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ABSTRACT

Author	Year of publication
Jonathan Cremieux	2011

Department	Degree programme
Department of Media - Media Lab	New Media

Title
Fulldome content production: A bricoleur's approach

Type of work	Language	Number of pages
Master Thesis	English	78

Abstract

It has been only a little more than ten years since the introduction in planetaria of digital projection systems that can fill the entire dome of the theater. This technology called fulldome video has considerably changed the experience delivered by these institutions as it brings the immersive power of wide field displays and the possibility of interactive shows to astronomy education. Today, many established venues have upgraded their traditional system and many others are about to follow the trend.

This technology facilitates content creation because it allows to make use of the digital tools already available to more conventional digital audiovisual productions such as 3D animation. Therefore fulldome also opens new vistas for artistic expression beyond traditional astronomy and science themed content. As the new medium redefines the experience delivered by dome theaters, it also challenges the identity of these venues. By looking at the technical and cultural aspect of this transition through the media theory of remediation, this thesis identifies areas of tension between tradition and innovation as well as challenges and opportunities for new productions.

Complementing this research, a design enquiry on new means of productions inspired by the do-it-yourself methodolgy and defined as design as bricolage is explored. The result is a specification for an open source fulldome production pipeline and an implementation using existing software and custom built tools. The metaphor of bricolage is evaluated as a practical mental model for the activity of design, and provides insights on the practice of design itself.

In a synthesis of the theoritical and practical research results, a strategy based on the notion of property rights as distribution (open source) is proposed to promote new alternative fulldome productions. Problems and affordances of this model in the context of fulldome are discussed on the basis of previous implementations in software development and 3d animation production,and including thoughts and comments from members of the fulldome industry.

Keywords
bricolage, do-it-yourself, fulldome, open source, planetarium, remediation

Acknowledgements

I am grateful to the people working at **Heureka**. Without their enthusiasm I would probably not have encountered the fulldome medium in the first place. I would especially like to thank the manager of the Vattenfall Planetarium **Kai Santavuori** for his time and letting me use the mini-dome.

It is a pleasure to thank my supervisor **Markku Reunanen** for keeping me focused and introducing me to new concepts. His advices and help all along the process have played a major role in this thesis.

I would like to show my gratitude to the members of the Yahoo! Fulldome forum and the good people of the dome theater community for taking the time to answer my questions and sharing their thoughts and experiences. In particular, I would like to thank **Joyce Towne**, **Hue Walker**, **Tom Casey**, **Mario Di Maggio**, **Jack Dunn**, **Jason Fletcher**, **Ed Lantz**, **Ken Miller**, **Ron Proctor**, **Rob Spearman** and **Ryan Wyatt**.

I am also grateful to **Paul Bourke** for his precious feedback on my software.

I am truly indebted to the faculty and staff of Media Lab Helsinki for their support in diverse forms, and especially the head of studies of the master program in New Media Design **Rasmus Vuori**, producer **Pipsa Asiala**, facilities manager **Ilpo Kari** and laboratory technician **Heikki Tuononen**.

Finally, a big "Thank You!" to all my fellow students that read early versions of this thesis and gave me feedback, inspired me or simply provided moral support. This project would not have been the same without **Ramyah Gowrishankar**, **Ben Dromey**, **Lauri Kainulainen**, **Niko Knappe**, **Samy Kramer**, **Martti Mela**, **Gokce Taskan** and **Sanna Vilmusenaho**.

Table of contents

List of figures

List of tables

1 Introduction

A couple of years ago, sitting with other students in the Vattenfall planetarium at the Heureka science center near Helsinki, I was about to be blown away. Like in a regular cinema theater the light got slowly dimmed down, announcing the show was about to start. However, this was not a conventional screening. To begin with, in this venue the spectator faces a screen which is the 17 meters of diameter dome of the building. There is no frame, your entire vision is filled by the projection. That's not all as what we were about to watch was not the regular program of astronomy themed presentation the planetarium propose to its visitors. When the light went down, instead of the usual solar system on a star field background, a high definition animation of what can be best described as a dynamic light tiling started to cover the ceiling to finally shatter in a multitude of pieces floating in space. Then we followed some abstract geometrical shapes evolving in a three dimensional universe, taking sharp turns, rotating, accelerating and slowing down like an airplane to the rhythm of an electronic music soundtrack. The experience was not only auditive and visual, sometimes you could actually feel yourself moving although you were really just sitting on regular theater chairs.

This private screening organized by the Heureka planetarium for the students of Medialab Helsinki is the experience through which I discovered the immersive medium and why I considered this subject for my master's diploma final work. I had seen shows at a planetarium in Paris some fifteen years ago, but the only vague memories I have from then is the starry sky and the dome shaped theater. Time has passed, digital technology has evolved rapidly and nowadays more and more planetaria are equipped with digital video projection systems that can fill the entire hemisphere of their dome. Accordingly, this technology is called *fulldome*. Fulldome opens up all sort of possibilities as a planetarium can now show any type of digital content with only one projection system. With powerful computers coupled with state of the art graphics processing units, even realtime interactive 3D shows are possible.

What makes a fulldome show so special is the all encompassing projection. In a cinema theater, the screen is always there, and while one can get mesmerized by the film and forget about it for a while, it does not take much for the frame to become noticeable again, creating a clear boundary between fiction and reality. When the screen does not have a frame anymore, strange things happen. In this situation, without the need for any special goggles or a head mounted display, a well crafted image can make us truly believe it is not a curved flat surface in front of us but a genuine three dimensional world. Even non realistic animations can make our body feel as if it is moving, this illusion might go so far as to cause physical discomfort in some spectators. This capacity to involve the senses as if transported in a virtual universe is called immersion.

Traditionally, the dome has been particularly suited to teach astronomy as its shaped screen provides a direct metaphor for how we experience the sky from the surface of the Earth. Since humanity has been to space, the Earth bound perspective is not enough to present the latest discoveries of astronomy. Scientifically correct models used in conjunction with fulldome video allows to take the audience to space where they can experience scale, distances and time from a new perspective. While certainly an amazing tool for education, this is not what got me excited in the first place. Rather, my experience at Heureka made me imagine the artistic possibilities of being able to remove a layer of mediation between the public and the art work. Fulldome is a powerful medium because it literally puts the spectator in the center of the action.

Perhaps an appropriate metaphor would be to imagine conventional video projection as looking at fishes swimming in a large aquarium. You can see the creatures swimming from one glass wall of the tank to the other, getting closer or farther away from you only in a certain direction, and they cannot swim above you, as they are constrained like the images on a screen. Imagine now that this aquarium has a glass tunnel built inside that takes you to the center of the tank. You are now surrounded by water (except for the tunnel) and a school of fish comes towards you, getting around the tunnel. You can see the multitude of creatures swimming everywhere, as if they were actually dodging you. This is what a fulldome show feels like. How to use or even misuse its qualities to convey all sorts of emotions and messages was the original question I wanted to research. I wanted to first understand how the system works on a technical level and how to incorporate different media, then I intended to experiment by creating animations that would play on the illusion of motion and space.

1.1 What is Fulldome: Technical Fundamentals

In order to make the rest of this text understandable, it is first necessary to present the technology that is at the core of the discussion, starting with the theater that uses it. A dome theater is a room with a hemispherical or dome shaped ceiling. Venues differ in terms of size, the seating arrangement and by how much the dome is tilted. Sizes of dome vary from about 4 meters to more than 25 meters in diameters, with seating capacities for tens to hundreds of spectators. Traditionally, planetaria have been designed so that the dome is horizontal and the seats are arranged in a concentric fashion (Figure 1 a). This seating layout optimizes the use of the space and is suitable if there is no preferred direction of projection. This traditional design is probably also taking into account the need for early opto-mechanical star projectors to stay in the center of the structure to be able to project on the entire surface of the dome. However, it does not offer the best comfort for the viewer because one has to look up during most of the show, which puts strain on the neck. In some venues, this configuration has been improved by building a gradual slope from the center to the edge of the

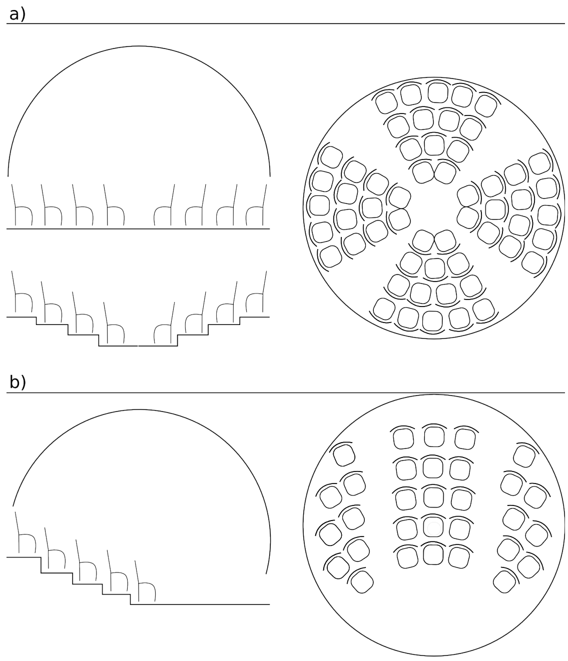

Figure 1: Seating configurations

auditorium, raising seats as their distance to the center increase and thus improving the visibility of the spectators.

When there is a preferred direction of projection, which can be useful when using additional projectors and surround sound for instance, the seats are laid out in a horseshoe or hemicycle (Figure 1 b). In some theaters the rows of seats are also stepped to improve visibility. Additionally, some designs add a tilt to the dome, usually between 10° and 30°. This configuration increases the seating capacity as higher rows of seats can be added. Many large venues and new dome theaters follow this design. The inconsistency between the tilt of the domes can raise some issues as a show designed for a horizontal dome might be perceived rather differently in a tilted dome, especially when there is some sort of horizon like the sea in Figure 2. In the horizontal dome (top) the scene will be consistent with our experience of the sea, but in a dome tilted by 15° (bottom) it will look like the sea itself is tilted, which looks rather odd.

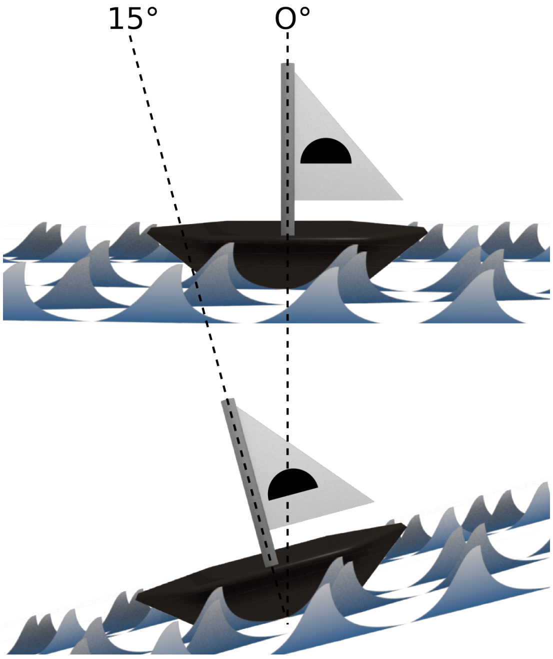

Figure 2: Inconsistency between dome tilts

The projection system itself is composed of one or more digital projectors connected to a digital source, usually one or many computers. In a one projector setup, the device is equipped with a lens system that combines a macro objective and a wide angle, usually 180°, fisheye. The macro is used to focus the beam of light of the projector so that it can be scattered on the entire surface of the dome by the fisheye. This configuration requires the projector to be at the center of the theater and is only effective for small to medium size domes. Another solution using one projector uses no extra lens but a spherical mirror that reflects and scatters the light on the dome (Bourke, 2005). Multi-projectors setups split frames into fragments which are re-assembled seamlessly at projection. This configuration can cover a larger dome and allows the center of the theater to be freed for the public. More costly, it is usually found in the larger science centers and other big venues.

While the label fulldome covers diverse projection setups, it also defines a frame format known as the *dome master*. This format, in the process of being standardized, defines a sets of characteristic show producers can follow to create content (Imersa, 2011). At the core of the format is the definition of the geometry of the frame and how the image is mapped to the dome when projected (Figure 3). The dome master format defines a conventional orientation where the bottom and the right edge of the frame respectively correspond to the front and right in a unidirectional theater setup. Only the pixels contained inside the inscribed circle of the square frame are projected. The part colored black can be filled with meta-data such as the timecode of the frame or the name of the show. The format specifies that the dome should be projected on the frame using an *equidistant azimuthal fisheye* projection (EAF). Projections are methods first used in naval and terrestrial navigation to represent objects in space on a plane (Snyder, 1993). In mathematical terms, projections are functions that take the 3 dimensional coordinates of a point in space and transform them into 2 dimensional coordinates on the plane. Conversely, the inverse of the same projection turns 2 dimensional coordinates into 3 dimensional ones. EAF does not actually describe one mapping function but a set of different projection functions that create results similar to those exhibited by photographs taken with a fisheye lens or the reflection of the surrounding on the sticker inside the cover of this document.

