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# Surface Detail Mapping in 3D Modelling

LAHTI UNIVERSITY OF APPLIED SCIENCES
Media Technology
Bachelor’s Thesis
2014 Spring
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Lahden ammattikorkeakoulu
Mediatekniikka

LUHTAPURO TEEMU: Pintatekstuurien käyttö 3D-mallinnuksessa

Mediatekniikan opinnäytetyö, 33 sivua

Kevät 2014

TIIVISTELMÄ

Tämän opinnäytetyön tarkoituksena oli keskittyä pintatekstuurien tärkeyteen ja selvittää, miten pintatekstuurit toimivat ja mihin niitä käytetään 3D-mallintamisessa. Pintatekstuurit ovat tekstuureja, jotka luovat yksityiskohtia ja realismia 3D-objektien pinnoille. Opinnäytetyössä käsiteltiin bump-, normal- ja displacement-pintatekstuureja.

Ensiksi opinnäytetyössä tutkittiin 3D-mallintamisen perusteita kertomalla mitä 3D-mallinnus on. 3D-mallinnuksen perusteiden jälkeen opinnäytetyössä kerrottiin, kuinka tehdä pintatekstuureja erilaisten tekstuuriteknologioiden avulla. Opinnäytetyön tutkimuksen päätarkoituksena oli selittää ja demonstroida pintatekstuurien tärkeyttä vertaamalla tekstuurien merkitystä 3D-mallinnetuissa objekteissa ja ympäristöissä.

Pintatekstuureja luotaessa ja käytettäessä on tärkeää tietää, käytetäänkö pintatekstuureja reaaliaikaisessa renderöinnissä vai valmiiksi renderöidyissä materiaaleissa. Bump-tekstuurit eivät ole niin tarkkoja verrattuna normal-tekstuureihin, mutta kuitenkin bump-tekstuurit pystyvät saavuttamaan tarkkoja yksityiskohtia reaaliaikaisessa renderöinnissä sekä valmiiksi renderöidyissä materiaaleissa. Normal-tekstuurit voivat saavuttaa realistisia tuloksia molemman renderöintityypin kautta. Normal-tekstuurien nopeuden ja tarkkuuden ansiosta pelit ovat näiden tekstuurien ideaali käyttökohde. Displacement-tekstuurit ovat erinomaisia valmiiksi renderöidyissä materiaaleissa, koska lähikuvissa displacement-tekstuurit pystyvät saavuttamaan fotorealistisia yksityiskohtia.

Avainsanat: mallinnus, 3D, pintatekstuuri, tekstuuri, normal map, 3D-mallinnus

Lahti University of Applied Sciences
Degree Programme in Media Technology

LUHTAPURO TEEMU: Surface Detail Mapping in 3D modelling

Bachelor's Thesis in Visualisation Engineering, 33 pages

Spring 2014

ABSTRACT

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This thesis will focused on the significance of surface detail mapping in 3D modelling. Surface detail maps are texture maps that create extra detail and realism on 3D objects. The goal of the thesis was to introduce what surface detail maps are and what they are used for. The surface detail maps covered in this thesis were bump, normal, and displacement maps.

First, the thesis goes through the basics of 3D modelling. Second, the thesis deals with different texture technologies and methods to explain how surface detail maps are created. Last, the case demonstrates the importance of the surface detail maps by demonstrating and comparing 3D modelled scenes with these surface detail maps. The main point is to show the differences and compare the results between these specific surface detail maps.

After exploring the results of the case, the results demonstrate how important it is to know the basics of surface detail maps before applying them in a 3D scene. It is necessary to know if these surface detail maps are going to be used in real-time rendering or in pre-rendered materials. Bump maps are not as fast as normal maps in real-time rendering but still they are used in both pre-rendering and real-time rendering to achieve fast details on surfaces. Normal maps can achieve impressive results in real-time rendering and pre-rendered materials. Normal maps are most commonly used for games due to their impressive speed and the details achieved in real-time rendering. Displacement maps are ideal for pre-rendered high detail close-up images and videos that require photorealistic details and silhouettes by forming new geometry to object surfaces.

Key words: modelling, 3D, surface, texture, normal maps, displacement, bump

LIST OF CONTENTS

# 1 INTRODUCTION

The importance of three dimensional (3D) modelling has become unparalleled in the media industry. This particular technology has evolved in the past twenty years to the point that it is finally scratching the very true potential of computer generated graphics. Technology is rapidly moving forward, meaning that there is enough power in today's computers to produce realistic, three dimensional objects and characters, and even worlds. This thesis will cover theories studied on the courses of 3D modelling and a practical test of different texture technologies based on professional manuals, articles and numerous Internet websites.

The focus of this thesis will be on the significance of texture mapping technologies as well as how the specific texture types work in the 3D modelling industry. Alongside with the textures, this project will explain the different methods of producing photorealistic results by creating and combining different surface detail maps. The Project focuses on a 3D scene which uses different texture types for various purposes and will be an example of how to create professional surface details to 3D objects. The main purpose of the project is to introduce and demonstrate how even a simple object can achieve photorealistic results with surface detail maps by creating a complex 3D modelled scene which includes different surface detail maps.

This project is a qualitative research study. Therefore, parts of the theories have been taken from secondary sources in order to research different methods of creating reasonable results, contemporally disapproving debatable methods which failed to bring forth the main attributes of the texture technologies. However, primary sources such as manuals, magazines, books and software websites will mainly be used as theoritical sources, which increase the reliability and validity of the thesis. First, the project will be guiding through the basics of 3D modelling by explaining what 3D modelling is before the project is proceeding to the primary topic. Second, the thesis will introduce different types of texture technologies and methods. Last, the thesis will explain the importance of the surface detail maps by demonstrating and comparing 3D modelled scenes and specific surface detail maps.

# 2 3D MODELLING

3D modelling is a form of computer aided design. Its purpose is to create objects that can take familiar or unfamiliar forms. 3D modelled virtual objects can be found in many fields, for example movies, games, and media. These virtual objects can achieve photorealistic results by combining the knowledge of 3D modelling, texturing, and rendering. (Autodesk 2014a.)

## 2.1 Basics of 3D Modelling

This part of the thesis will cover the basics of 3D modelling. This information is necessary in order to understand surface detail maps.

### 2.1.1 Modelling

Three dimensional modelling is used to produce and develop 3D objects with specific programs that are intended for 3D modelling. 3D objects are often recognized by their specific structure of lines. Every 3D object consists of vertexes (vertices) which are specific points in 3D space. Between these vertices are line segments that are also known as edges, connecting the structure to become a whole. (Autodesk 2014a.)

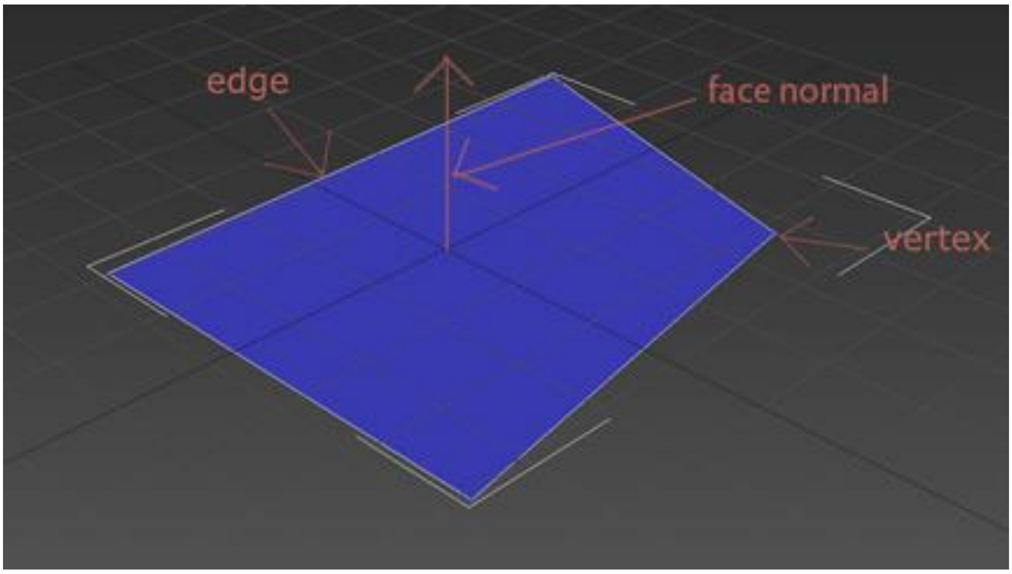


Image 1, Polygon

After the formation of these edges, edges can form a plane in the gaps between the edges. These polygons form the object’s surface, which is also known as polygon mesh. The surface of the polygon area is called face, and each of these polygons has their own face normal that is in the middle of the polygon. Polygon is demonstrated in Image 1. (Autodesk 2014a.)

