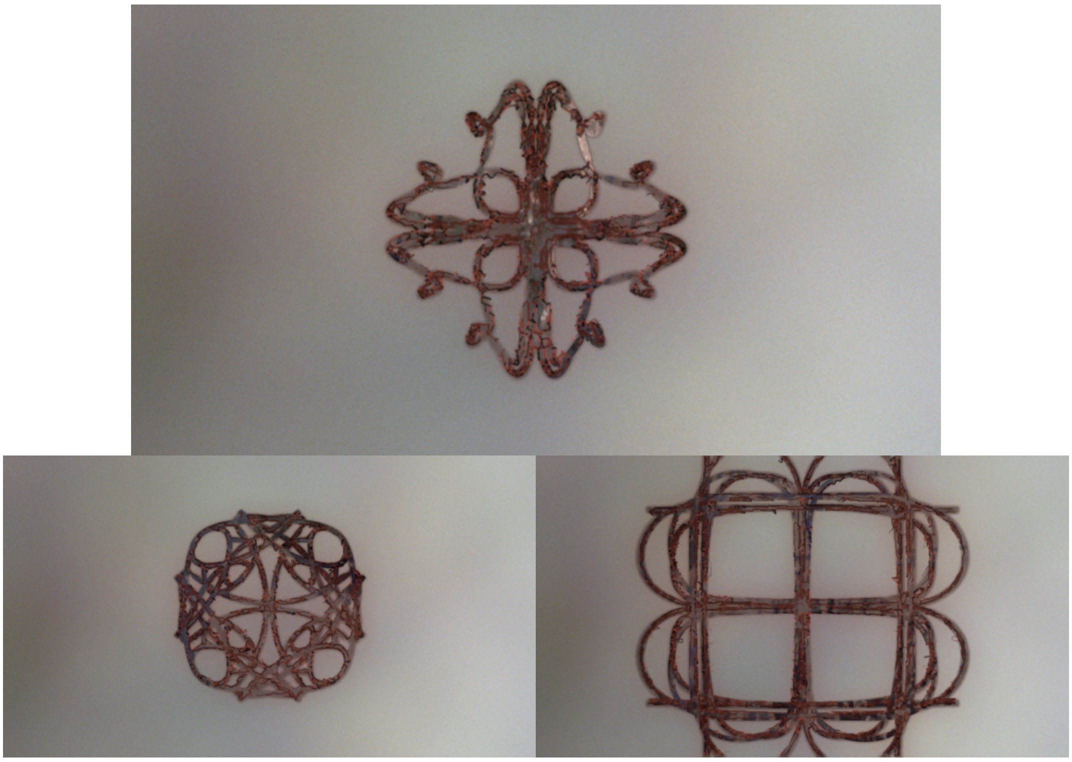


**Figure 21 Example frames from the second shot of the animation.**

### 4.2.3 Scene 3: Action paint

This sequence shows some examples of the paint like fluid effects that although are different in style, carry on the same theme of colours and background. The hope with this sequence was to capture some of the feeling that is created by 'action painters' such as Jackson Pollock and help move away from the style of previous two scenes and lead into the next scenes.