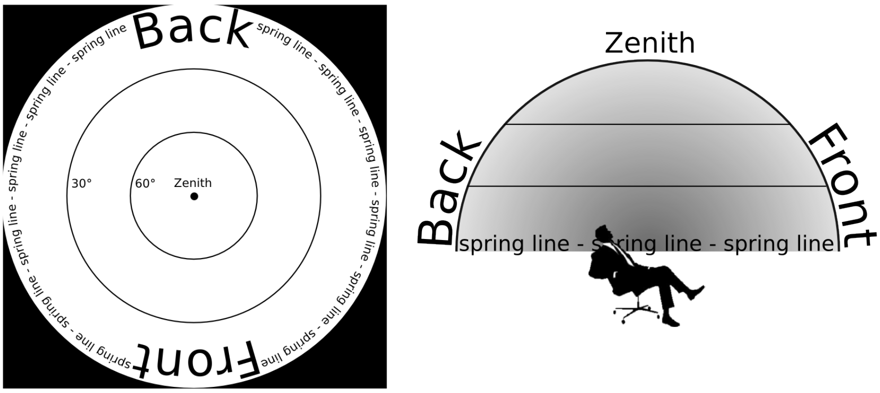

Figure 3: Dome master and dome mapping

A dome master is usually of a bigger dimension than a regular video frame. Square frames with edges of 4096 pixels are not uncommon, and newer systems accept frames of 8192^2 pixels. As a comparison 6 frames of the HD 1080 (1920 by 1080 pixels) video format could fit in a single frame of a 4096 by 4096 pixels dome master (Figure 4). This high definition is necessary to maintain a good visual quality all over the dome but also means that video processing is much more demanding and powerful computers and graphics processing units (GPU) are needed for smooth playback or realtime rendering, especially at higher frame rates such as 60 frames per seconds (fps).

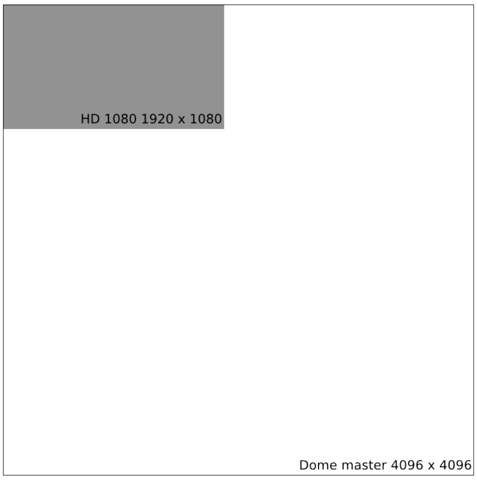

Figure 4: Comparing HD 1080 and dome master 4096

Dome masters allow the projection system and the theater configuration to be treated as a black box by content creators as it puts the responsibility on the operators of the venue to process shows in the dome master format to fit their system requirements. This is the only format accepted by festivals such as the Fulldome festival (Germany) or Domefest (U.S.A.). In the case of a single projector with a fisheye lens, the frame can be projected as is. When a spherical mirror is used, the frames first need to be deformed, or warped (Figure 5), to accommodate the surface of the mirror. This can be done at projection time using dedicated software running on the computer delivering the video source (Bourke, 2005).

Figure 5: A dome master wrapped for projection on a spherical mirror (Bourke, n.d.)

Multi-projectors settings require the dome master to be partitioned in overlapping pieces following certain patterns so it can be re-assembled seamlessly on the dome surface (Figure 6). Fragments are made to overlap because it is extremely difficult to get a pixel perfect match when using several projectors. Instead, by aligning the overlapping parts and applying the appropriate blending mask on the overlapping areas, pictured in darker grey, a seamless image is projected. The technique is invisible, especially on wide domes where the audience is far away from the wall. In addition to splitting the frames into fragments, multi-projectors systems distribute the pieces among several computers to optimize playback speed. The partitioning process is called *slicing* and, in the case of pre-rendered shows, usually done before projection as it can take a certain amount of time due to the dimensions of the frames.

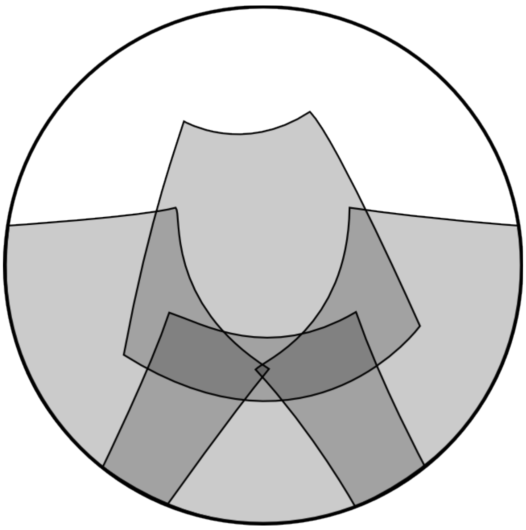

Figure 6: Dome master slicing pattern

1.2 Design as Bricolage

It has been my wish since the beginning of this project to apply a hands-on methodology, but I also wanted to take the opportunity to read and reflect about design, and try and integrate any insights I would get to my own practice. This interest to know more about the theoretical side of design thinking, initially came from an argument I had with an artist, who was and still is my partner on the project Mimodek which was exhibited in Prague in 2011. It started after an interview for the Czech television where I decided to present myself as a designer rather than an artist. My partner insisted that in this case I should not have presented myself as the designer of our piece but should have said I was an artist. While the matter is for all practical purposes rather trivial, it does however raise the classic question of what makes the difference between art and design, if there is at all a difference. At first, I though that it was a matter of purpose; the purpose of design being to perform and the purpose of art to evoke human experiences. The argument is problematic because performing is not a concept that is limiting enough, as one could say that an art piece performs well in the sense that it successfully conveys emotions to its audience. Furthermore, performance is not a criterion that forbids an extremely designed object such as a sports car to also be considered a piece of art by many.

The problem is that the choice of what is considered art is not left up to the creators of artifacts, but ultimately it is the user, in the broad sense of the term, that decides. However, it does matter to me how I approach the creation of artifact and consider the outcome of my work. Positioning my own practice and thus defining further my own intents is what helps me establish a small space of clarity and order in the otherwise complex and abstract environment of creative thinking. As I started working on this thesis, I realized that I needed some sort of conceptual framework in which I could organize my thoughts and direct my design research. It is by following practical considerations that I found a model of design as an activity that fits my need.

One of the aspect of fulldome production that seduced me is its relative complexity which, it seems, can only best overcome with state of the art equipment. Hence I thought it would be highly interesting to try and approach it with a do-it-yourself strategy instead. My hypothesis was that constraining the type of tools that I could use to only those that I could readily acquire or build, would force me to come up with original solutions. While searching for literature about the thinking process involved in this kind of method, I stumbled upon the work of the french anthropologist Claude Lévi-Strauss and his analogy of *bricolage* opposed to engineering to compare and discuss mythical concrete thinking and scientific abstract thinking. Bricolage is a french word which can be roughly translated to tinkering, although the english word is less rich in meaning. While bricolage also has a pejorative connotation in french — saying that a repair work on a car is " bricolage" for instance could mean that it was not a job well done — it can also describe a work that was elegantly accomplished by an ingenious usage of what was at hand. Therefore I will use the french term for the rest of the discussion as it is more appropriate.

Bricolage as it is discussed here is defined by four attributes (Hénaff, 1991, p. 155; Lévi-Strauss, 1962, pp. 16-22):

1. Bricolage solves punctual and incidental problems by using whatever artifacts are at hand at that moment. A piece of cardboard placed under the leg of a shaky table is a common act of bricolage. The bricoleur might also employ things that have been collected beforehand for their potential usefulness but without a particular purpose in mind.
2. Bricolage implies a relatively limited set of tools that are only specialized to a point that the bricoleur himself does not need the specific skills and knowledge of a trade. Tools that can be employed in multiple ways are preferred, thus it is not surprising that screwdrivers and knifes are popular tools among bricoleurs.
3. Because the bricoleur is not a craftsman *per se*, she does not possess skills in a specific trade and does not work following a coherent methodology. Since the approach is rather intuitive and usually relies on loose combinations of artifacts, it leads to results difficult to predict and even harder to reproduce.
4. As a science of the concrete, bricolage implies a close relationship with the material one works with. Indeed, the whole process can be thought of as a dialogue between the bricoleur and the elements she is working with. It is an iterative process of learning about the elements associations and their qualities by manipulation rather than deducing association and qualities from pre-conceived rules.

One can experience a rather literal example of this dialogue when playing a situation puzzle game. In this sort of riddle, a player describes a strange and often morbid situation such as: *"A man/woman jumps from the top of a building to commit suicide, but during his/her fall he/she hears a telephone ring which makes him/her instantly regret his/her last action…"*.

The other players must find the correct explanation behind it by asking questions that are only answered by "yes" or "no". The storyteller can also give additional clues by answering that the question is irrelevant. The solution can only be found by asking the right questions, which means evaluating many scenarios. At the beginning of the game, most players will ask various and unrelated questions about practical details. They are trying to compose a scene where they can picture the action and try to understand the context. Later when one realizes that this information is irrelevant, questions move to the psychology and life style of the character. Often at that point, a player will be able to start putting the pieces of the puzzle together and soon her questions will be much more precise and she will quickly find the solution.

This example of problem solving also serves as a good illustration to Panagiotis Louridas' (1999) usage of bricolage as a metaphor for the design activity. For him, "bricolage is the creation of structure out of events" (Louridas, 1999). Events are all the influences and constraints that are either part of the external environment or inside the bricoleur herself. Interestingly, this vision of design can be paralleled with Herbert A. Simon's (1996, p. 113) definition of the object of what he called the science of the artificial:

"The artificial world is centered precisely on this interface between the inner and outer environments; it is concerned with attaining goals by adapting the former to the latter.".

A bricoleur integrates parts of herself, such as her experience or beliefs, in the development of a solution simply because they play a role in the selection of elements and the choice of the manipulation methods. This aspect was called the "poetry of bricolage" by Lévi-Strauss (1962, p. 21) and can also be related to the notion of style as understood by Simon (1996, p. 130):

"What we ordinarily call "style" may stem just as much from these decision about the design process as from alternative emphases on the goals to be realized through the final design.".

When trying to solve the puzzle, the player must create a story from the little pieces of information he can obtain. The questions he chooses to ask and how he understands the answers in the story he is developing are influenced by his very personal experience and also implicates the way he relates to the world.

By working closely with the elements and engaging her idiosyncrasy, the bricoleur is very sensitive to unforeseen events and thus must deviate from her initial intentions in case she can not use or re-combine elements that are available to her. For Simon (1996, p. 124) this explains why design is not so much about assembling a solution but rather searching for assemblies that are appropriate. Hence, bricolage is driven by events that shape or structure how the elements are combined. If the story the player develops is invalidated by the answer to a question, he can modify its scenario to make it fit with the new piece of information if possible. If it is not possible, then he has to revise his story completely. For this reasons, Herbert A. Simon (1996, p. 124) advises that:

"it is often efficient … not to follow out one line until it succeeds completely or fails definitely but to begin to explore several tentative paths, continuing to pursue a few that look most promising at a given moment.".

How well the structure responds to contingencies determines the success of a bricolage. Poor bricolage is the development of a solution that has not been able to adapt to the environment; it is an incomplete explanation that only shed light on a part of the mystery and might not stand if more information is provided. Good bricolage does not need to provide the best solution as long as it fits well in its context, or *satisfice* (Simon, 1996, p. 119) the design problem. Often, when such a solution is created it will seem straightforward in retrospect, which is a sign of elegant bricolage.

While design as an activity can not be reduced to bricolage, Louridas (1999, p. 15) proposes that design is a kind of metaphorical bricolage, in the sense that the designer is engaged in a similar dialogue with diverse metaphorical representations of the object being designed rather than the object itself. Indeed, while nowadays designers work with simulations and other computer models, previous practitioners have employed sketches and prototypes that they used to manipulate and evolve a design. To avoid being vague, perhaps it would also be useful to try and precise what is meant by design since it is an ambiguous concept employed in numerous disciplines and diverse contexts. Yair Wand and Ralph Paul (2007) have conducted a review of the many definitions of design as a noun in the literature and after identifying similarities and areas of disagreements, they have formulated a definition of design (Figure 7) that is unambiguous and covers all the phenomena that are and have been called design but also excludes those that are not.