There are many ways of modelling: polygonal, primitive and nurbs modeling - polygonal modeling being the most popular method. In polygonal modelling, 3D models are created by 3D software that sets points in specific xyz coordinations by modifying and changing the polygons of the object. (wiseGEEK 2014.)

Primitive modelling is a modelling method where the user creates mostly geometric objects like spheres, boxes and cylinders. These objects allow precise perspective propotions to the scene. Geometric objects can also be a base mesh for more complex 3D models. Users can modify this object by increasing the polygon count and modifying the edges and vertexes. (wiseGEEK 2014.)

NURBS modelling is a more complex technique of 3D modelling. It can be found in the most advanced programs and the technique allows the user to create smooth surfaced objects. In polygonal modelling, curves and smoothened surfaces are just nummerical approximations of the true curve. Unlike polygonal modelling, NURBS modelling can make a true curve between different surfaces. (wiseGEEK 2014.)

### 2.1.2 Software

There are numerous programs available for 3D modelling purposes. Many of the programs are specialized in fields like digital sculpting, animation or even specific subcategories like environments. 3D programs usually offer a great range of features and are advanced in their own way. These programs are often applied when producing photorealistic images, animations, game graphics and special effects.

For basic 3D modelling purposes, the most famous of the programs are 3ds Max and Blender. Mostly, these programs are equal in their features, but the Blender is open-source 3D modelling software. Although some of the programs are free open-source programs - many of the commercial programs are still superior in some features.

## 2.2 Textures in 3D Modelling

Texture mapping is a 3D modelling method to add bitmap textures to 3D objects. When adding a texture to an object, its main purpose is to give a texture on its surface and give an illusion of a smooth, rough or even rocky surface. These images can be anything, such as photos, hand-painted pictures or photoshopped illustrations. When textures are applied, the texture wraps around the object with the purpose of covering the entire surface of the object. Sometimes, textures wrapped around the object are stretched and confusing. Therefore, textures can be modified in a material editor by changing texture tilings and the transparency, or adding reflections to the objects. Thus, with these features, problems of stretching and confusion may be solved. In the material editor, texture combinations and other advanced texture blendings are possible.

The texture maps, wrapped around the object, can be altered and changed in one of the 3D software tools called UVW map. UVW Map can modify the position, size, wrapping style and tiling of the texture map. UV unwrapping is a method very similar to UVW map. During the UV unwrapping process, the user unfolds the 3D object by unfolding all the polygon faces to one flat image. One of the methods of doing this is to break the object into bigger pieces that can be easily unfolded and flattened into an image. One good example is Image 2. (Ahearn, L 2009, 70-72.)

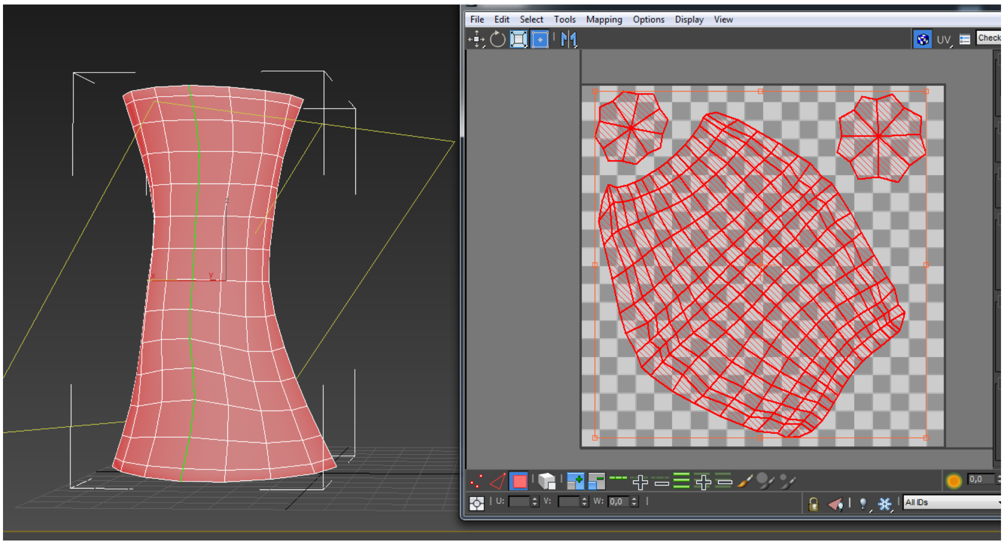


Image 2, Unwrapped pillar

There are many different texture types which can be categorized in many ways. There are surface detail maps, diffuse maps, reflection maps, and similar. Most important are diffuse, bump, displacement and specular maps.

Diffuse map is the colour map that defines the colour of the object itself. Diffuse map is the core of the textures because the colour depends on it. Diffuse maps can be a photograph, a hand-painted picture, or a computer generated picture. Bump and displacement maps are textures creating shadows and bumps on the object surface. Bump maps create illusions of shadows and depth by changing the face normals of the object surfaces while the displacement maps lift the parts of the surface to create real bumps and formations on the object surface. The purpose of the specular map is to illustrate the surface of the object as well as to reflect light from the surface of the object. (Ahearn, L 2009, 15-20.)

## 2.3 Rendering

Rendering is the most complex phase of 3D production. Basically, rendering is a number of calculations processed by 3D software render engine: the engine creates the scene from a mathematical equation to a finalized image. During the process, the entire scene lighting, the textural and form information are processed to determine the colour of each pixel.

Rendering reveals the final high detailed textures in the 3D scene and while it renders it the computer calculates every pixel with all the reflections and the shadow details that are attached to the texture itself. All this is happening alongside with rendering the camera effects such as fog and depth of field.

### 2.3.1 Types and Techniques

There are two major types of rendering called real-time rendering and offline rendering. The difference between these two is that real-time rendering is done by the computer’s processing power in real time. Real-time rendering is the rendering type used in games; it is required because player actions are impossible to predict. (Slick, J 2014.)

Pre-rendering has also been in public a lot. Pre-rendering, also known as offline rendering, has been used in videos and images that have been rendered before showing them. Therefore, there is a clear distiction between pre-rendering and real-time rendering.  For example, the 3D animated movies are pre-rendered and the games are making use of real-time rendering. Meanwhile, real-time rendering is happening simultaneously while the pre-rendering happens within a more open time frame. Due to a longer rendering time frame, offline rendering can achieve photorealistic results as seen in the animation movies and concept pictures. (Slick, J 2014.)

There are very advanced settings for rendering. There are multiple techniques and rendering softwares to use for the final process. The three major rendering techniques are scanline, ray tracing and radiosity techniques. Each technique has their own unique computing method, giving them advantages and disadvantages compared to each other.  (Slick, J 2014.)