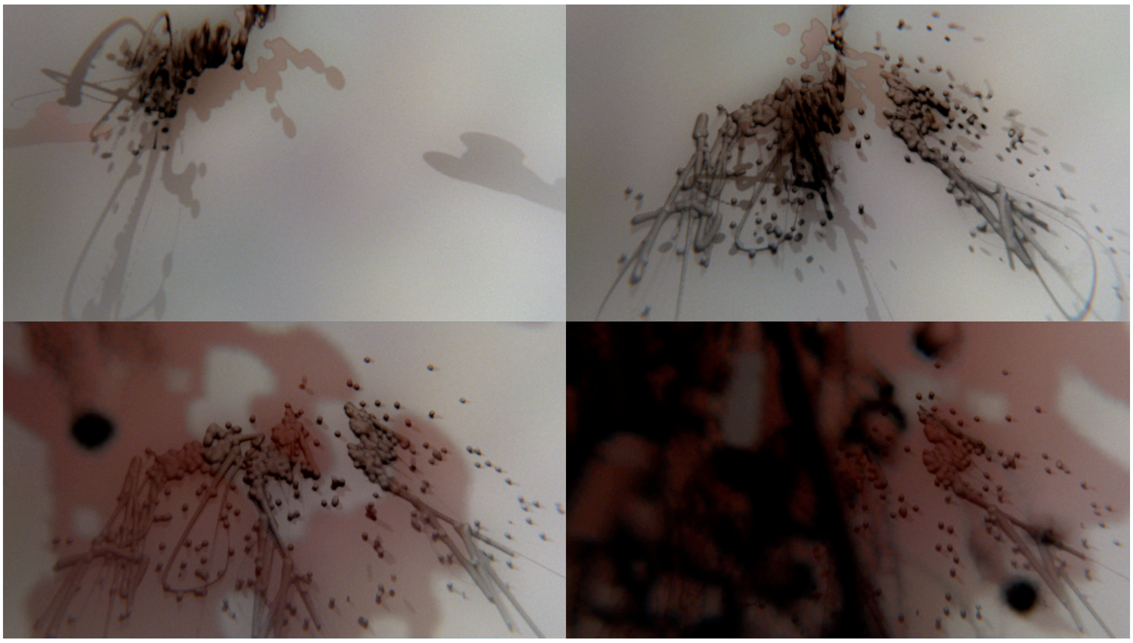


**Figure 22 Example frames showing paint fluid effects which close on the paint covering the camera.**

### 4.2.4 Scene 4: falling cubes

The falling cubes uses a scene that was created by Luke Titley[6] as a base. It serves as a transition between the previous scene and the next sequence of red object based scenes.

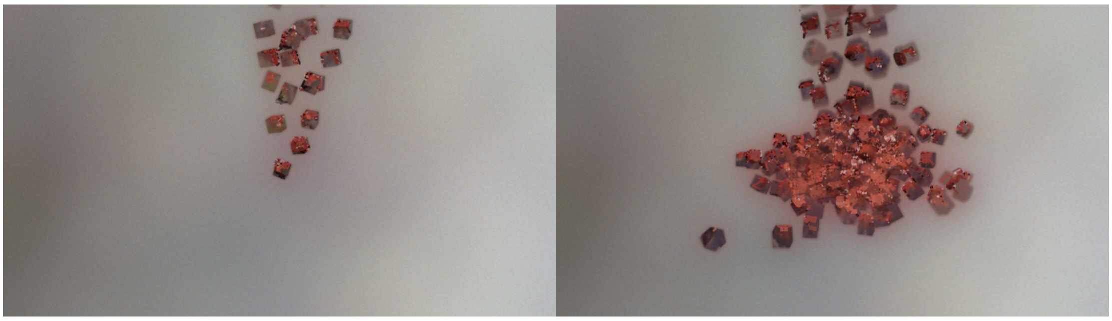


**Figure 23 Example frames from falling cube animation.**

### 4.2.5 Scene 5: Flying cubes

This scene follows on from the previous scene with use of red cubes but are now larger and more defined and as a result is one of the best examples of the non-photorealistic effect in it's raw form. The scene consists of cubes being spawned from a point in front of the camera and moving towards it to result in a graphically striking animated sequence.

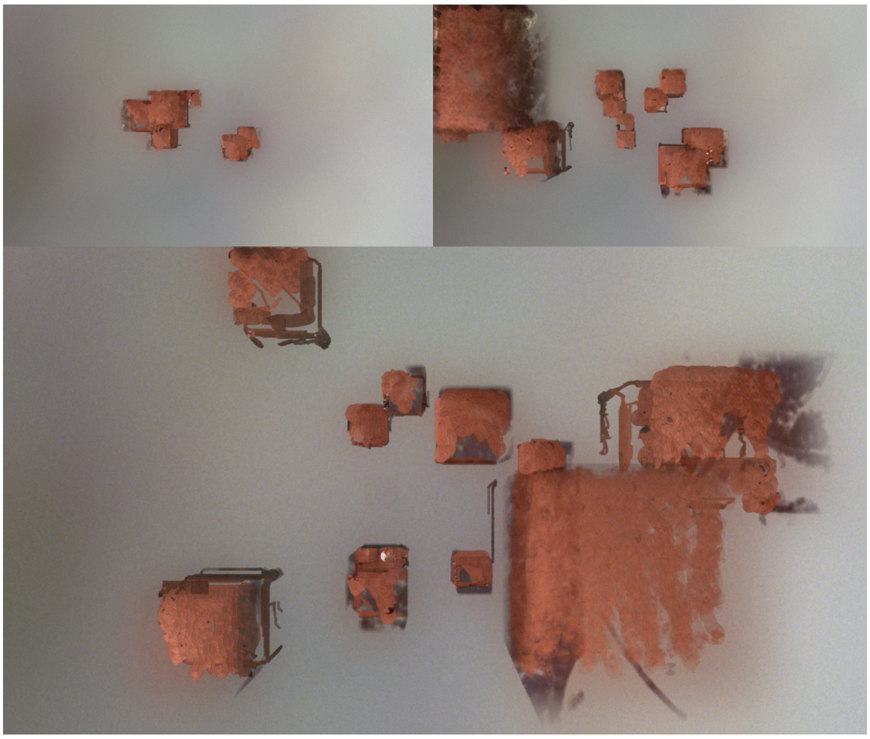


**Figure 24 Examples from flying cubes shot with non-photorealistic effects applied.**

### 4.2.6 Scene 6 & 7 : Walking man

These two scenes that are examples of applying the non-photorealistic rendering effects to an animated character from two angles, a red ball continues the motif of the red ball. The animated character that is in this scene was originally created and animated by Rory Cooke[7].