> "(noun) a **specification** of an **object**, manifested by an **agent**, intended to accomplish **goals**, in a particular **environment**, using a set of **primitive** components, satisfying a set of **requirements**, subject to **constraints**;
>
> (verb, transitive) to create a design, in an environment (where the designer operates)"

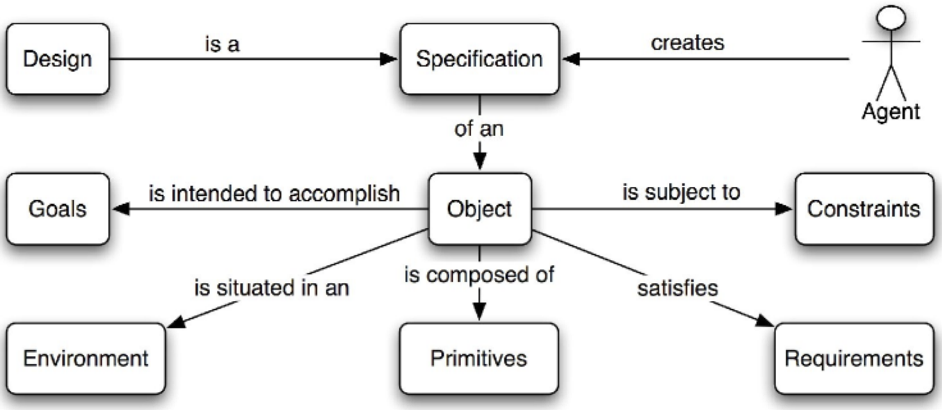

Figure 7: Conceptual Model of Design (as a noun) (Wand and Paul, 2007)

Thus, a design is not the object itself but its specification. In this definition the role of the designer is restrained to creating the specification but it does not exclude the possibility of extending her role to the implementation as well. Artifacts that are the results of accident or unintentional discoveries are excluded from the category of designed objects, because design implies intentionality in its production process. What to make of "Eureka!" moments and other serendipitous discoveries "by accidents and sagacity" (Boyle, 2005) that are inherent to a design process seen as bricolage? To dissipate the ambiguity, it is useful to look at the stories behind penicillin and sildenafil citrate, two discoveries that have had a great impact in the field of health and illustrate the difference between intention and accident.

Penicillin was first discovered by Alexander Fleming in the 1920s when he was attempting to create an internal antiseptic. To test the solutions he was developing, he was growing Staphylococcus cultures. One day he noticed that some of the bacteria had been destroyed by something that had contaminated the culture by accident and which he later identified as penicillin. What is interesting is that Alexander Fleming was actively looking for something like penicillin and thus it was possible for him to see this incident as meaningful in the context of his research. Hence, the use of penicillin in medicine is something that has been designed, not accidentally discovered. Another case of accidental discovery happened in the 1990s when sildenafil citrate, a drug that was developed to treat a form of angina, was clinically tested on men. The test revealed that the drug was inefficient at treating the angina, however it had the side effect of improving penile erection (Osterloh, 2007). The laboratory that had conducted the development then decided to abandon research on angina treatment and develop the drug as a treatment for erectile dysfunction and finally released it under the commercial name Viagra. In this scenario, although there was the intent of developing a drug, the discovery had very little to do with the original goals. While the marketing strategy that oriented development on a new target was intentional, the initial drug itself is the product of an accident.

1.3 Structure of this Thesis

The previous sections have laid out a general context for this thesis, where its main subject is the fulldome video medium — which was also briefly introduced — and where the driving method to the design activity is bricolage. I stated that my original intent was to approach the medium through the creation of experimental animations. However, as I started researching the medium in more depth and particularly when it was suggested to me that I could get some insights from remediation, a theory of the evolution of media, I realized that there was an opportunity to empirically verify some of its propositions. The following chapter gives a brief introduction of the theory of remediation and looks for evidence that support it in the fulldome medium. Three aspects of the medium have been explored and are presented in the following order:

1. The history of the medium since the creation of its ancestor the panorama painting more than a century ago (section 2.1).
2. The differences of discourse in online advertisement between venues with a traditional system and theaters with a fulldome system (section 2.2).
3. How recent productions have used the medium and what can be learned from them (section 2.3).

More than contributing empirical evidences to remediation, this study enabled me to identify opportunities for design but also discover constraints and requirements while providing valuable background information that helped me all through the thesis.

Since the beginning of this project, I have conducted concrete experimentations in fulldome content production. The third chapter presents the work that I have done and an evaluation of the process using bricolage as a model to gain insights on my practice (section 3.1). Inspired by practice based design research proposed by Alain Findeli (1998), I discuss and develop the metaphor of bricolage itself from the perspective of my hands-on exploration. Following this initial search phase, I have designed a fulldome production pipeline based on a specific technique called cube map rendering, and I propose an implementation solely using open source solutions which includes an original software called CubeAnimator (section 3.2 and appendix D). Finally, to limit the scope of this thesis, I have decided to focused my research only of the visual aspect of the medium. Interactivity, which is only partly covered by discussing visuals, and sound in particular are the other important aspect of fulldome that should not be forgotten.

In an effort to synthesize what I have learned from researching fulldome as a technical object but most importantly as a medium reach of cultural meaning, I attempt to foresee what it could become. Because my own interest is in the development of creative content, and since it seems that the question is relevant in this period of transition from analogue to digital, in an effort to promote the genre I propose that alternative fulldome productions should be tried out following the model of open source projects (section 4.1). To extend my proposition to the community involved with the medium and further a critical discussion that I have already initiated (appendix C), I detail more concretely how such a project could be implemented by referring to similar initiatives in software development and 3d animation production.

2 Fulldome: a Hybrid

In the book *Remediation: Understanding New Media*, J. Bolter and R. Grusin invite readers to consider the evolution and history of media as an interplay between the logics and strategies of immediacy and hypermediacy. *Immediacy* is a desire for a completely transparent medium, which ultimately leaves the viewers only in presence of the content, so it can be felt as real. It is a strategy to create an immersive experience, a feeling of presence or authenticity. Transparent immediacy is what proponents of virtual reality hope the technology will one day deliver. The logic of *Hypermediacy*, on the other hand, makes the viewer aware of the existence of one or more underlying media that support the information and seems to come from a fascination for mediated experiences. Here it is understood that the experience of the representation provided by a medium, may it be of reality or imaginary, is in itself enthralling. Hypermediacy by re-enforcing the presence of the medium in its multiplicity and fragmentation of representations, is particularly well illustrated by the computer desktop interface and its multiple windows that can simultaneously show text, image, and video. (Bolter and Grusin, 2000)

While at first glance transparency and hypermediacy might look like opposing logics, in reality they can coexist because their meaning change depending on the point of view. For instance, the selling argument of stereoscopic three dimensional films is to offer the audience a much more immersive experience than traditional cinema. However watching such a film now requires to wear special glasses, which adds another layer of mediation and in a way makes the medium less transparent. Thus, hypermediacy can be the result of attempting immediacy. Likewise, an hypermediated experience such as a VJ act — a video analogy to the night club disk jockey (DJ); the visual jockey performs live manipulation of video, often in synchronicity with music — with its combination of music usually played loud and engaging moving images can nonetheless create an authentic experience.

The theory of remediation acknowledges Marshall McLuhan's (1964, p. 8) idea that "the 'content' of a medium is always another medium" and goes further by making it a "defining characteristic of the new digital media" (Bolter and Grusin, 2000, p. 45). In this respect, a new medium can not transcend the old and create new means of expression but must repurpose or refashion one or more media. The relationships and rivalry between media is at the heart of the remediation theory as it implies that modern media can only be defined by comparison with other media (Bolter and Grusin, 2000, p. 66). A new medium remediates other media not only by technical improvement (e.g. color versus black and white cinema), but it can also cause change in social or political practices (e.g. the role of social media during the protest of 2011 in Tunisia and Egypt (Delany, 2011)). Furthermore, Bolter and Grusin (2000, p. 66) note that the proponents of a new medium claim that it provides a more authentic experience than previous media, and by doing so they also contribute to a redefinition of what society considers real.

However, remediation does not agree with McLuhan's view of a society that changes and progresses under the impulse of technology. On one hand, the theory argues that technology, or at least modern technology, live inside a hybrid network of science, culture and society as defined by Bruno Latour (1993) in *We Have Never Been Modern*, and thus technological determinism alone is not possible. On the other hand and for the same reason, it also denies that technology is entirely determined by society, but rather that social pressure shapes technology and that in its redefinition of authenticity technology affects society (Bolter and Grusin, 2000; Turkle, 2011).

As the following sections will show, the fulldome medium is a particularly good candidate to be examined under the lens of remediation. To begin with, its genealogy of remediation can be tracked back to the end of the 19th century which allows to layout its technical and social components and frame the medium in the context of the present work. Secondly, by looking at the advertisement rhetoric of fulldome theaters and current fulldome productions, it is possible not only to see how remediation happens in this context but also to have an insight on what might be the social impact of this new medium. Finally, fulldome clearly exhibits the struggle between immediacy and hypermediacy which explains its development and give directions towards areas that new productions could explore.

2.1 Short Story of Wide Field Displays

The hybrid nature of fulldome is best expressed by its filiation to two main distinctive families of media which are wide field projections and planetaria. Wide field projection here refers to any system that uses unconventionally large screen to display content. In order to clearly layout the genealogy and show that this union is not a coincidence, but rather a logical step in respect to the history behind the development of the two parents media, the two branches of the family tree will be presented separately.

2.1.1 From Panorama Paintings to IMAX

The oldest distinctive ancestors of fulldome are probably the panorama paintings of the 19th century. The nowadays familiar term *panorama*, from Greek "pan" (all) and "horama" (vision), was coined by the painter Robert Barker (1739 – 1806) for his patent of 1787. Panoramas were large scale landscape paintings depicting 360° views which were exhibited around the inner walls of a cylindrical construction called a rotunda (Figure 8). The building was designed so that visitors would look at the landscape from the middle of the gallery, a position from where they would experience the illusion of 'being there'. This feeling was enhanced by taking special care in hiding the bottom and the top of the painting, and in some cases by building a contextual theater set between the spectators and the painted walls.

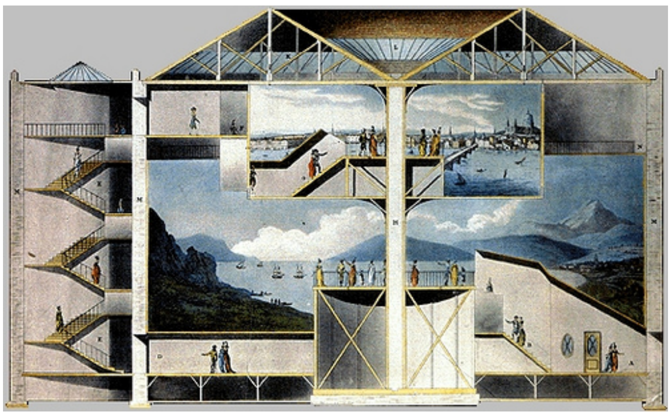

Figure 8: Panorama rotunda (Mitchell, 1801)

Even light inside the rotunda was designed to participate in the illusion. The biggest difficulty was to manipulate perspectives to adapt sketches made on flat surfaces to the curved inner wall of the rotunda. At first, the subjects of Panoramas were the cities they were exhibited in, later war scenes became popular and finally what would be called nowadays touristic vistas of landmarks and far away lands. (Comment, 2003)

From a technical angle, while panorama evolved from landscape painting, it can also be seen as an evolution of the linear perspective technique and the related trompe l'oeil drawing developed since the Renaissance. Indeed, understanding linear perspective was a necessity to work with the notion of point of view which is paramount in panorama painting, and it is by manipulating the rules that the illusion of a 360° view could be created. Not surprisingly panorama painters, or panoramists, like other painters of this period using perspective in their work would use the camera obscura and later photography to draw accurately.

However, panorama was not so much a technical achievement than an evidence of a change in the relation of the European society to aesthetic and culture that happened at that period. This medium prefigured photography and film in its automatic treatment of its subject. Unlike traditional landscape painting, where the painters would more often than not transform the nature they depicted for artistic and aesthetic reasons by applying specific compositional rules, panorama had a more technically objective approach (Comment, 2003, p. 86). The intent of the Panorama was obviously immediacy through transparency, both for the artists and the audience. Indeed the medium claimed the viewer inside the rotunda would experience the same sight if she would actually stand at the same place where the panoramist made his sketches (Comment, 2003, p. 84). By combining the use of tools such as the camera obscura and all the information that could be gathered about the terrain, a panorama was constructing an illusion of the physical world, which qualified more as a reproduction than as an original work of art, since the process narrowed the artist point of view to the selection of an adequate vantage point. Because of this, the medium encountered the same criticism about its automatic nature that photography would face some years later (Bolter and Grusin, 2000, p. 25; Comment, 2003, p. 86).

Furthermore, the Panorama was a mass medium, with a hundred million spectators from 1870 to the beginning of the 20th century (Oettermann, 1997, cited in Comment, 2003), and as such was opposing the status of painting as an elitist art form. This fact, the critics about its soulless nature and probably the rivalry between panoramists and other painters due to the financial success of the medium, led its detractor to deny it the title of art work but merely acknowledge a well executed illusion. One can see here the opposition between the old and the new at a cultural level that the theory of remediation calls a redefinition of authenticity.

The fulldome medium is in lots of ways a recipient of the legacy of the panorama. To begin with it shares many similarities, from the desire to a transparent, immersive experience, to the predominance of one point of view and the circular shape of the buildings that house both media. Fulldome also solves some of the limitations of its ancestor by enabling the presentation of dynamic scenes with sound. Of course since the 19th century so much has changed in every aspects of life that it would be fruitless to try and compare the two in terms of content. However, fulldome and panorama express a same taste for engrossing illusions. The rest of this section outlines the technical evolution that bridged panorama to the planetarium and made fulldome what it is.