Scanline rendering is a rendering technique that produces primary visible surfaces. The objects on 3D scenes are projected onto a 2D viewing plane and sorted by their x and y coordinates. The image is then rendered as horizontal lines. Scanline renderer sends a ray from the camera through every pixel of the rendered images. If the ray crosses a surface, the colour of the pixel will be calculated. The colour of this pixel is determined and affected by texture map, light source values, the angle to normal of the surface, and the angle of the camera to that surface. (Autodesk 2014b.)

Ray tracing rendering also sends rays from the camera to the surfaces in the scene like the scanline rendering does, but when the ray enters the surface, the ray checks the surface's reflectivity and bounces on to the next object. This develops better and more realistic reflections and caustic effects. (Rademacher, P 2014.)

The radiosity technique is a rendering technique that has the ability to reflect material properties to other materials. These materials work as if they were a second source of light that illuminates the colour and other properties to scenes other materials. (Blender.2011c)

Ray tracing is a rendering technique that generates the finalized image by tracing the path of the light from a 3D scene. Ray tracing processes and calculates the light rays that are reflected and created by the surfaces. This technique can achieve a high level of photorealism. Results of these techniques are usually more realistic and higher quality than the results from the scanline technique, although this has its own cost. The ray tracing technique requires a massive amount of processing and computing power. Therefore, this technique is mainly used in prerendered environments, such as movies and still images. (Rademacher, P 2014.)

### 2.3.2 Renderers

Renderers, also known as render engines, are engines that do all the rendering and processing. As there are many 3D modelling programs, there are also many renderers that are competing with each other. Many of these have different features and are based on different rendering techniques. The render engine determines how the 3D modelled scenes are rendered and depending on the render engine's method, they can also be rendered with a graphics card (GPU) or by a computer processor. (Blender.2011c)

The processor has been a popular method of rendering, but lately the GPU rendering has become famous due to the increase in the GPU's speed and power. For instance, the Blenders Cycles rendering engine uses this method. Still, minor setbacks like shortage of video memory can be an issue with this new rendering method. (Blender.2011c)

The most notable renderers are Mental ray, iRay and Vray. The mental ray is Autodesk’s standalone renderer and as the name suggests, it is capable of using the ray tracing technique. Vray is a plug-in renderer for many programs that support a 3rd party. (Blender.2011c.)

# 3 SURFACE DETAIL MAPPING

Surface detail maps are texture maps that create illusions or forms to the surface of the object to create realistic shapes and bumps. The texture maps are well known in the 3D modelling community and the entertainment business and most importantly in games. As mentioned earlier, games cannot handle high polygonal objects and characters. Therefore, the details of these objects need to be done with something else than with the polygons themselves, and that is when the surface detail mapping comes in. These surface detail maps add details of high polygonal objects with textural maps that illustrate details by normals and height maps.

## 3.1 Bump Map

A bump map is a texture map. Often textures contain information about colours but a bump map contains a greyscale height map (Image 3).

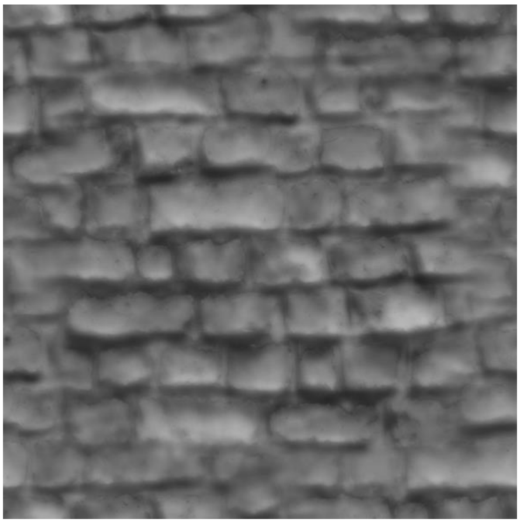

Image 3, Bump map

Bump maps are the oldest texture type of surface detail maps, and they are supported by the majority of the 3D modelling programs. So it is easy to use these maps for the reason that most renderers and programs recognise and support this texture type. (Hugo, E.)

Bump maps are textures that have an intensity, which allows the bump map to affect the surface of the object applied on. The Bump map is a grayscale image.

Greyscale values on the bump map determine height of each pixel. Darker valued areas lowers and whiter areas lift the surface. To explain this further, there are smooth and hard-edged bump maps. A hard-edged bump map does not have a variation between dark and bright values. Hard-edged bump maps only have a few values on the texture, so there will be big difference between greyscale values, and the bigger the jump between greyscale values, the stronger the bump is. If the bump map forms a gradient like a transmission between dark and bright, then the map forms a smoother transmission. Bump maps act like the height maps do; whiter areas are the highest points of the map and the darkest ones are the lowest points. (Hugo, E.)

Bumps maps do not apply a physical change on the object's surface. The bump information is in the texture itself, and these bumps are not shown in the 3D software without a renderer. While rendering, the render engine processes through the bump maps and calculates the face normals of the bumps. By doing this, each bump and height point has its own face normal. These face normals show the new direction for the pixels to go by (see Image 4). Pixels will either move in the direction or opposite direction of newly calculated face normals from the camera viewpoint. (Blender 2011a.)

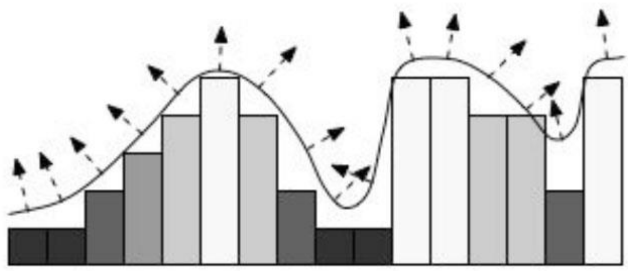

Image 4, Bump surface with face normal (Pixologic 2005)

In other words, bumps of the object are details formed by modified surface normals. By calculating the surface normals, the bump creates an illusion of shadows and details on the surface of the object. Basically, with the height map information, the renderer calculates the average from the height map to create new surface normals for the texture. While forming this surface normal, the renderer will calculate proximity from the height levels of the bump map and create the surface normals from the proximity information (Image 4). (Blender 2011a.)

The bump map strength can be enhanced by modifying the intensity of the bump map, which will change the relative height of the pixels from the camera view. The bump map height information ensures that the object's surface details change as the light source moves in the scene to make bump formations act naturally with the environment and lighting. Although bump mapping creates bumps for the objects, the surface still stays flat. Bump maps create the illusion of formations in the object but when viewed from an angle, it is not in the silhouette of the mapped object. (Blender 2011a.)

Bumps maps are often used in 3D, to add little details like scratches, fractial surface formation, bumps, wrinkles, and hard-edged details. Unfortunately, these bump maps are not effective enough to show big formations on the surface, but great enough to make impressive results.

Image 5, Sphere with a bump map

The bump map is easy to apply in 3D programs due to good support and a long history. Material editors have seperate place to add bump maps to the materials. After applying the texture to the object and modifying the bump settings, details of the texture map will achieve better results (see Image 5).

## 3.2 Normal Map

> *A Normal Map is usually used to fake high-res geometry detail when it's mapped onto a low-res mesh. The pixels of the normal map each store a normal, a vector that describes the surface slope of the original high-res mesh at that point. (Polycount 2014.)*

Normal maps are popular in the gaming culture as these maps provide a high detail to characters and objects and by that create an illusion of an immersive game world and at the same time allow high details in games. An advantage is that they are not as heavy for computers to process as the other surface detail maps. (Polycount 2014.)

Normal maps can be sub-categorized in the bump maps category. Normal maps act like the bump maps but on a more sophisticated level. Like with the bump maps, they form surface details on the objects, but they already contain the face normal information in every pixel. (Blender 2011a.)