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[6] Luke Titley BACVA3 (2007). Luke.titley@gmail.com
[7] Rory Mark Dixon Cooke, BACVA3 (2007). email

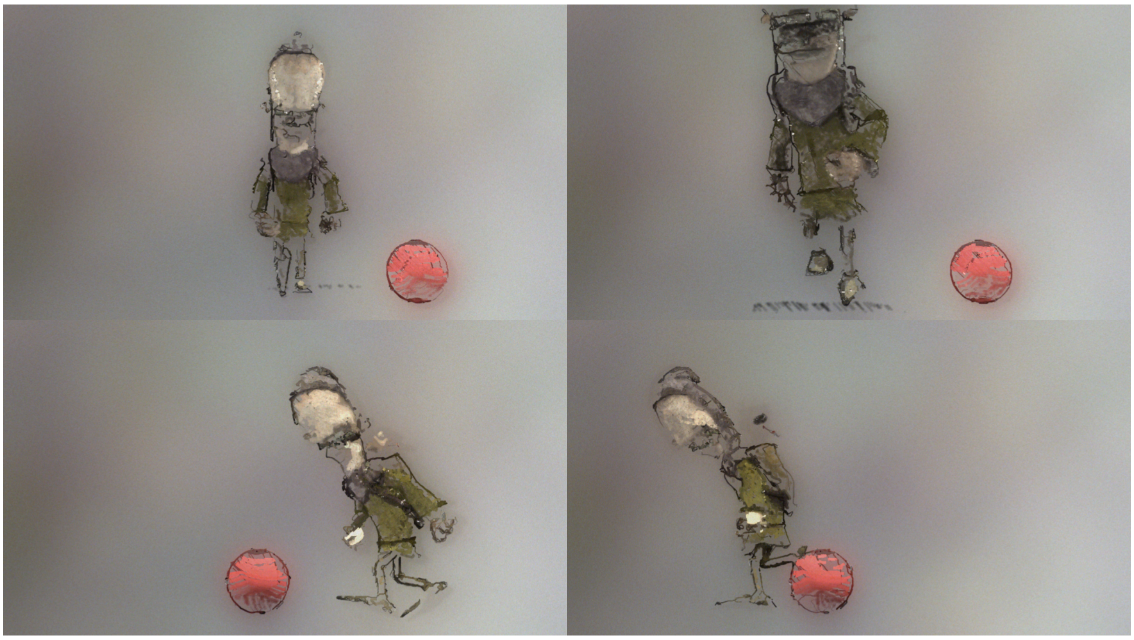

**Figure 25 Example frames from animated character animation.**

### 4.2.7 Scene 8: Bouncing ball

This scene is based on the development animated sequence of the bouncing ball and has been changed little as the feeling was that the standard is good enough to be included in the final demonstration animation. This scene was created as homage to the common 2D and 3D animated bouncing ball tests and includes the motif of the bouncing ball that is seen elsewhere in the animation. This scene finishes with a zoom into the ball and a fade to white for the transition into the next scene.

**Figure 26 Example frames from bouncing ball scene with non-photorealistic rendering effects applied.**

### 4.2.8 Scene 9: The house and room

This scene used the largest amount of the passes of all of the scenes, with the exterior and interior scenes being rendered separately, A shadow pass was also rendered for the interior spot in addition to the standard edge/contour and fill passes. The scene is meant to reflect the lyrics of the accompanying music and lead into the next scene with the device of the opening cupboard, also the motif of the red ball is visible on the table. The models of the chair, table and cupboard for this scene were modified from free models downloaded from Tubosquid[8].