The panorama and all the other 'oramas' spin-offs that it contributed to create became obsolete and out of fashion with the maturation of photographic processes* and the invention and development of cinema at the end of the 19th and beginning of the 20th century. However, very early attempts were made to bring together panorama and cinema. The *Cinéorama*, presented at the Exposition Universelle, was a setup of ten film projectors and ten nine by nine meters screens arranged to form a circle around a viewing platform. The material projected was the ascension of a hot air balloon over Paris from the point of view of its passengers, shot by ten cameras rigged together in a circle. The ride was accompanied by an actor playing the role of the captain of the balloon and giving information about what the spectators were witnessing, much like the presenter of a planetarium show. Technical difficulties, and notably the intense heat generated by the ten projectors, prevented the Cinéorama from becoming a success. (MacGowan, 1957)

Filmmakers also experimented with other types of wide field displays. French director and producer Abel Gance (1889 – 1981) designed *Polyvision*, a process created to film and project his silent film *Napoléon vu par Abel Gance* (1927). The director wanted his oeuvre to captivate the viewers like they never had been before. He wanted to deliver an experience that would transform the passive spectator into a psychologically active actor involved in the drama. To this end, Gance felt that he needed an expanded field of view in order to grab the audience into the film. However, with traditional techniques this meant that the action would need to be shot from further away, thus only allowing a distant point of view. Abel Gance came up with a solution involving several cameras each recording a fraction of the wide field of view. He had it implemented by André Debrie's company who created a system made of 3 independently pivotable cameras stacked vertically on a common axis to record a wide view of the scene while staying close enough to its action. Additionally, the cameras could be synchronized by an electric motor. To display the recorded images, 3 projectors, also synchronized by an electric motor, would simultaneously project three reels of film on 3 projection screens laid out in a strip for an aspect ratio of 4:1. (Meusy, 2000)

While editing the film, and in a certain contradiction to his own ideal, Gance also discovered that by composing this triptych on the basis of contrasting or simultaneous actions or even symmetry and division, the setup opened up interesting narrative possibilities by avoiding the predominance of the singular point of view of the panorama and pre-figured stylistic editing techniques such as the "split-screen". In regards to remediation, originally the Polyvision triptych was motivated by a desire for transparent immediacy, but because of the fascination for the medium itself it turned out to be also an outlet of hypermediacy. The effect of Polyvision when Napoléon was revealed to the public was a nearly unanimous critical success (Meusy, 2000, p. 11-14). Even if technically it was not perfect — they were apparent seems between screens — spectators were already acknowledging the expressive power of expansive and dynamic compositions.

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* Daguerre, co-inventor of the first commercial photographic process was also the inventor of the Diorama.

Like the Cinéorama, the Polyvision suffered from technical difficulties related to the projectors and took many years and several re-incarnations to become a reliable mature system. *Cinerama* (U.S.A., 1952), a very similar system using three synchronized 35mm projectors, is probably the most successful descendant of Gance's Polyvision. It was designed to project films shot from a special camera made of 3 objectives pointing at different directions and sharing the same shutter, in effect recording a field of view of 146° horizontally and 55° vertically. The screen was made of thin slides of perforated reflective material arranged side by side to subtend the 146° of arc. The perforations were intended to prevent light reflecting back to the screen and washing out the image, an issue that is common to every curved wide field projection systems. The Cinerama camera, due to its wide angle and 3 cameras setup, introduced deformation phenomena and apparent overlapping between the three images. Inside the "sweet-spot" – an area of the theater where the distortions are kept to a minimum – the spectator could enjoy a nearly undistorted wide picture, but the further away she was seated from this area, the worse the distortion. Furthermore, the process added technical difficulties during shootings: as each camera effectively recorded a different perspective, parallax would introduce difference in direction and movement in the three fields of view which would cause actors to appear to look to different direction than they did in reality. (American Widescreen Museum, 2010)

In the context of the technological competition during the Cold War, it seems that a "Wide Projection Race" was going on between the U.S.A. and the U.S.S.R.. For example, engineers behind the Iron Curtain created the *Kinopanorama*, another 3 lenses, 3 reels, 3 projectors system. At the same period, two systems improved the Cinéorama by building upon the technological development in cameras and projectors to show films on a 360° display. The Walt Disney company launched its *Circarama* or *Circle-vision* in 1955 (9 cameras, 9 projectors), while the public of the U.S.S.R. could watch *Krugovaya* or *Circular Kinopanorama* in 1959 (11 cameras, 11 projectors). In this story, technology did not do much to shape society — wide field projection was certainly not something that could redefine the world like the atomic bomb — however it was important for both sides for their propaganda, by showing their supremacy in the all around technological race. Where the Polyvision was intended as a stylistic cinematographic technique, the Cinerama and its Cold War descendants were the message, the content only playing a second role. Thus, society was shaping the development of the medium to be constrained to technical sophistication. As such, those inventions did not really redefine cinema. They did provide a new way of recording and displaying films, but in failing to develop an artistic language of its own, the wide screen cinema of this period was a gimmick similar to today's stereoscopic 3D.

Among other technical difficulties and costs induced by multi-camera/multi-projectors setup, the biggest issue for the viewer were the appearing seams when the images overlapped. The first IMAX system was developed in the 1960's and contrasted with its predecessor in the combination of only one camera with a larger film stock and only one powerful projector that could nevertheless cover a field large enough to fill the spectator's field of view. To date, the IMAX system has been a commercial success with many venues all over the world. The single projector design makes it much more practical to convert smaller size films, and the use of a specialized camera is not a necessity, making a much larger collection of productions available for screening. (IMAX Corporation, 2011)

But IMAX is not only the outcome of half a century of development in wide field projection system. It is also a link between wide field display and the planetarium world that would later give form to the fulldome medium. In 1973, a variation of the IMAX system using a fisheye lens on the projector was created for the Reuben H. Fleet Space Theatre in San Diego, U.S.A.. The IMAX Dome system, previously called OMNIMAX, project a field of view of 180° horizontally, 100° above the horizon and 22° below the horizon for a viewer at the center of the dome (IMAX Corporation, 2011).

2.1.2 The Modern Planetarium

The first implementations were probably paintings on ceilings of monuments like the tomb of ancient Egyptian architect Senenmut and then later the creation of globes that would depict on their surface the position of constellations. With the antiquity came a better understanding of mechanical science and engineering and of the movements of celestial objects which lead to the creation of smaller, more elaborate devices called orreries. Orreries typically simulated an heliocentric view of the solar system, the Sun assuming the center place and the planets represented as small globes orbiting around it using a clockwork mechanism. Until the creation of the Zeiss Mark I planetarium projection system (Figure 9) in the 1920s, further developments kept the same approach, scaling up to large theaters with an hemispheric ceiling and using large, complicated mechanical components to move objects around the sky dome. (Chartrand, 1973)

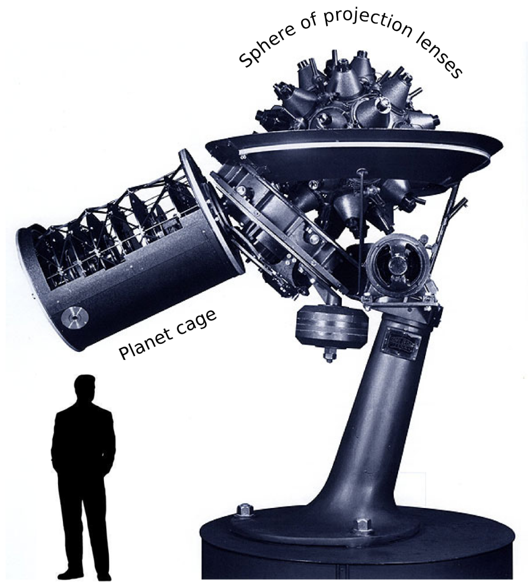

Figure 9: Zeiss Mark I, first opto-mechanical planetarium projection system

The Zeiss Mark I opened the era of the modern planetarium (Figure 10). The system was the first to combine in one huge apparatus a projection system and a scientifically accurate simulation of the motion of celestial objects. While the Second World War limited further development and dissemination of the technology, Germany and the products of the Carl Zeiss company were dominating the planetarium market.

After the second world war, motivated by the Space Race of the 1950s and the 1960s and determined to popularize planetarium theaters by creating more affordable systems than the costly Zeiss, the U.S.A. entered the planetarium industry and market. It is in this context that the American Armand Spitz developed the small and affordable Model A in the late 1940s. Japan joined the industry two decades later through the companies Goto and Minolta, the former successfully marketing smaller models. (Petersen, 2003)

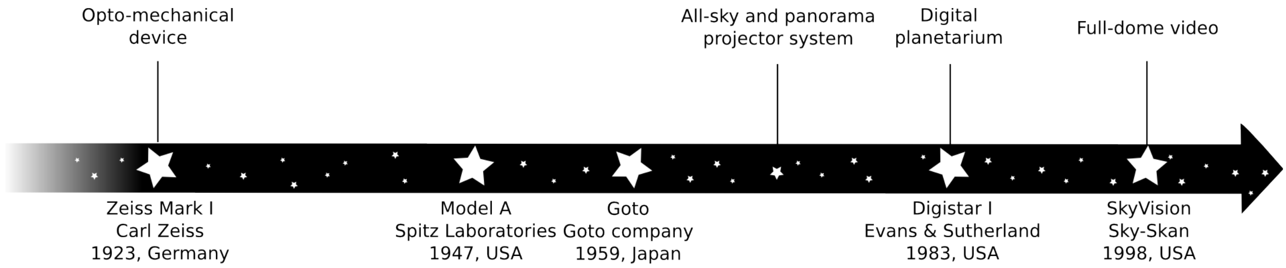

Figure 10: The modern era of the planetarium

While the previous developers of the planetarium had clearly transparent immediacy in mind, that is to say the experience delivered was to be scientifically equal to watching the night sky, cinema which was also developing at the same time influenced a current of hypermediacy in the planetarium world. Until the beginning of the 1980s, the development effort on planetarium focused on providing a richer multimedia experience by including additional projections systems to display photographic panoramas, films (e.g. OmniMax system), and new features such as laser shows, sound systems and the creation of special effect projectors to show comets and auroras for instance. This period also witnessed a growth in the number of planetaria worldwide. (Petersen, 2003)

Perhaps this period also marks the first encounter between the planetarium and pure art and entertainment. Indeed, in may 1957 at the Morrison Planetarium of the California Academy of Science, the musician Henry Jacobs and the painter and experimental filmmaker Jordan Belson (1926–2011) performed the first of a series of about a hundred "electronic music concerts illuminated by various visual effects" called *Vortex Concerts*. A Vortex Concert was a blend of music by avant-garde electronic music artists and original light composition created by Belson. He combined projected interference-patterns with projected films and used special effects projectors of the planetarium to create a cosmic abstract imagery that was to become characteristic of his filmic work. (Youngblood, 1970, pp. 388-391)

In 1983, a new technical innovation came to challenge the existing solutions as the American computer graphics company Evans & Sutherland* presented the first ever digital planetarium projection instrument. The Digistar I consisted of a computer storing information about stars which were rendered by a graphic processor and displayed through a fisheye lens fitted on a high intensity cathode-ray tube. Contrary to its predecessors where optical components were the most expensive parts, the cost of this system laid mainly in the computer unit. The relatively low brightness of the projection compared to previous generation of instruments prevented it to become a commercial success but opened the doors of the planetarium to the computer. While computers and graphic processors became more and more powerful and cheap, other

* In 2006 Evans & Sutherland bought the Spitz Inc. Company, becoming the biggest supplier of planetarium equipment.

companies like Sky-Skan and GOTO took the digital road and worked on improving the projection system which resulted some years later in what is now called “Fulldome video”,and installed in a planetarium by Sky-Skan for the first time in 1998.

While the history of the planetarium in the last century share common traits with the media of the previous sub section (e.g. specialized venues, development accelerated during the Cold War, overlapping technologies) it is however very different in its purpose as an astronomy education tool and its very specific format. On one hand, this link to the scientific world and the need for interactivity explains how easily the computer has found its way under the dome, not only as part of the projection equipment but also as a tool to actively assist the transmission of knowledge and, by extension, the creation of content. This differences also gives some clues as to why the fulldome medium is more focused on the traditional logic and interpretation of transparent immediacy than other digital media. On the other hand, the particularity of its projection surface and the configuration of the theater are an obstacle to simple and affordable conversion of other digital video content. Culturally, and using the metaphor of the evolution of species, the medium is a sort of island; relatively isolated from mainstream film and animation productions, it has developed quite uniquely.

Indeed, it is only recently that the medium has crossed over to include pure entertainment content, but it is still shyly doing so. The Vortex Concerts of the end of the 1950s are in a way a freak episode of this relationship — the right time, the right place, the right persons, “It was such an absurdly perfect situation” were the words of Jacobs — and ended on the decision of the direction of the planetarium (Youngblood, 1970, pp. 388–391). Fifty years later, festivals presenting the latest fulldome production include a good part of alternative content, however these shows are rarely seen outside those special events. While many educators and planetarium owners have shown enthusiasm for the new medium, there is also a tendency to think of it as a threat to the model of the planetarium as an educational institution above all. This anxiety reveals that remediation is taking place and authenticity is being challenged. To acknowledge this ambiguous moment, I will use the ambiguous term dome theater for any venues which host a dome projection system and planetarium only for those venues that are part of a museum or assimilated institution.