The surface normal direction is stored inside the normal as a vector. The surface normal of the objects geometry is used for calculating the lighting.The purpose of the normal maps is to modify and change the normal of the object's surface which makes the lighting look bumpy. This bumpy lighting can be exported from a high poly object or can be made with specific programs. (Polycount 2014.)

Image 6 demonstrates the bumpiness and the illusion of the map surface. The top part of the image is the surface of the high poly object and the bottom of the image illustrates how the normal map creates the bumps. Normal map has the same bump and surface normal information as the high poly object but it is a flat texture map. Unlike the bump maps, normal maps have the exact surface normal information from the high poly object and the renderer does not calculate surface normals from proximity. Normal maps have the true surface normals from the high poly object already in the normal map texture. (Polycount 2014.)

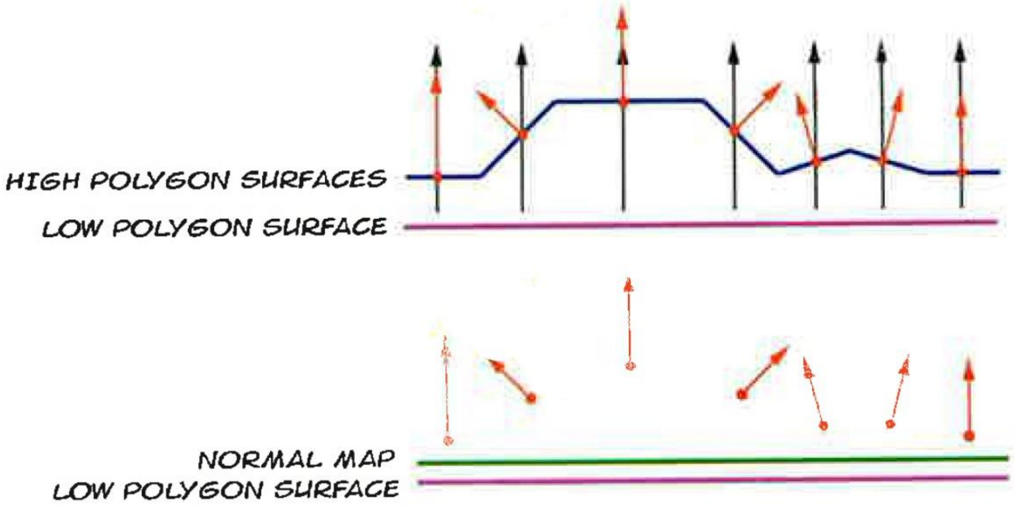


Image 6, Normal directions (Ahearn, L.a)

Unlike with bump maps, normal map pixels do not move in the directions of the face normals. To further explain this, normal maps have face normal direction in its every pixel. When the light is hitting from the light source to the normal, the angle between the light ray and the face normal determines the darkness and the brightness of the pixels, thus forming the details of the high detailed surface. This feature itself already saves the render engine's time from calculating the directions of surface normals. The angle between the surface normal and the light vector determines the pixels darkness and brightness (Image 7). (Blender 2011a.)

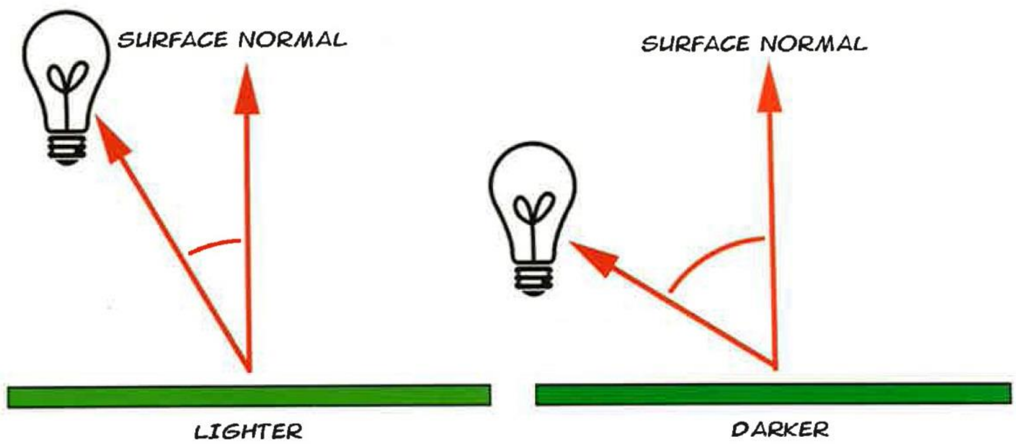


Image 7, Surface normal and light angle demonstration (Ahearn, L.b)

The normal maps store the direction in three-dimensional coordinates and represent these coordinates in specific colour channels: red, green and blue. The red colour represents the coordinates of an x axis, green represents the y axis and blue represents the z axis. To put it shortly, normal maps use RGB colour values to inform the rendering engine about how to change the way the light reacts to the surface. An example can be seen in Image 8.

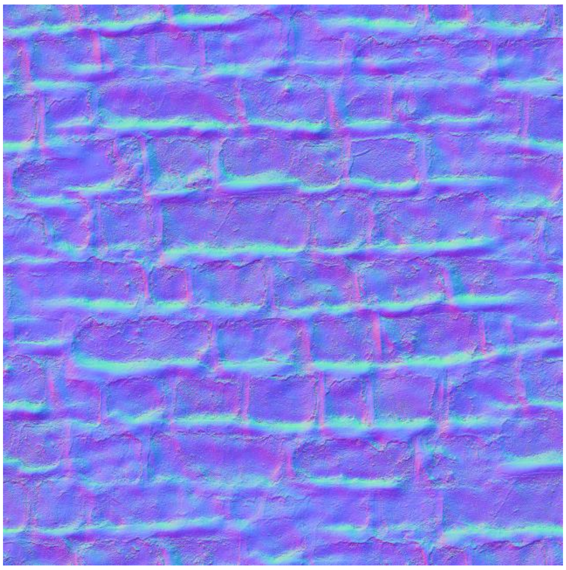

Image 8, Example of normal map

Normal maps can be made in multiple ways but there are two types that are common. These types are tangent-space and object-space. Object-space is also known as local-space.

Tangent-space normal maps are the most recognisable and the most popular of the normal maps because of their blue appearance (see Image 8). Tangent-space maps almost look bluish because the blue colors seen in the normal maps are thought to point to the direction of face normals. Objects with tangent-space maps can be rotated and deformed, meaning that this type of normal map is ideal for characters and other objects that require having a vertex deformation like water and plants. (Polycount 2014.)

However, object-space normal maps have rainbow coloured appearance. These maps allow objects to be rotated but not deformed. Deforming an object-space normal mapped object, leads to wrongly shaded areas. Object-space normal map is ideal for an object that does not need to change its appearance like doors and other hard physical objects. Unlike the tangent-space normal maps, the object space maps can not be reused easily due to the meshes requiring unique object-space maps. Therefore, object-space maps are harder to control and modify but offer a slightly better performance in rendering. (Polycount 2014.)

Creating the normal maps by hand is a difficult process. As mentioned earlier, normal maps have information of three-dimensional bumps in colour channels. Because of this information, the creation of normal maps usually requires an allegorithmic program to produce or convert the needed normal maps.

Normal maps are most popular in realtime rendering. Games and real-time render engines can save a lot of power from processing high polygonal and detailed objects by just rendering these normal maps that have information of the high polygonal details. In 3D modelling software, normal maps are quite easy to use. Normal map settings can be altered in the material editors. Materials contain import options for the normal maps. After importing the normal map, the normal map values can be increased to add effectiveness on the surface object. Depending on what type of normal map is at hand, the user can choose the specific mapping type to represent mapping types like object-space or tangent-space. Other factors like light intensity or caustics can affect the detail of objects directly (Polycount 2014).