**Figure 27 Example frames from the hours/room scene a example of blending between scene.**

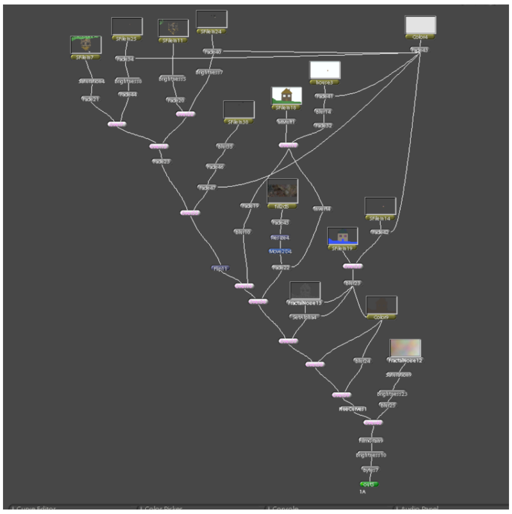

**Figure 28 Screenshot of the shake network used for the final compositing of this scene.**

### 4.2.9 Scene 10: The finally

This is one of the largest and most complex and longest scenes that the non-photorealistic effect was applied to. It was created using a scene originally created by Steve Sandles[9], it uses a slightly earlier and simpler non-photorealistic rendering scene creation scripts, although because of the

[8] http://www.turbosquid.com/

[9] Steven Sandles' BACVA3 student (2007), email: d1112815@bournemouth.ac.uk

amount of detail in the scene extra complex effects used on most of the other scenes seemed needless. Also the feeling that we have arrived at our destination has been supplemented with the fade to white before the credits to try to amplify this.

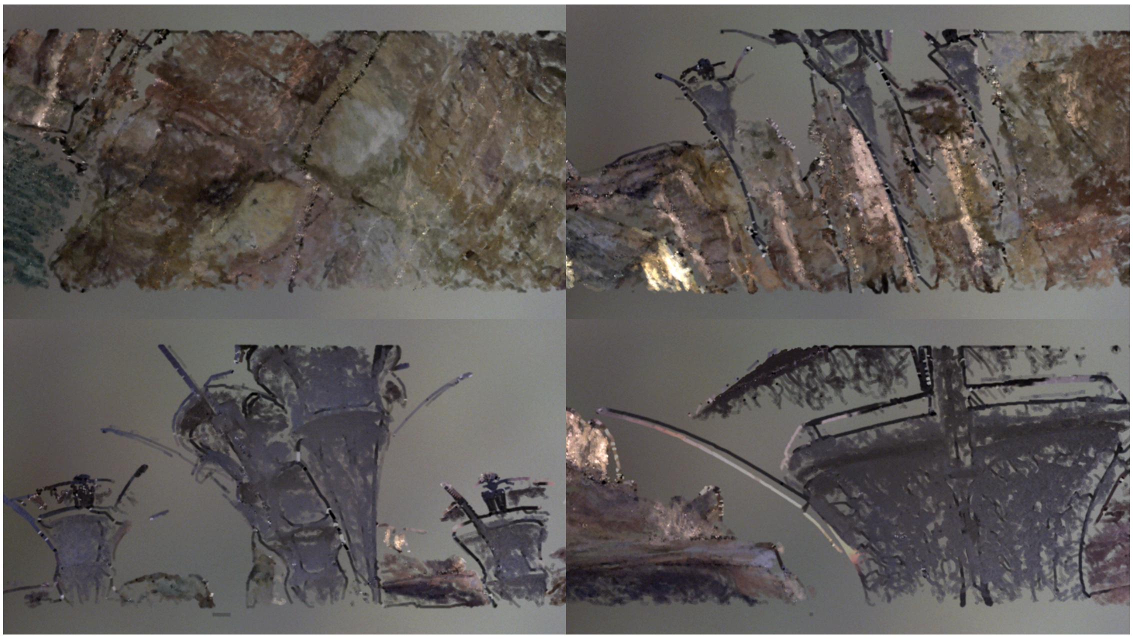

**Figure 29 Example frames from shot that shows non-photorealistic rendering applied to a complex 3D scene.**

## *4.3 Conclusion*

Although the animation was in generally of a high quality it suffered from cutting corners such as scenes being cut or changed to something simpler, due to bad time management.

# 5 Project Evaluation

As a whole this project was a good experience with generally positive results, the research undertaken was generally relevant and useful in particular the production of original traditional painting as it gave a real insight to the techniques and led to the approach and visual style that the effects developed towards and ultimately used in the final technology demonstration animation. The non-photorealistic rendering effect was the more successful of the two developed areas and mostly fulfilled the brief that was set by itself. The second developed area of the close up fluids of paint was a useful educational process although couldn't progress as originally intended with the available time span, but did show good potential for future development. The animated technology demonstration was generally a success but due to bad time management the quality suffered, and in the future the decision to make a animation of such length would be made shorter. As for this report it as also suffered in quality because of poor time management, which unfortunately has been a theme towards the end of this project, mostly because of being very ambitious with what could be done in such a short space of time.

# 6 Bibliography

## *6.1 Books*

GOOCH, B. GOOCH, A. 2001. Non-Photorealistic Rendering.
APODACA, AA. GRITZ, L. 2000. Advanced Renderman.