2.2 Dome Theater Advertisement

Since the creation of the first planetarium in Jena, the mission of this institution has always been education and more precisely the dissemination of knowledge about astronomy. Arguably, if the planetarium stands out as a cultural institution it is because of its unique dome shaped theater and the modern and unique equipment it houses. With the popularization of fulldome systems, traditional planetaria are lagging behind in terms of technology and it is not surprising that many of them are getting there equipment upgraded (Bruno, 2010). It seems probable that in a close future, virtually all planetaria will be equipped with such a system. This transformation is accelerated by innovations and the general reduction of cost in electronic equipment. For instance, in 2003 Paul Bourke (2005), associate professor at the University of Western Australia, conceived a dome projection system especially for small to medium domes that uses only a regular projector and a spherical mirror.

This change is not happening in a situation of total consensus. In 2005, the International Planetarium Society (IPS) published two special issues in of its journal *The Planetarian* on the topic of "Digital Domes and the Future of Planetariums". Through a series of 8 selected articles the reader gets a panorama of the opportunities and issues of the new technology from the point of view of education, astronomy visualisation, technology and storytelling (The Planetarian, volume 34, September - December 2005). These articles reveals that a majority of dome theaters operators are favorable to the adoption of the fulldome system, but they also highlight two main concerns. To begin with, some planetariums managers are still weighing the usefulness of the new medium as an educational tool against the cost of upgrading their installations. In this case, the main argument among others in favor of fulldome comes from studies that suggest that a 3D immersive environment enhance the transmission of knowledge, and can also help people visualise astronomical phenomenon better than star projectors because it allows to present multiple perspectives (Yu, 2005). The second concern is about what will be the type of content available, and ultimately the experience delivered by dome theaters in the future (Matthews, 2005). Most articles echo the previous argument and underline the opportunity for education, and especially for real-time interactive shows that create unique experiences. However, they also acknowledge that some dome theaters are not only focused on astronomy anymore, and some others are not even focused on education at all (e.g. The Tholos theater at the Foundation of the Hellenic World, Greece). Thus, some planetarian worry that committing to the new medium will change their culture more than they want to.

In order to grasp what changes are taking place, one needs a way to compare the old and the new, the traditional and the modern. The previous section dealt mainly with technological change, which is a rather well documented phenomenon, but discussing cultural changes in the context of the Fulldome medium requires a less straightforward approach. One can get some indications on how the medium reshapes the image of the dome theater by looking at how those institutions present themselves online though their websites. The rational behind this strategy is that by comparing theaters housing a traditional system to those equipped with a Fulldome system on the basis of their publicity, similarities and divergences would indicate where the changes are happening as the new technology redefines what is considered important.

Content analysis is a research technique that allows the researcher to gain an understanding of a particular phenomenon by looking at a body of text, analyzing how the message is delivered and making inference on the author's goals or what is the intended effect on the audience. As a research methodology, it supposes that the analysis operates within a well defined context of investigation and its results be replicable (Krippendorff, 2004). In this case, the analysis is driven by a lack of qualitative data on the cultural and social impact of the fulldome medium on dome theaters. It seems reasonable to think that a broader understanding of the phenomenon is needed to make hypothesis on what the medium could become.

2.2.1 Compiling Online Advertisement Texts

The analysis has been performed on a collection of text extracted from the official websites of dome theaters from all over the world. A list of venues with links to their websites and additional data, the Dome Theater Compendium*, can be obtained online and has served as the main resource for locating websites and acquiring samples. A total of 52 websites of different venues in 22 countries have been visited, and the advertisement text specific to the dome theater extracted, and in some case translated to english using Google Translate. In an effort to produce a representative collection of texts, the selection of a venue to be included in the collection has been guided by 3 criteria:

- The type of projection system in use and special features of the theater
- The diameter of its dome
- The country of the theater

It should also be noted that the choice has been constrained by the availability of texts for certain criterion. Furthermore, although half of the dome theaters are located in the U.S.A., it was decided not to reproduce this reality in the samples collection to limit the weight of a unique culture on the analysis. These constraints and decision have slightly biased the sampling process. However, for the purpose of this analysis it is felt that the samples are representative of the state of affair of dome theaters.Table 2, Error: Reference source not found, and Table 3 show how the samples are distributed according to the criteria defined above. Note that a dome theater can fall in more than one category (e.g. a portable dome with a fulldome projector).

Europe	21	North America	14	Asia	10
Bulgaria	1	Canada	3	China	2
Finland	2	Mexico	1	India	4
France	3	United Stated	10	Japan	2
Germany	2			Qatar	1
Greece	1			South Korea	1
Hungary	1				
Ireland	1				
Italy	1				
Portugal	1				
Romania	1				
Spain	1				
United Kingdom	6				
South America	**4**	**Africa**	**1**	**Australia**	**2**
Argentina	1	Egypt	1		
Brazil	1				

Table 1: Samples distribution by countries

Non-fulldome	Fulldome	Portable	Stereo 3D
17	38	3	2

Table 2: Samples distribution by theater categories

* http://www.lochnessproductions.com/lpc/lpc.html

Diameter unknown	From 4.0 to 9.9 m	From 10.0 tot 14.9 m
1	15	9
From 15.0 to 19.9 m	**From 20.0 to 25m**	**Above 25 m**
15	11	1

Table 3: Samples distribution by dome diameters

Along with each text samples, their respective sources and the URL where they have been found and the date the site was last visited has been recorded. In order to format the information in a way that is at the same time easily decoded by a computer program and easy for a human to read, it has been decided to code data using the JavaScript Object Notation (JSON). In accordance to the JSON specifications*, the records are saved in a UTF-8 encoded text file. One record looks like this:

```
{
"name":        "Vattenfall Planetarium",
"size":        17.5,
"country":     "Finland",
"website":     "http://www.heureka.fi/portal/englanti/planetarium/",
"lastvisit":   "18/07/2011",
"type":        "fulldome",
"text": "Heureka’s Vattenfall Planetarium is one of the most modern digital
planetariums in Europe. The shows are mainly animated planetarium films
based on newest technology, and the theatre has been fully renovated."
}
```

In some cases some minor modifications have been made to the original text because some reserved characters like **"** must be escaped, that is preceded by the **** character, or removed in order for the text to be parsed properly. Since this information is of little value for the analysis it has been decided to simply remove any occurrence of the characters in question. A text file containing the entire collection of samples is available in appendix D.

2.2.2 A Simple Word Counting Software

Already through the act of collecting the texts, one gets a good sense of the trends and patterns in the discourse. The most striking discovery was that it was actually difficult to find dome theaters which did not have a fulldome system, and among these many were temporarily closed because they were getting a new digital system installed. Regarding the thematic of the advertisement texts, a reference to astronomy is almost always present, not surprisingly, but the texts also usually mention something about the technical aspect of the theater, either stressing out the modernity in case of a fulldome theaters, or its historical and cultural interest in the case of domes housing an old opto-mechanical stars projector. In order to verify some of those observations and to get a sense of the importance of each subjects in dome theater advertisement, a computer assisted text analysis was carried out.

* http://www.json.org/

To analyze the body of text in a systematic way, the selected strategy was to go through every words in each samples, counting the number of samples where the same word or group of words occurs, one sample being counted only once even if the words was repeated several times in the text. To limit the amount of noise — common words such as *the*, *or*, *a*, *it is* — only words or group of words present in at least 2 samples would be considered. For the purpose of comparing fulldome and non-fulldome theaters, it was decided that it should be possible to specifically analyze sub-collection of samples based on the 3 selection criteria (country, dome diameter, category). A program was written in Java to extract the required information (see appendix D). It is designed to be run from a command line console and outputs results in the form of lists of words with the corresponding number of occurrences for the selected sub-collection. It enabled me to make queries such as "*Considering only theaters equipped with fulldome systems and which domes diameter are between 15 and 20 meters, what are the groups of 4 successive words that occur in more than one text?*", which can be translated into command line argument like this:

```
-t fulldome -m 15 -M 20 -w 4
```

Which would result in the following output:

```
======== { 4 words, fulldome, size range: [15.0;20.0] } ========
the art digital projection  = 2
of the art digital  = 2
the planetarium has a  = 2
is one of the  = 2
planetarium is one of  = 2
a seating capacity of  = 2
the wonder of the  = 2
motion of the planet  = 2
has a seating capacity  = 2
state of the art  = 3
```

Additionally it can be used to extract some statistical information about the collection itself, or to check that the JSON file is correctly formatted. On its own this program does not give much information on the context in which words or groups of words are used, but this can easily be checked using a text editor with a search function. Most importantly, it is only a tool to count words and does not perform any content analysis *per se*.

2.2.3 Word Count Analysis

In the following section, main themes will be written in bold characters while quote from text samples will be written between quotes and in italic. The analysis started by looking at the whole collection and what expressions (groups of 4 consecutive words) were commonly used. It appeared that most of the content of the texts revolved around 5 main themes. As expected a majority of texts refers to **Astronomy**, the *"night sky"* and the *"wonders of the universe"*. **Technology and Innovation** seemed to be the second dominating theme, expressions such as *"state of the art"* being often used, however when looking at non-fulldome samples alone, the subject was not addressed as much. Additionally it was found that **Education**, the **Experience** delivered by the show and the specific **Architecture** of the theater – the word *"dome"* being present in a majority of the texts - were common themes. This early analysis gave some credit to the initial observations and already seemed to indicate that there was indeed a difference between the discourse of fulldome theaters and traditional venues. A closer look was needed in order to confirm those findings.

By counting single words and reducing the sample group to only fulldome revealed a more defined set of thematics popular in advertising the dome theaters. It was found that the two dominating themes were indeed **Technology** and **Astronomy**, then **Architecture**, followed by **Education** and the **Experience** delivered by the theater. Furthermore, it seemed that the subject of **Immersion and Interactivity** had a certain importance as well. By sorting words into these themes and calculating a score based on the number of words per themes and the number of occurrence of those words (see Appendix A for an example), a clear picture of how each themes relate to each others in terms of importance was created as shown in Figure 11. The same process was carried out targeting only texts from non-fulldome theaters. The picture presented in Figure 12 is sensibly different.

Figure 11: Main themes and their importances in fulldome theaters online advertisement

Figure 12: Main themes and their importances in non-fulldome theaters online advertisement

In these visualizations, the size of the letters for each theme and its vertical position represent its importance relative to other themes in online advertisement. A shift in the importance of the **Technology** is clearly apparent here. This phenomenon has to be understood as traditional theaters being focused solely on **Astronomy** and not so much as fulldome theaters being only about **Technology and Innovation**. Figure 11 shows that **Astronomy** is still a major theme, but it competes with **Technology** as the main selling argument of fulldome theaters. What those pictures do not show is the difference between the meaning of **Experience** for each cases. For non-fulldome theaters, **Experience** is linked with **Education**, it is about being taken away into a realistic reproduction of the night sky and learning about the objects that populate the Universe. This could also explains why samples of this category are more descriptive about their **Audience**, stressing out that they are educational tools that can benefit not only children but anybody with an interest in astronomy. This holds true for fulldome theater, however there the **Experience** is enhanced by the **Technology**. Under this light, **Immersion and Interactivity** can be seen as the added value that **Technology** gives to the dome theater experience. Not only does the theater display space and its wonders accurately, but it also offers a more engaging experience for the senses.

2.2.4 Interpretation and Consequences

The results of the text analysis conducted is consistent with the first observations but also show where the new medium is challenging its predecessor. Clearly this simple analysis is incomplete as it only takes into account a fraction of the existing theaters, and in particular it undermines the influence of small and portable domes which might host up to 40% of the visitors of the world's dome theaters (Fluke and Bourke, 2005). However, the results tend to be confirmed by the reality depicted by members of the dome theater community themselves, hence these results must carry some truth and can be interpreted in the light of the discussion surrounding the technology.

Fulldome theaters claim their modernity, and as a marketing strategy it seems logical to stress out the uniqueness and novelty of the technology. The fact that fulldome theaters also put emphasis on the particularity of their architecture could indicate a will to re-establish themselves as landmarks. They also seem to give more and more importance to the experience they can deliver to their audience. Altogether, it appears that the new technology is reforming dome theaters by prompting them to embrace new values and position themselves as technological and sensory spaces. Even if this result is to be interpreted carefully, it is particularly interesting that Figure 11 puts **Technology** above **Astronomy** in this picture. As we have seen, fulldome enhances the immediacy and transparency of the medium; where a huge machine used to occupy the center of the room, now the projectors are hidden from the audience's gaze. It is precisely this fundamentally transparent technology that fulldome theaters are putting forward in their presentations, quenching the thirst of the public for the experience of mediation. If one considers the interests of the industry in the development of interactive fulldome shows, it is possible that the traditional immediacy of the planetarium may have to compete with the hypermediacy associated with the digital technology.

While many are upgrading to fulldome, other traditional dome theaters seem to exhibit a greater commitment to their cultural mission which is astronomy education. It appears they are following a different logic and target a certain community of amateur astronomers. Furthermore, the increase in the number of portable dome, bringing astronomy education to a larger public and to places that did not have access to it before should be taken into account as a mark of change in how astronomy education is disseminated. For those mobile theaters fulldome has a different. The new medium affords easier transportation, more dynamic and customizable presentation. Their resolution is bound to the capability of one projector and thus is much smaller than multi-projector domes. On the one hand the visual quality is less, but on the other hand a recent laptop computer can easily handle the format which might facilitate and even encourage experimentation.