## 3.3 Displacement

> *"Displacement mapping is a technique for adding geometric detail to surfaces at render time. In contrast with bump mapping, which works by just changing the surface normal to create the illusion of surface detail, displacement mapping modifies the surface itself." (ChaosGroup 2014.)*

Displacement maps are not bump maps, although it may feel and look like they would be categorised to bump maps. Displacement maps are greyscale maps just like bump maps, but they are used in prerendered materials like animation movies and pictures. Using a displacement map to modify a 3D object is a good way to increase the level of detail that is not available with normal or bump maps. Displacement maps can also be used as bump and height maps. (ChaosGroup 2014.)

Displacement mapping allows you to physically push out and pull in the surface of the object in order to allow a better detail and depth than with bump and normal map techniques.

How a displacement map works is simple. When applied, displacement maps use black to white intensity variations to pull and push the surface in or out, effectively modifying the silhouette of the 3D object. Unlike normal maps, a displacement map does not alter the surface normals. The displacement map's deformation goes in the direction of the point's surface normal. Due to no alteration of face normals, displace effect goes to direction of original face normal. While rendering, displacement maps produce new polygons and pixels to points where displacement map indicates height variations from the polygon surface. (Pixologic 2014a.)

These variations are determined by the displacement map's black-to-white data. The bright values represent the highest point and the dark colour determines the lowest point. Displacement maps work the way as bump maps but they can achieve better detail and formation. Displacement maps are capable of generating realistic shadows and silhouettes on the displaced surfaces. These features cannot be shown or done by applying bump or normal maps. (Pixologic 2014a.)

Displacement maps do not show in preview windows or change the geometry of the object before rendering. Applying displacement maps is easy, but to make them look natural and impressive the user needs to change displace values of the material itself. The user also needs to change the renderer engines displacement settings to add more detail to achieve photorealistic results. People often think that it is enough to apply the displacement map to material and set its values to give good shape to 3D objects but adjusting the details from the renderer gives all the little details like smaller bumps and shapes.

Image 10 Normal map Image 9 Displacement map

Displacement maps can achieve great results. One of the advantages of these texturing types is that the displaced surfaces have a silhouette and it is not flat as compared to normal- and bump maps. See the comparison in images 9 and 10. Displacement maps are recommended when taking close-up animations and pictures from a 3D object that has details on the surface just because it has the real form on the surface of the object. (Pixologic 2014a.)

For many years displacement maps were a delicacy on high-end pre-renderering engines while real-time rendering engines has just started to learn about the displacement maps. Today, displacement maps can be used in games to give form and shape to the object. Tessellation is a method in real-time rendering engines to bring details and forms to flat surfaces. The technique increases the geometry complexity by dividing existing polygons to smaller ones. Surface displacement can be changed by modifying the values of the displacement scale so it can achieve different shapes on the object. Real-time rendering can not process displacement maps as well as the pre-rendered picture can achieve because computers and technologies are not powerful enough to handle the displacement in such detail.

During rendering, there is a noticeable difference in the detail when the renderer’s displacement settings are changed. These values determine the amount of detail generated by the rendering process (see Image 11)


Image 11, Displacement map details

# 4 CREATION OF TEXTURE MAPS

Creating textures is a long process. Texture maps can be created in different programs with different techniques. These texture maps can be generated by 3D programs, texture generators, photographs, and image-editing programs.

## 4.1 3ds Max

Autodesk 3ds Max is 3D modelling, animation, rendering and simulation software. Mostly, 3ds Max is used for the above mentioned features but the program also has he ability to extract textures. 3ds Max allows to extract bumps and normal maps out of the object. Texture generation will be demonstrated by creating the surface detail maps from the door shown in Image 12.

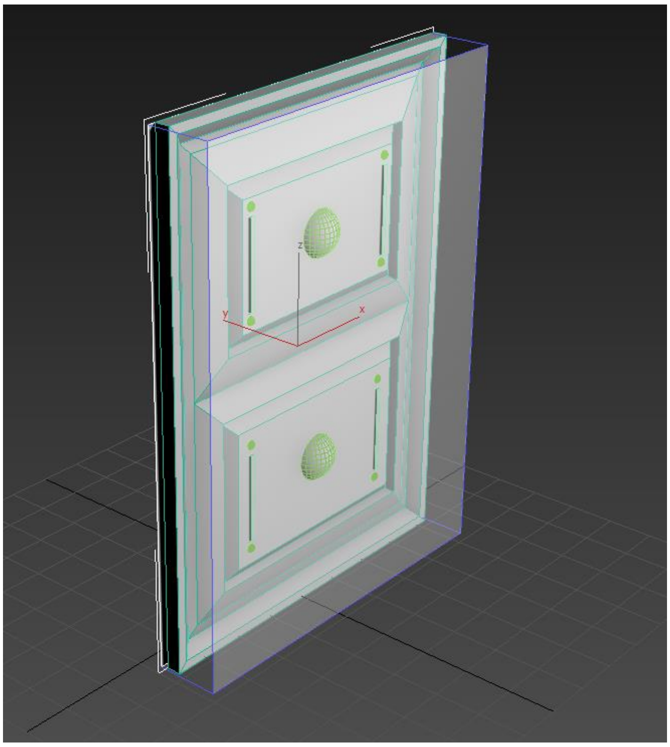

Image 12, Projection field

The details of the door are extracted to the textures with a technique called projection field that will project the forms and surface of the object. This technique basically allows the user to extract details from the detailed surface to create different textures, like diffuse, normal, bump, and displacement maps. The field recognizes the forms on the surface of the object and therefore generates the appropriate texture maps. Projection field is demonstrated in Image 12. (N3V Games 2014.)

Applying these extracted textures to a 3D object is typically done through material editor. 3ds Max is capable of extracting multiple types of textures, but the program is commonly used to project and extract normal maps from the objects. Results are impressive, as it shown in the Image 13, where the door on the left has higher polygonal count and the door on the right has the extracted texture. Difference is not big but it saves the time while rendering in bigger scenes. (N3V Games 2014.)

Image 13, Comparison between original and the extracted texture

## 4.2 Digital Sculpting

Digital sculpting is done in 3D programs that allow users to modify 3D objects polygonal surface as if it were digital clay. Basically, digital sculpting allows the user to move vertices of the 3D model by pulling, pushing or giving the object more realistic surface modifications.

There are two sculpting techniques worth mentioning, mesh and voxel sculpting. Mesh sculpting is based on polygonal surface editing and voxel gives more freeform, which means that in voxel sculpting the object is made of little cubes and it does not have any restrictions. However, they are not applied in this case.

With sculpting, it is noticeable that the software allows the modification to become really detailed and complex. To have a very detailed version of the object often requires hundreds of thousands of polygons in the object by subdividing the already existing polygon in the base mesh. This possibility of modifying the surface of the object allows the user to create high detailed and realistic 3D objects.

Digital sculpting has become popular on TV, in movies and in games. This technology allows creating hyperrealistic 3D worlds and characters, and by combining these, it allows to get immersed in the world generated. In the recent years, nearly every game company and movie studio has used sculpting in some form. It allows creating a new kind of imaginative characters to movies and games.

### 4.2.1 Sculpting the Texture

In the start sculpting process, sculpting requires a base mesh. The base mesh can be a self made complex object or it can be started from a primitive geometric object, for example sphere. This base mesh can be referred to as the spine of the complex object, which means that the mesh is the basic layout for the sculpture and the software allows modifying it. To add more detail to objects you need to go to higher subdivision levels by subdividing the polygons. This multiplies the object's polygonal count and allows more precise detailing. (Pixologic 2014b.)

> *"To understand the power of this ability, consider the following example. At a low subdivision level, you sculpt a polymesh plane so it appears as rolling hills. Then, at a high subdivision level, you add a "bumpiness" that gives the appearance of rocks, dirt, etc." – Zbrush (Pixologic 2014d.)*

The sculpting process is to create the detailed high polygonal 3D object and afterwards the details of these objects will be extracted.