In the way it advertises itself through technology and its unique configuration, the fulldome medium probably replicates the strategy used by planetaria of the beginning of the modern era. However, fulldome theaters operate in a context where virtual reality is becoming more tangible and where spectators are familiar with digital technologies and have higher expectations. Modern dome theaters now capitalize on the immersive quality of a wide field display, bringing it forward as an added value in the competition with other digital media for an authentic experience.

Following this content analysis, I have later been discussing online my results with some members of the fulldome industry (appendix C). It has been interesting to see how the effects of remediation is actually perceived by the people that work with the medium. The reality seems to confirm the findings that the redefinition of the identity of the planetarium is at stake. Some explains the traditionalist tendency as being a consequence of years of marketing to establish the institution as a provider of astronomy and science education; others have already embraced the new technology and are open to experimentations. It is clear that nobody is left unaffected by the technology. This state of affairs shows through recent fulldome productions.

2.3 Modern Content

The previous sections introduced the fulldome medium first from a technological and historical point of view and secondly as a vector of change in the identity of dome theaters. However, what the spectator can see in these theaters has not really been discussed yet, and as one would expect this new technology also has an impact on how shows are produced and on the nature of their content. Before fulldome, the first dome theater show producers were the vendors of projection system like Evans & Sutherland or Sky-Skan. Their primary motivation was to expand the catalog of titles so that their products would sell better. Some planetaria with the necessary financial capacity also contributed titles to the medium, first to have something unique to show their visitors and then to distribute to other venues. Production companies independent of a planetarium or a vendor were virtually inexistent[*]. As the cost of the computers is decreasing while the processing power increases and since the fulldome is becoming widespread, more and more planetaria are becoming producers. The production model also as evolved as productions are now also done as partnership between planetarium, digital content producers and fulldome system vendors, which allows for the creation of more ambitious projects (Bruno, 2010). In the last decade, independent companies have been created and propose services such as the creation of 3D content, photography and live action capture for the fulldome system (e.g. Antares Fulldome Production, Dome3D, Home Run Pictures, Softmachine). Outside these structures, punctual and often experimental productions but also commissioned works are realized by artists, students and academics.

To this day astronomy and science education shows account for the majority of the titles in the catalogues of the principal distributors of fulldome shows Evans & Sutherland and Sky-Skan. The former only proposing 7 titles classified as entertainment out of 97, while the later lists only 9 of them out of their 88 shows. This is not surprising as most dome theaters are part of science centers or museums and compose the core of the clientele as well as the majority of show producers. Moreover, the medium has received interest from the scientific community as a tool to visualize all sorts of theoretical and natural static and dynamic structures and phenomenon, not only at the scale of planets and stars but also at the atomic level. However, fulldome has also been a fecund environment for the seeds planted by the Vortex Concerts of the 1950s (see

* Loch Ness Productions, a well known and active independent company started operating already in 1977.

subsection 2.1.2) and is becoming an outlet for artistic experimentation. Much like modern film productions, shows are becoming mixture of the above genres, blending stylistic techniques, subject and conventions to create an original experience (Gant, 2009). Finally, the latest interest of the industry is in real-time and interactive shows or performances involving the audience even deeply. This aspect however does not concern exclusively the fulldome medium and forms a large and multi-disciplinary field that combines, but is not limited to, Virtual Reality, Interactive Cinema, Video Games and VJaying. To stay within the scope of the present work, interactivity in the context of fulldome will not be detailed.

To give an overview of these modern shows, representative works have been selected from the programs of planetaria and from dedicated festivals such as the Fulldome Festival (Germany, 2006–2011) and DomeFest (U.S.A., 2004–2009) who showcase the latest productions from all over the world. These works will be described and discussed relatively to their use of the medium, what trend they represent and what they tell us about show production. Since the genre of astronomy education represent the majority of what is produced for the medium it seems reasonable to discuss it first. Data visualisations and simulations are explored next because they share with astronomy shows the common intent of dissemination of scientific knowledge. Finally, modern shows that have more artistic claims will be discussed on the base of their contribution to remediation and how they deal with immediacy and hypermediacy.

The rational behind the method employed to understand these shows is related to film analysis and presented in appendix B. Additionally, and before the shows can be actually discussed, it is necessary to introduce a framework for discussing composition of visual elements in the dome space. An interesting and relevant approach was suggested by Ben Shedd, an IMAX filmmaker, during a talk during Dome Lab 2010, a fulldome production workshop held in Australia in 2010 (ANAT, 2010). The filmmaker proposes that fulldome composition should be considered through the dynamics of relationships between centric and eccentric systems as described by Rudolf Arnheim (1988) in his book about composition in the visual arts *The power of the center*.

2.3.1 Dynamics of the Centers in Fulldome Composition

Arnheim's thesis is grounded in the idea that humans perceive the world first in an ego-centric way, that is by picturing it as being centered around them. He calls this self-centered perspective *centricity*. However, through interaction with the world, the individual recognizes that she is one among other centers that she must acknowledge, especially as part of a society, but also to a certain extent repel to keep her integrity. Arnheim refer to this second model as *eccentricity*, which should be here understood from its technical definition of not being placed in the center. Hence, the relation between humans and the world is necessarily a combinations of the centric and eccentric tendencies.

> *"Neither total self-centeredness nor total surrender to outer powers can make for an acceptable image of human motivation."*
> *(Arnheim, 1988, p. 3)*

Furthermore, centricity and eccentricity are not only mental relations but also spatial ones that can be depicted visually. Centricity evoke the circle and the attraction towards a center in an orbit, while eccentricity can be visualized as being out of a circle, attracted by several scattered forces. Arnheim proposes that since their dynamic interactions are the base of human motivations, and art being the representation of these motivations, the force of centricity and eccentricity must be apparent in works of art.

"since the psychological relations that art is called upon to depict are motivational strivings, their images, too, must display the action of directed forces." (Arnheim, 1988, p. 3)

However, it seems that there is a contradiction between the static nature of a painting or a sculpture and the dynamic forces of centricity and eccentricity. While this might seem less of an issue with moving images, the answer to this problem is still relevant to the study of composition in this context as it relates directly to motion of objects and point of view. Arnheim writes that a static view of an art work is only useful when it comes to understanding the structure or order upon which the work is constructed (Arnheim, 1988, p. 3), which relates to what as been defined as "seeing in" and "seeing as" (appendix B). It follows that if one wants to understand what human experiences are being expressed through this structure, shapes must be given a dynamic dimension. Indeed, as a cognitive process visual perception does not deal with static information but with configurations of forces and therefore one must not consider static elements such as shapes as compositional structures but rather look for vectors that represent forces emanating from a center and, if in presence of others center, aimed at targets (Arnheim, 1988, pp. 3-4).

In practice then a composition can be analyzed by identifying centers and trying to understand how they interact through vectors of attraction or repulsion. In this regard, two ends of a spectrum of compositional systems can be considered. On the one hand there is the centric system where all forces radiate from a primary center that dominates other secondary centers. On the other hand, in an eccentric system there is no such primary center and all centers influence and are influenced by the other centers. Figure 13 shows diagrams of vectors and centers for these two systems (fig. 13, **a** and **b**, after Arnheim), as well as examples taken from nature (fig. 13, **c** and **d**). On the left, the pure eccentric system can be interpreted as forces from outside interacting with each others, much like the ones that shaped the Giant's Causeway of Northern Ireland which are cracks caused by contraction in rapidly cooling lava in contact with water (fig. 13, **c**). On the right, the pure centric system is shown with its primary center which radiates forces in every directions, a configuration that is visible in the pattern resulting from the process of seeds emerging from the center and pushing each others towards the edges on the head of a sun flower (fig. 13, **d**). As it is made apparent in the examples, each systems are supported by specific structures, concentric circles for the former and network of lines, or grid, for the latter (Figure 14 **a** and **b**, after Arnheim). In practice, both systems are mixed in different ratio in a composition. City plans for instance have clearly defined hubs such as New Delhi's Connaught Place (fig. 14 **d**) which act as centers of radiating forces towards and from neighborhoods that are often themselves structured in an eccentric fashion like Helsinki's Punavuori (fig. 14 **c**) next to the principal hub of the city that is the central railway station. (Arnheim, 1988, pp. 4-12)

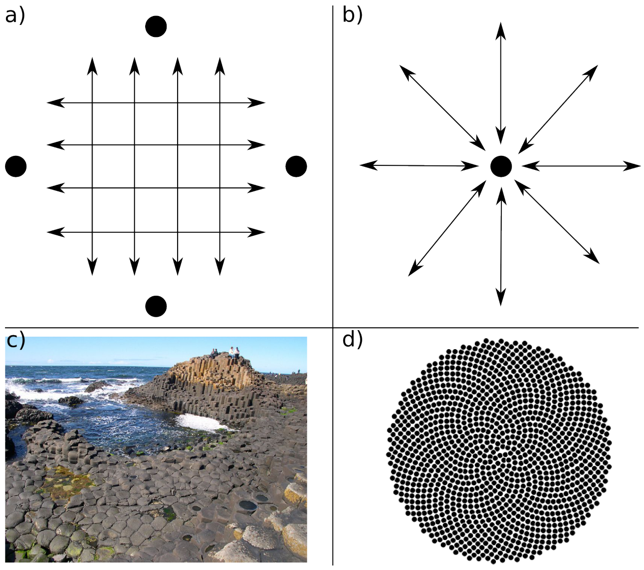

Figure 13: Eccentric and centric vectors of forces

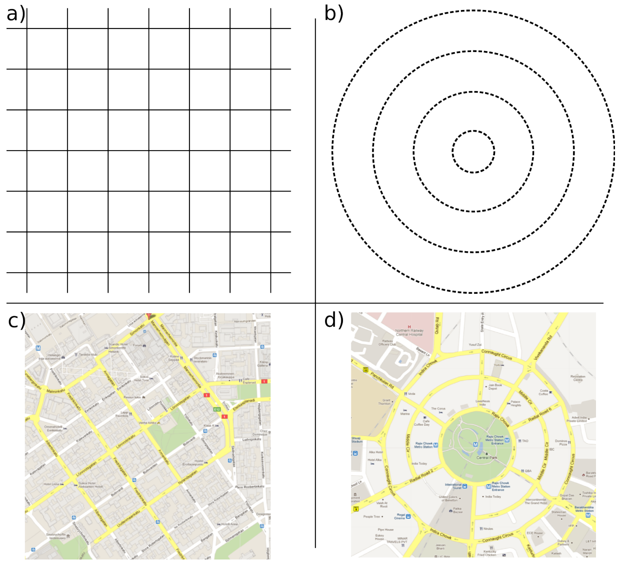

Figure 14: Eccentric and centric structures

In the case of fulldome the prevailing system is centric, since the situation is similar to the one created by any dome found in other buildings. However the primary focus of the centric forces might not necessarily be situated at the pole of the hemisphere. To begin with, many fulldome theaters have tilted dome and their seating arrangement introduce a preferred viewing direction (see section 1.1), and since there is a natural tendency for the spectator's gaze to rest in front of him rather than looking sharply up or down, which is less comfortable, the primary center, also called the *sweet spot* in fulldome terminology, is a certain area situated on the portion of the dome that face the spectator (the lower part on a dome master) somewhere midway between the top of the dome and its edge. In any art work the viewer herself is an important source of eccentric force, thus the sweet spot is actually the target of vectors from the viewer challenging the center of the architecture as the dynamic center of the composition. Hence, the sweet spot like the center of a regular frame will confer a particular weight in terms of composition to any object placed there (Arnheim, 1988, p. 46). Indeed, as is apparent in the dome masters of the next section, most fulldome works organize their composition around this area. The existence of a sweet spot not only reveals the presence of an eccentric system alongside the predominant centricity, but also an imbalance between the front and the rear of the dome. As it will be shown in the following sections, this area of the dome (the upper part on a dome master) is often lacking elements.

Another much more obvious unbalanced and vertical eccentric force should also be acknowledge. This force is not inherent to the fulldome medium but rather a consequence of living in a world under the influence of gravity which pulls us toward the center of the earth. The seating arrangement and the tilt of the dome create a back and a front, likewise gravity creates a up and a down. This situation makes us perceive what is happening horizontally differently from what is happening verticality. In regards to composition, objects which are shown in the top area will have more visual weight than similar one in the lower part. (Arnheim, 1988, pp. 15-18)

They are other factors besides these that influence how and why things are shown in a particular way in a fulldome video. Because of the curvature of the screen, light projected on one area will reflect on other part of the screen. While it is customary to use perforated tiles of reflective material to build the inside of a dome precisely to reduce this problem, fulldome projection is still sensitive to large bright areas which will bleach out the rest of the picture. This explains why so many shows exhibit a rather dark palette of colours and a solid black background is often used. Furthermore, while the spectator's field of view (Table 4) is entirely filled by the image, which often extends beyond, it should be noted that due to the distribution of photoreceptor cells on the retina only the foveal vision — a small part of about 1° to 2° at the center of the field of view — is capable of seeing small details (Goldstein, 1989). Outside this area, our perception of shapes and color becomes less and less accurate as light hit the edges of our retinas. This is of course something important to consider when showing text or numbers. To some extent the immersive power of the medium comes from the ability for the viewer to look around, it is expected that the audience can track moving objects and thus there is a risk that details outside the spectator's field of view will go unnoticed. For this reason, motion paths should be arranged so that the spectator does not miss important elements. In practice, most shows simply keep the action around the sweet spot, while some adopt the opposite strategy and have the action happening all over the dome, even behind the spectator.

	Horizontal FOV	Vertical FOV
Monocular	~150°	~120° to ~135°
Binocular	~120°	~120° to ~135°
Combined	~180°	~120° to ~135°

Table 4: Human vision average field of view (Hezel and Veron, 1993; Kalawsky, 1993)

2.3.2 Astronomy and Education

Produced by the Melbourne Planetarium (Scienceworks Museum, Museum Victoria, Australia, 2007), *Black Holes: Journey into the Unknown* introduce the astronomical phenomenon known as a black hole and explains what it is, how it was discovered and what questions remain to be answered. The images are completed by a narration by the actor Geoffrey Rush (“The King's Speech”) and a soundtrack of music dominated by a string instrument, probably a violin, and sound effects. The subject of the show and the information it conveys makes it a typical astronomy and education program. However, its creative use of mixed media and of the three dimensional space are representative of the modern fulldome shows (Figure 15).

Still **a** shows a very common treatment of astronomical objects. Here it is a representation of a black hole that is rendered and animated as a 3D object in front of a star field. For the spectator it feels as if the object is laying out its spirals in front of her, an effect which is reinforced by placing the black hole on the sweet spot. Still **b**, **c** and **d** are interesting as they show 2 strategies of structuring information on the wide screen. Still **b** shows how the dome master is partitioned in a 2D grid, creating multiple windows or frames. This particular pattern gives the impression of being in some sort of cage, and while the top of the dome play the role of the primary center, the strong eccentric system acts as a counter balance and avoid that any particular window dominates the others. The presentation in stills **c** and **d** also fragment the space but they also make use of another dimension. While this fragmentation creates a structure that can be navigated in space, it retains a mostly centric composition around the sweet spot such that the important information can be easily identified by the viewer while retaining a good amount of dynamism.

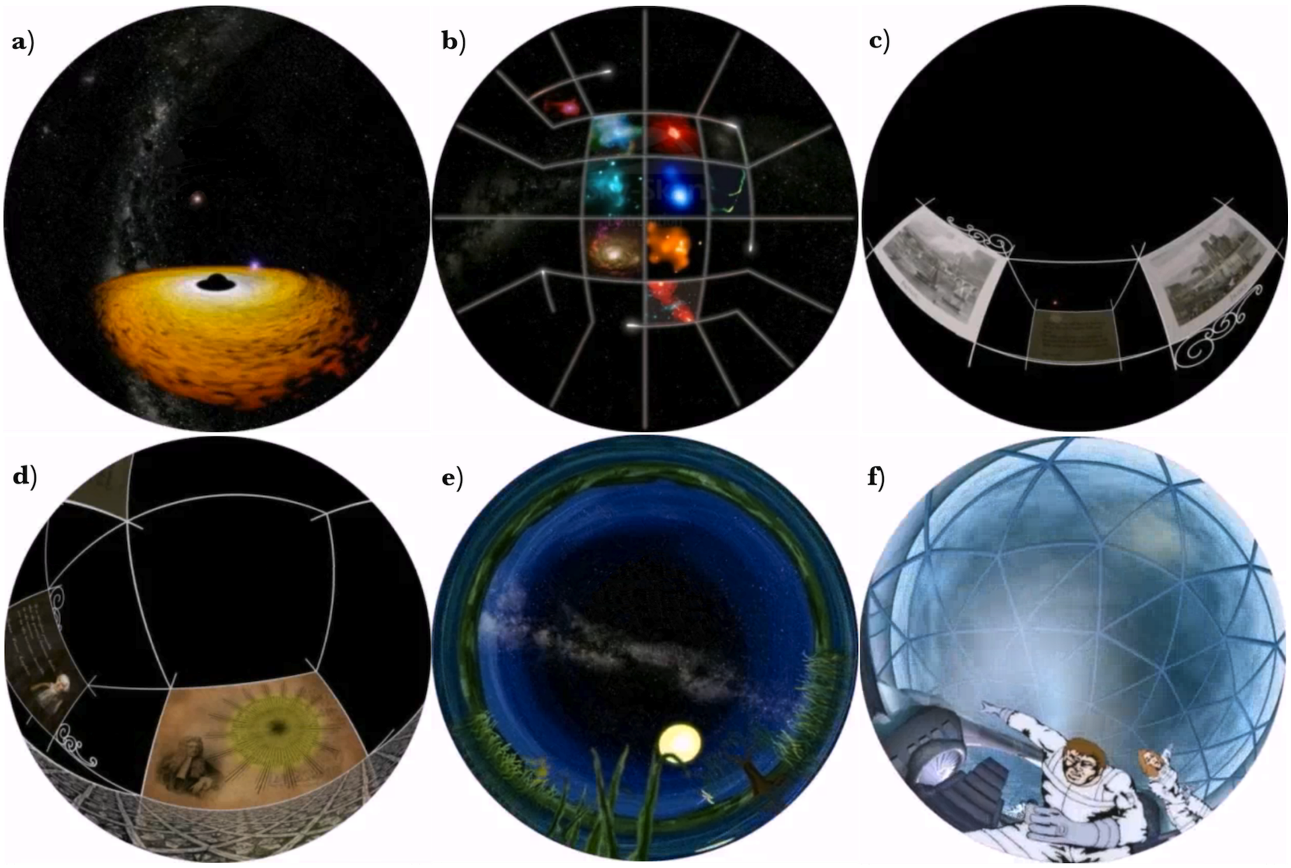

Figure 15: Still frames from Black Holes: Journey into the Unknown

Still **e** and **f** contrast with the others in their graphical style. These differences can be explained in reference to the narrative context. During the two sequences from which the stills were extracted, the narrator uses metaphors, respectively an analogy of a dragonfly nymph leaving forever the aquatic world when it turns into a dragonfly and a science fiction novel (Gateway by Frederik Pohl) to illustrate the explanations. Still **e** represents a panorama of a pond with dragonflies flying around. It is 3D computer graphics and the modeling, texturing and lighting are fairly simple, even naive. This type of landscape panorama – often used to show scene at the surface of a planet – are easily identified because they create differently colored rings around a mostly uniform center circle that represents the sky. This particular frame also tells us that the show was created for a horizontal dome because the circles of the panorama and the circle of the dome master are concentric. Important details, here the moon and the dragonfly, are kept around the sweet spot, but since the composition is nearly purely centric the spectator can easily be tempted to look around. Still **f** has a comic book feel to it, with 2 "cut-out" figurines of astronauts placed in a spaceship settings rendered in 3D. We can notice that the interior of the spaceship is not leveled but rolled to the right, this is also noticeable in the posture of the two figures. This suggest that the ship is being rocked around by the strong gravity pull of the black hole. The all around projection makes this effect almost physical as the visual system of the spectator register this as motion.

Black Holes exhibits a typical use of the medium in educational shows about astronomy. The visual composition is kept very clear, and most of the time the primary center conform to the sweet spot. Immersion and simulated motion are used sensibly to give a physical dimension to the presentation without going over the top and risking to induce simulator sickness in the spectator. Regarding the use of computer graphics and particularly 3D animation, it is not only present in visualisation of astronomical objects but also support the explanation with rather simple or cartoonish models that are still convincing and most importantly fits the narrative. In terms of marketing, this commercial show uses the strategy of commercial films by employing a celebrity to narrate the story. This is usually the mark of well financed production such at the shows *Journey to the Stars* (2009) narrated by the actress Whoopi Goldberg and *SonicVision* (2003) which sound track was mixed by the musician Moby.

2.3.3 Data Visualisation and Simulation

Thanks to the large screen estate available, fulldome is well suited to visualize rich sets of data. The traditional astronomy shows are themselves visualisations of planets systems and other cosmic phenomena. However, numerous shows now visualise all kind of subjects, may they be natural phenomena or abstract mathematical constructs. Furthermore, the medium and its immersive property add a new dimension to simulations of all sorts. As a result, the field of simulation is popular among fulldome shows and is even a ground for artistic experimentation. Figure 16 displays still frames captured from representative animations of this genre.

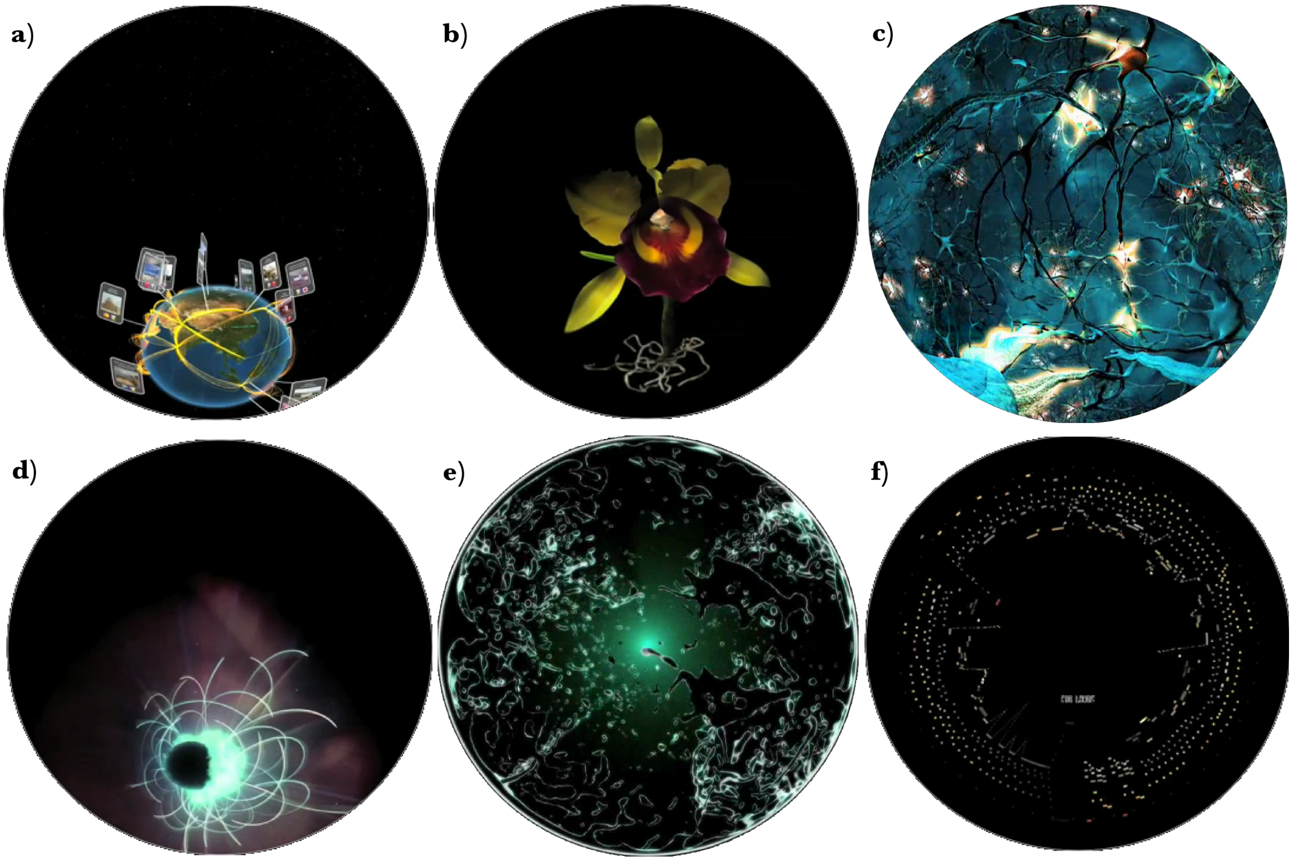

Figure 16: Examples of data visualizations and simulation

Still **a** from *Astronomer 2.0* (NSC Creative, 2009) illustrates a common technique which involves augmenting a 3D model of a planet or some other object with additional information. In this particular case the picture is augmented with places of interests on Earth, pinned down with flag-like labels which bear additional data, and what seems to be geodesics[*] between these places. The space available allows for multiple facets of the data to be presented at the same time.

Fulldome is also good at showing large things in their totality, which is interesting when examining structures. Still **b**, extracted from *Orchids - Plant construction* (Tilt Productions, 2009), shows a model of an orchid. One has to imagine that when projected the image is spread on several square meters, which in term of scales means that the audience is looking at the plant from a point of view closer to the ant than the human. It is possible to explore the model from many angles, while keeping the entire object in the frame. It is also possible to get closer, focus on one element, the flower for instance, and animate parts. The usage of a black background not only avoid washing out the image, but also helps intensify the illusion that the model is floating in front of the spectators.