### 4.2.2 Extracting the Textures

The process of extracting the textures is also called baking. In other words, baking means texture extraction from the digital sculpture. Sculpting programs are capable of producing multiple textures at the same time.

To generate the textures from the sculptured object, complex objects require having an unwrapped texture in the object information.

Baking is recommended in 3D objects and scenes whenever it is used in animations and most importantly in real-time rendering. A high polygon character contains too many polygons to render it smoothly, so it must be reduced to a level where computers can render the character in real-time. Therefore, it is necessary to produce a low polygon version of this character and apply the textures produced from a high polygon version.

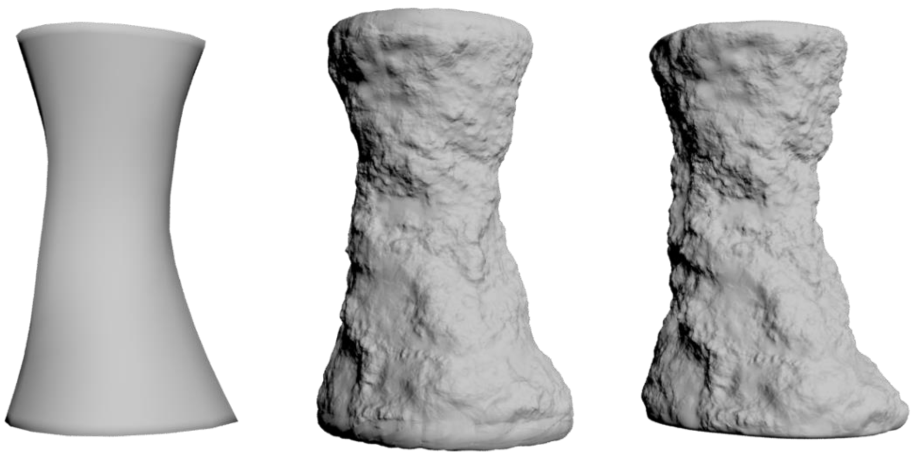

Image 14, Low polygon model (left), extracted textures in the low polygon model (middle), and the high polygon model (right).

After the texture creation procedure, the textures are applied to a low polygon version like in Image 14. The right pillar demonstrates the high polygon model in a sculpting program and the middle one is the low polygon version having these new exported texture maps from the right pillar. The left pillar is the original low polygon model.

Sculpting programs understand the unwrapped information in the objects. A basic low polygon model with unwrap can be modelled in 3D software and then imported to a sculpting program. While in the sculpting program, the low polygon object’s polygon count can be multiplied and then sculpted to high realistic details. After achieving the wanted details for the object, all the sculpted and colored information can be extracted from the sculpting program to the flatten UV image of the low polygon model. As the sculpting allows modifying the surface with higher details, it also allows colouring to the object the same way as sculpting by saving the information to UV map image. (Pixologic 2014b.)

## 4.3 Texture Generators

There are several texture generation programs on the market. Texture generators have become more popular in the 3D deveplopment business due to increased capabilities in image detection and understanding. Texture generation programs create ready-to-use texture images for 3D softwares. These programs can modify colour, brightness and saturation of the textures as they would be modified in an image-editing program.

Some of the programs have the shape regocnition that calculates and determines the shape of the texture through a multiple of algorithms. For example, in the brickwall it recognizes the grudges and the detail of the stone and its basic form (Image 15). Even though it is a flat picture, the program calculates the detail and creates the surfaces like they are in the real world by shaping bumps and variations in height.

Image 15, Examples of shape recognition (Quixel 2014)

After the program has imported the image and recognized the forms in the picture, it allows the users to manipulate how the surface is formed. Advanced programs even allow users to decide how the light reflects on the surface of the texture map by changing the algorhytmic values.

Creating the textures with these programs is fast, yet effective and detailed. The users can import pictures taken by a phone or even draw a picture themselves, and still the program calculates and detects all the shape information from the given picture.

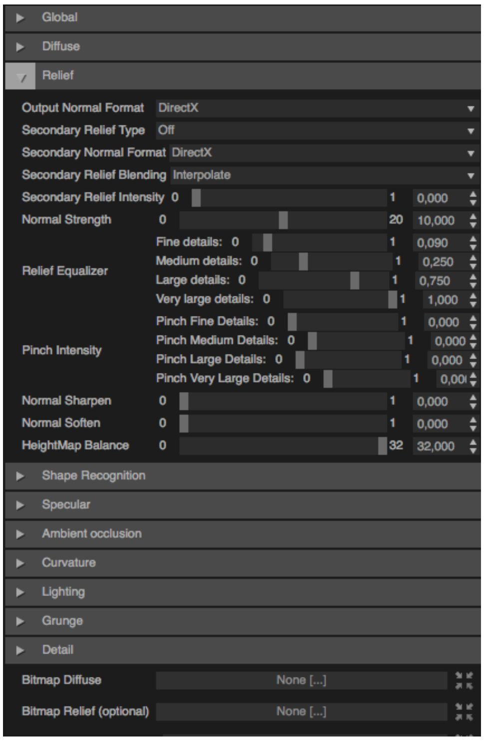


Image 16, Texture settings

As shown in Image 16, there is a vast amount of options to modify the texture. On the program, there is a preview of the 3D object, with texture applied on it, so the user can see modifications and changes in the texture simultaneously. This allows a fast and precise editing of the texture.

The user can alter the texture as much as the program allows. Furthermore, modifying the textures can result in extreme details and levels. It can change the look of the texture dramatically and create nearly the opposite look from the original texture image. The software allows previewing the texture in 2D, and there are many texture types the user can modify. In Image 17, there is a prime example of how many texture types the application can produce.

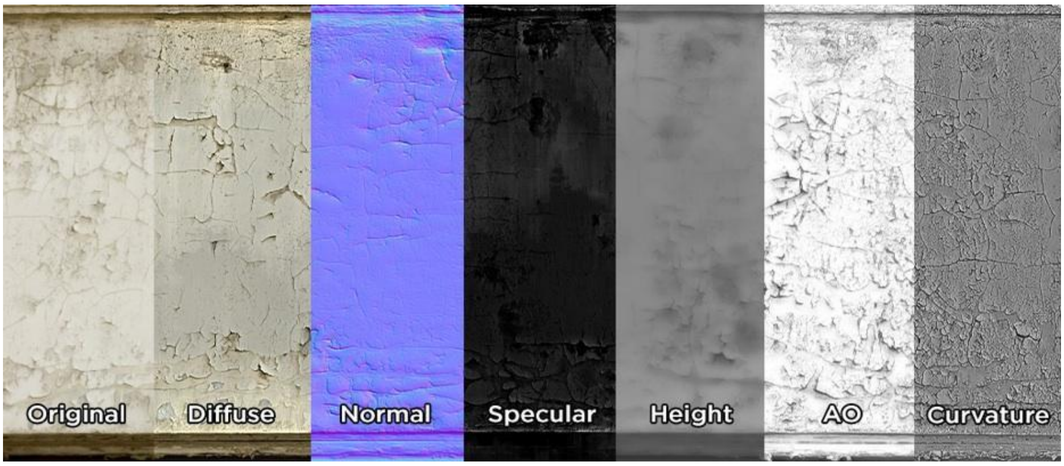


Image 17, Different types of texture extraction types (Allegorithmic 2014)

When the texture is finally ready, the user needs to export the textures. Furthermore, the user needs to select which texture is to be exported and in what quality. After exporting the texture, textures are now ready to be applied in the 3D software and to the objects in the 3D scenes (Allegorithmic 2014).

## 4.4 Image-editing Software

Image-editing is a powerful way of altering textural images. Artists and engineers can handcraft photorealistic results using this software by combining and drawing textural photos and images to create one’s own texture maps. Photomanipulation programs are capable of producing prodecural textures that are generated through specific allegorithms. Generating prodecural textures can achieve impressive results when used right.

The most powerful way of creating these textures is to edit existing pictures by mixing layers with effects and other photographs. These effective methods allow users to create photorealistic textures easily. Applying this method, the user can create the textures desired without any limitations. These programs are usully used for diffuse and bumps maps.

One of the useful functions of these programs is to colour the UV unwrap maps. These maps are easy to colour on simple objects and surfaces, but on more complex maps it becomes hard to understand which area belongs where in the objects. That is where sculpting programs are good as they allow colouring straight to the 3D objects. If there is already an existing UV map of the object, the colouring is also updated to the UV map itself.

There are many plug-ins for the image-editing programs. Many of these plug-ins are meant to convert normal bitmaps into normal maps. There are also newer plug-ins that gives the user an ability to modify and paint normal maps in real-time. Some of the new plug-ins are capable of importing UV maps created in 3D software to the image-editing software, and there the plug-ins can fold out of the existing UV maps back to the 3D model inside the photo-editing software. These new plug-ins then can freely modify and colour the object’s surface.

There are a few methods worth mentioning. By creating the texture and mixing images in the image-editing software, the user can transfer created textures to texture generators that can adjust and modify the settings of the texture and export multiple texture types. This procedure saves time and can easily create a fast preview of the texture for the 3D objects. (Quixel 2014)

# 5 CASE

To support the theories and methods, it is necessary to create a 3D model to visualize the differences between these detail surface maps. As a support for previously mentioned theories, the objective is to study if these maps can achieve greater results compared to what they have been used for. To investigate these results, several 3D objects have been made in different scenarios to see which one works best in a specific situation. Another aim is to find out which methods is the fastest in order to process these textures.

Modelling and rendering the objects and the creation of texture maps and the result will be done with programs like 3ds Max 2014, Bit2Material, and Painter 12. For rendering and processing, 3ds Max will be used as the main program as it has qualitities for using and creating the necessary results to research the theories and methods. The mental ray was the primary renderer for the project. Even though, 3ds Max is an extensive and advanced program for modelling, texturing and animating, 3ds Max still has rudimentary ways of making the textures themselves. For texture and surface detail maps, procedural texture generation programs and photomanipulation are used to create the specific texture maps for the finalized images.

## 5.1 Project

The goal of this thesis is to study where and in what kind of situations these surface detail maps can be used, what they are best suitable for, and if there is an alternative and better way to reproduce this effect. For this scenario, I have chosen a number of simple products to be created by applying surface detail maps. The purpose is to research which has best details, and how they work in different screnarios like brickwall and road.

First, the surface detail maps will be tested as to how detailed they can look in close-up pictures. In the sources usesd in the thesis, it was mentioned that displacement maps are best for closeview scenarios like this. I will be researching and using the basic brick textures, and brick textures are generated by texture generators.

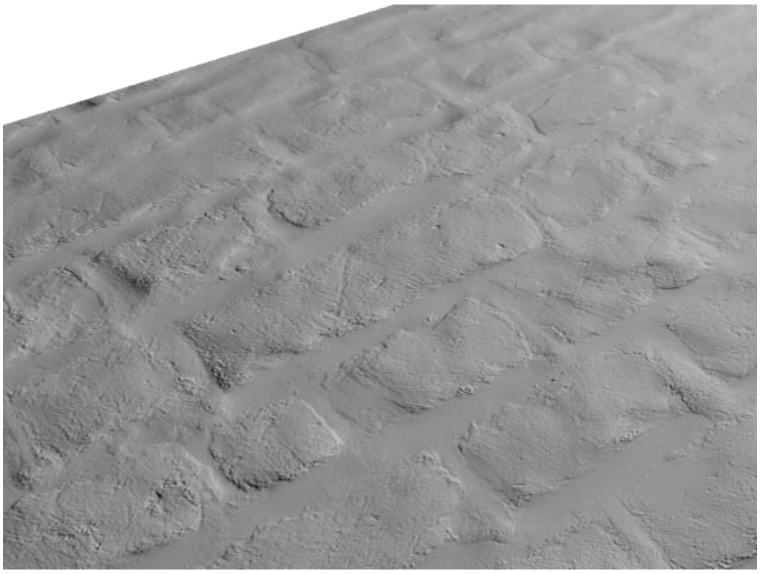

Image 18, Bricks made with bump map

The bump has limited but specific details that can show in even low light situations. Unlike the normal maps, the bump map height is not dependent on the light intensity, but on the values of the bump itself. Example in Image 18.

Image 19, Bricks made with normal map

In the normal map picture, the texture created a huge amount of details. In the right lightning conditions and values the normal map looks realistic and yet fast to render. Although, the details are impressive and great, they are not perfect. When looking at the edge of the texture, a flat edge can be seen which is not the intended form for the surface, as seen in Image 19.

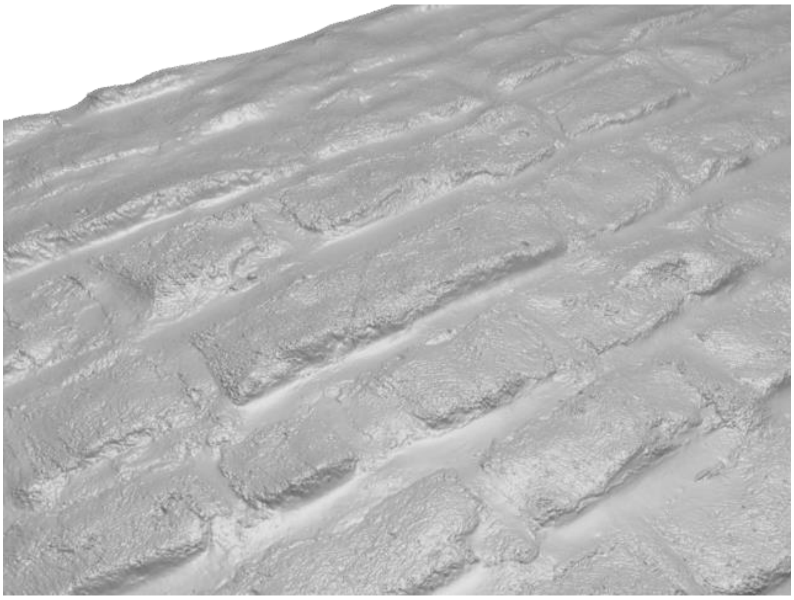

Image 20, bricks made with displacement map

The picture above (Image 20) with displacement map shows more shapes and formations on the surface of the texture. It gives a better and more realistic look to the object by having true geometry on the surface.

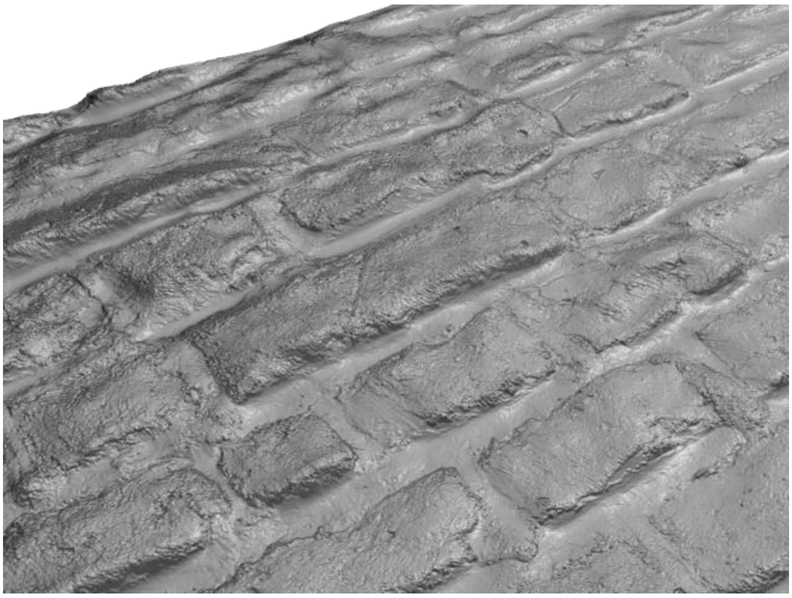

Image 21, Combination of the maps

Combining the surface detail maps gave the object great and precise results by giving nice and realistic formations on the surface and by adding small details like shadows and small bumps. This combination is shown in Image 21. It combines the detail values from normal bumps and at the same time it also preserves the displaced surface of the object. All in all, the combination creates impressive and more realistic results than what the other textures are able to produce alone.

The silhouette is the main feature of displacement maps. Bump and normal maps are incapable of producing silhouettes on object surfaces, so the best way to demonstrate the silhouette was to take pictures from one angle of the surface where the textures are. Images 19 and 20 are the examples of the differences between the displacement and the normal maps.

## 5.2 Combination of the Textures in the Scene

To examine the theories further, a scene was required to put the textures to a test. The main purpose of the scenes was to research what situation each of the surface detail maps are ideal for. The scene with a basic low polygon (image 22) street was created with walls and a road.

To look further into the close-up picture theory of the displacement maps it was necessary to put the displacement map on the first wall to show the variations on the surface of the wall. Clearly, on the edge of the wall details and bumpiness can be seen. Therefore, it increases the impact of realism to the viewer.

The theories suggested that the displacement maps are great to use for creating terrains and grounds. To demonstrate this, image 23 has a mountain range that is solely created by displacement maps the values of which are set high on height settings. The displaced hills in the background are a perfect example of the power of the displacement maps to show off the silhouette generated by these maps.

Image 22, 3D scene without any textures

Image 23, 3D scene with surface detail mapping

The image shows two different walls; the wall closest to the camera has the displacement map and the second one has the normal map. The purpose of the walls was to show the usage of the displacement map and the normal map and how they can be similar in details. Therefore, by applying the theories and methods in the scene, the walls still work together very well without losing any specific details. The image proves that the displacement map is not truly required on distant objects due to the effectiveness of normal maps. The normal map brings more than enough detail to the wall itself to be as detailed as the road on the same distance.

The bump could achieve nearly the same as the normal maps, but with side effects of not being as precise or as fast. Although bump maps are inferior to normal maps they could still achieve nice and impressive results.

# 6 CONCLUSION

Each of these surface detail maps is good for several purposes. With many advantages and disadvantages, these maps are good in different scenarios and rendering procedures. The most difficult part of the surface detail mapping is to use the maps in the right context and use their productiveness at its full potential. Different methods of creating and producing these texture maps will result in impressive findings.

Bump maps are perfect to use in scenarios where objects need small specific details on the surfaces of the object. Although most of the programs and renderers support these texture maps, it is clear that bump maps are inferior to normal maps in every way. Bump maps are no longer popular in real-time rendering due to the superiority of normal maps. Bump maps are preferred in pre-rendered situations due to the lack of detail and speed compared to normal maps.

Normal maps are most effective in game environments due to the preprocessed surface normals and the amount of detail they can posess in RGB colours. Normal maps are more efficient in rendering times than bump maps and therefore, they are ideal for real-time rendering engines. A disadvantage of the normal maps is that it is difficult to create normal maps by hand which is easy and fast to create in bump- and displacement mapping. Due to speed and visual quality, normal maps are ideal for game purposes, for showing displacements quality in real-time graphics.

Displacement maps are the most demanding of these three surface detail maps. The optimal scenario for displacement maps are the close-up pictures that requires the form of the surface to be seen from an angle. Unlike the bump and normal maps, displacement maps lift the surfaces to create a detailed silhouette for the object itself. On the other hand, the more detailed values the displacement gets the more processing and rendering time it requires. Displacement maps are superb for pre-rendered pictures and animations.

REFERENCES

Autodesk.2014a. 3d modelling [ referenced 13th March 2014] Available at: www.autodesk.com

Autodesk.2014b. Scanline Renderer [referenced 18th February 2014] Available at: http://docs.autodesk.com/3DSMAX/16/ENU/3ds-Max-Help/index.html?url=files/GUID-24D58C3F-7922-4215-A46C-620D76048F16.htm,topicNumber=d30e593137

Blender.2011a.Bumps and Normal Maps[referenced 23rd March 2014 ] Available at: http://wiki.blender.org/index.php/Doc:2.4/Manual/Textures/Influence/Material/Bump_and_Normal

Blender.2011b. Curves [referenced 23rd March 2014] Available at:

http://wiki.blender.org/index.php/Doc:2.4/Manual/Modeling/Curves

Blender.2011c. Render[referenced 23rd March 2014] Available at: http://wiki.blender.org/index.php/Doc:2.6/Manual/Render

Chaosgroup.2014. Displacement map[referenced 14th March 2014] Available at:

http://help.chaosgroup.com/vray/help/150SP1/tutorials_displacement.htm

Slick, J. 3D Defined – What is 3D? [referenced 22nd February 2014] Available at: http://3d.about.com/od/3d-101-The-Basics/a/3d-Defined-What-Is-3d.htm

N3V Games.2014. HowTo/Build normal maps in Max [referenced 8th February 2014]Available at: http://online.ts2009.com/mediaWiki/index.php/HowTo/Build_normal_maps_in_Max

Paul Rademacher.Graphics for the Masses [referenced 19th February 2014] Available at: https://www.cs.unc.edu/~rademach/xroads-RT/RTarticle.html

Pixologic.2014a. Displacement Maps [referenced 2nd March 2014] Available at : http://docs.pixologic.com/user-guide/3d-modeling/exporting-your-model/displacement-maps/

Pixologic.2014b. Guide to Sculpting [referenced 23rd March 2014] Available at: http://docs.pixologic.com/

Pixologic.2014c. Normal Maps [referenced 22nd February 2014] Available at: http://docs.pixologic.com/user-guide/3d-modeling/exporting-your-model/normal-maps/

Pixologic.2014d. Subdivision levels [referenced 2nd February 2014] available at:

http://docs.pixologic.com/user-guide/3d-modeling/modeling-basics/subdivision-levels/

Polycount.2014.What is a Normal map [referenced 22nd February 2014] Available at: http://wiki.polycount.com/NormalMap/

wiseGEEK.2014. What is d modeling? [mentioned 2.3.2014] Available at: http://www.wisegeek.com/what-is-3d-modeling.htm

BOOKS:

Ahearn, L.2009.*3D Game Textures.* Second edition.Focal Press [referenced 22nd February 2014]

## IMAGE SOURCES

Images 1-3, Teemu Luhtapuro

Image 4, Pixologic.b 2005, [referenced 22nd March 2014] available at:

http://docs.pixologic.com/

Image 5, Teemu Luhtapuro

Image 6, Ahearn, L.2009.a.*3D Game Textures.* Second edition.Focal Press [referenced 22nd March 2014]

Image 7, Ahearn, L.2009.b.*3D Game Textures.* Second edition.Focal Press [referenced 22nd March 2014]

Images 8-14, Teemu Luhtapuro

Image 15, Quixel 2014 [referenced 2nd March 2014] available at:

http://dev.quixel.se/sites/default/files/imagesndo/ndobig3.jpg

Image 16, Teemu Luhtapuro

Image 17, Allegorthmic 2014 [referenced 2nd March 2014] available at:

http://www.allegorithmic.com/sites/default/files/styles/page-elements-large/public/page-elements/images/Outputs_0.jpg?itok=xkvJ4T1q

Images 18-23, Teemu Luhtapuro