Many fulldome shows contain some sort of simulations, usually based on scientifically accurate information like the orbits of the planets, or abstract and imaginative like the liquid flow simulation and the light play of still **e** from *Liquid/Light/Flow* (R. Helmchen, Softspace, 2008). Still **c**, *Neurons* (R. Jones, P. Greasley, 2008), takes the viewer for a ride inside a network of neurons. The representation is fairly accurate, it shows how the neurons communicate by electrical impulses and how groups of neurons are connected

* The shortest path from one point to another on the globe.

through the dendrites and the long axons. Similarly, still **d** from *Astronomer 2.0* takes us inside a particle accelerator where two particles have just collided, visualizing the release of energy and the arched path of the particles away from the impact point. Being more than a scientific illustration, this type of show helps the imagination picture what we might never see with our own eyes by giving the phenomena a scale and an appearance. In terms of composition, while still **d** is similar to **a** and **b**, in the other three pictures one can notice that most of the frame is filled with elements, which contrast with the other shows. Furthermore, while still **e** retains a strong center in the top of the dome indicated by the halo and the direction of the flow, there is no such visual clues in still **c**, which would tend to reveal that focusing the attention of the spectator on a particular area was not the intention of the artists. The goal is rather to immerse the audience in the illusion by completely filling its sight and enticing the spectator to feel as in the middle of the action by enabling her to choose where and what to look at.

Thus, visualization in the dome is also about providing a new perspective on its subject. Because of the immersive property of fulldome, shows can tap in this aspect of the medium to propose an experience rather than only communicating data. In still **f** from *"Dome Night" Nocturne No 20 in C# Minor* (J. Tarbell, J. A. Dean, 2010) the score of Chopin's Nocturne No 20 in C# Minor played by an invisible musician follows the edge of the dome master. The score is arranged so that the notes respectively played by the left and right hand of the pianist are shown to come from the left and right edge of the theater. As the music is being played, "notes" are detached from the score and climb up above the audience, shrinking and vanishing as they get closer to the top of the dome. In this particular case the visuals are very abstract and functional in the sense that although a simple and limited set of shapes, colours and motion is used, the graphics manage to convey plenty of information about the structure of the music, much like the user interface of a midi sequencer software.

Data visualizations, while having their roots in scientific research and computer graphics, have become a subject of artistic exploration, especially since the computers enable to manipulate bigger and more complex set of data than ever and software such as Processing are making visual programming more accessible. On most screens however, the limited space puts a limit on the amount of information that can be displayed at the same time, thus calling for strategies to effectively cluster, organize and simplify the data set. A dome provides considerably more space and thus data can be shown in more detail and complexity if desired. Furthermore, the illusion of physicality that can be produced through the medium allows to present information as something to fully experience rather than something that is mainly read based on graphical conventions. This is consistent with new dynamic and aesthetic approaches to data visualisation which essentially try to free data presentation from the static state it traditionally assume in printed material and notably uses techniques from graphic design to make the messages behind information clearer to its audience.

2.3.4 Immediacy, Hypermediacy and Remediation

With the ongoing dissemination of the technology, more people have been able to create content for the medium. As a result, experimentations of all kind have explored possibilities outside the mainstream genres of astronomy, science and education. If the subjects and techniques of these modern shows are very varied, the experience they want to convey is always oscillating between immediacy and hypermediacy. Figure 17 contains still frames from shows that exhibit the two logics of immediacy and hypermediacy and demonstrates how other media can be remediated by the fulldome medium.

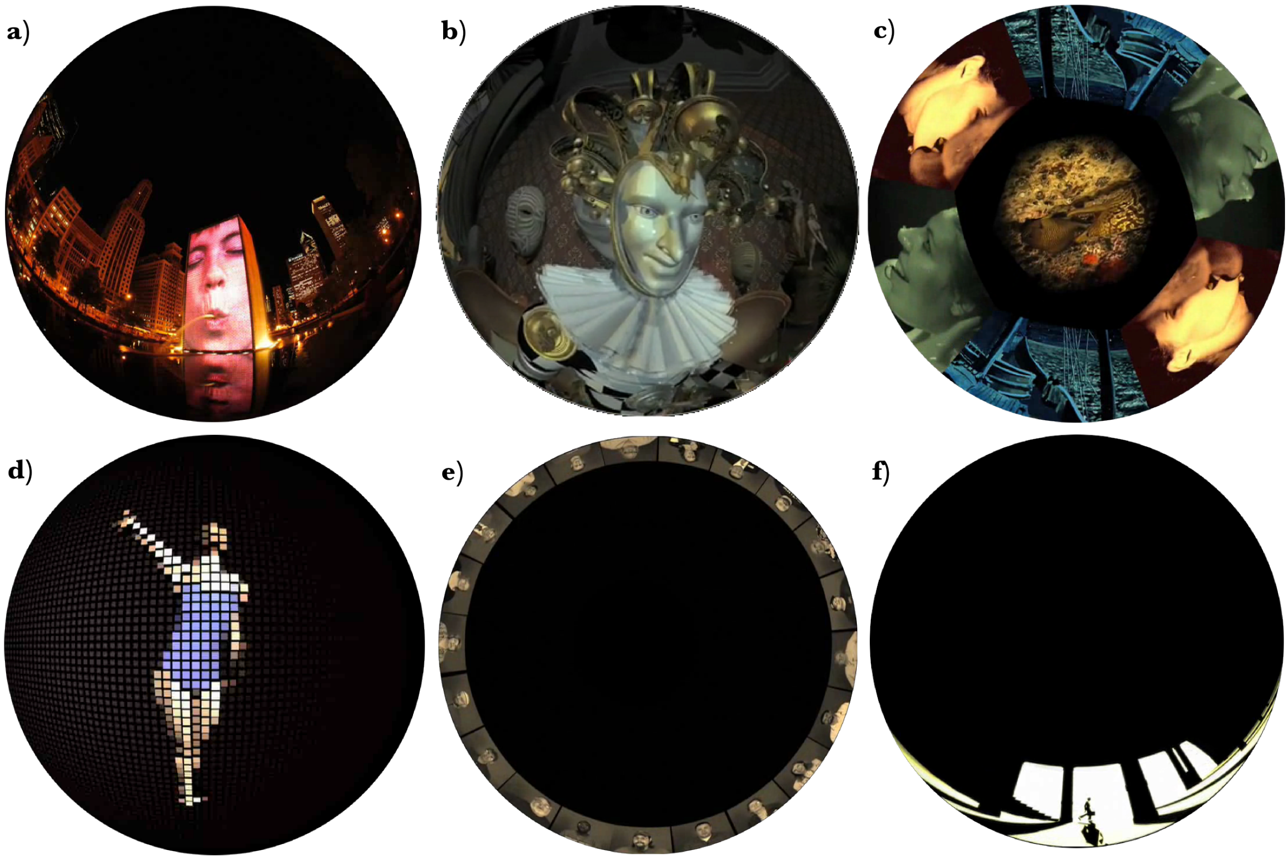

Figure 17: Immediacy, Hypermediacy and Remediation in fulldome

Immediacy is at work in still **a** from *Second City* (M. Mascheri, C. Willsher, 2008), a photography shot using a fisheye lens. The film the frame is extracted from uses the time-lapse photography technique to create motion from a sequence of photographs. This old technique, already used by pioneer special effect creator and filmmaker Georges Méliès (1861 – 1938), consists of showing a sequence of photographs one after the other at time intervals shorter than the real interval between the shots, effectively increasing the frame rate. A typical example of a time-lapse is made of photos of a blooming flower taken every 10 minutes or so and then played back at the regular 24 frames per seconds, thus compressing the complete blooming in a few seconds of film. Therefore, there is no novelty in the production of this film. However, projecting the outcome in a dome theater literally gives a new dimension to this kind of work. Indeed, in this setting the spectator can feel as if being inside the urban landscape recorded by the camera. In this case the photographic medium is not technically or artistically challenged by fulldome projection, even the urban theme match completely the first panorama paintings, but the experience is more transparent as the layer of mediation is made thinner by the 180° projection and the illusion of motion. In this particular case, it is through the logic of transparent immediacy that remediation happens.

Voices in the Dark (T. Rudat, J. Moravek, O. Jüregens, 2008), from which still **b** is extracted also follows the logic of immediacy but operates in a different way. Here the intent is clearly to immerse the spectator in the images, to put him in the middle of an action taking place in a dreamlike universe. A great deal of work has been engaged in the production of a detailed and sophisticated 3D representation of an imaginary universe, but this was done with a surrealistic agenda rather than in pursuit of photorealism (DRAMATICO Entertainment, 2008). The most striking proof of this statement is in the scale at which objects like the joker figure in still **b** are represented. Projected on a dome with a diameter of 10 meters, the figure would be about 5 meters high. Furthermore, other sequences of the animation are much more abstract, showing for instance choreographies of flying tarot cards. What is lost in realism, is gained in the effect these images will produce on the viewer. The show strategy is almost a sensory overload, implemented by using rich dynamic visuals which are amplified by the all around projection screen combined with a rock soundtrack. Thus the intention is to create immediacy in the experience of mediation itself. In other words authenticity of the mediated experience is achieved by hypermediacy rather than transparency.

TRIP - Remix Your Experience (F. Otto, B. Köhler-Adams, 2006) a short video montage from which still **c)** has been extracted, makes no attempt to conceal the mediation. This fulldome video is actually part of a wider art work which produced a musical soundtrack and 4 films that differ significantly in themes and styles and which are meant to be displayed together. This project has been exhibited in different formats. Edited as split-screens for projection on a single screen, or projected on multiple displays, the goal is to let the viewer create her own unique experience by choosing where to direct her attention (Ferry House Productions, 2006). In this instance, the split-screen montage has been adapted to the fulldome format by dividing the periphery of the dome master circle into 6 segments of equal dimensions arranged around a central area. Extracts from the 4 films are shown inside those areas, 1 in the central part, and the remaining 3 are doubled and opposed in the peripheral segments. By dividing the screen a new space that combines an eccentric composition inside a centric system is created, which is ideal to support the intention of the artists as no part completely dominates but still enough cohesion is retained. To make the experience complete, and maybe add to the intended confusion, the images are reinforced by a narration followed by a heavy psychedelic song. In this instance remediation happens by adaptation, since the work was not originally created for the medium but was translated to use the affordances of dome projection.

Brim of Time (G. Erf, 2008) is in continuation of the photographer's work where he uses circular frames and combines and arrange several photographs together in the intent of "disrupting the process of how we construct meaning" (Erf, n.d.). As shown in still **e**, most of the projection is left black and empty, while 21 filmed monologues are laid out along the rim of the dome master, which slowly rotates in a clockwise fashion. The soundtrack is made of an unintelligible background chatter, maybe a mix of the sound tracks of all the videos, from which only one clear voice emerge at a time. Since the composition is almost completely eccentric, at any time the only video that has more weight than the other is the one under the sweet spot, however the soundtrack diminish this weight almost to nothing since the two can not be related. This construction force the audience to actively try to match the voice to one of the video "screens" as no additional clues are available. This is a similar situation one could experience while being in the middle of a loud crowd and trying to figure out who is saying what. Here the spectator is engaged not by an overload of information but on the contrary she is stimulated to be active by a lack of it. In that respect this example is interesting because it illustrates how hypermediacy plays on and makes apparent our expectations toward the medium.

Hypermediacy can also be seen when the physical nature of the medium itself is emphasized and even augmented. It is the case in *50 percent illusion* (T. Greiner, 2008), illustrated by still **d**. According to the author's blog, this animation was created in reference to the character Blanche in the play *A Streetcar Named Desire* (Tennessee Williams, 1947).

> *"To demonstrate that the whole play could be seen as a mere mind game of Blanche, the color, luminance and position of the pixels of the photos of Blanche assign color, size and position to the cuboids in the film.*
> *The generated "look" is supposed to express the completely abstract world Blanche flees into at the end." (Greiner, 2008)*

Apart from the artistic intent, the treatment applied to the digital pictures that were used to create the animation reveal how they are actually collections of smaller elements, the pixels, that contain discrete information about colours and can be organized and manipulated in a geometric space. A digital picture is a matrix of pixels, but the viewer is usually not aware of it because in high definition images the pixels are so small and anti-aliasing techniques are applied such as the overall representation looks smooth and continuous rather than pointillistic and jagged. In *50 percent illusion* a lower resolution virtual matrix of prominent pixels has replaced the usual fine grid of high definition, and the images have been converted to this format by downsampling. Although the choice of the cuboid figure is consistent with the geometry of actual pixels, each of those new pixels is clearly visible and their individuality and boundaries are even pronounced by a gap between neighboring pixels. While one can think of real pixels as light bulbs that are either off or lit in various colours, in this case the pixels are also raised or lowered in a 3 dimensional space according to their luminance*. This produces an optical illusion, a sensation of solidity when projected inside the dome, as if the ceiling would be composed of tiles that could be lit of various colours as well as pushed and pulled. It should be mentioned that this effect is also often used in architectural video projection, also known as video projection mapping, to create illusion of volumetric deformation. Another interesting aspect of this work is in its complete coverage of the projection surface. Indeed, the dancing figure travels without obstruction from one edge to the other, much like a real dancer on a stage. If the figure had not been abstracted like it was this free motion would have looked rather strange, but here it serves the emotional message of the piece.

Another remediation strategy is the borrowing by the new medium of something that is associated with the medium it remediates. This something can be content, style or even the older medium itself (e.g. a calculator software on a computer that borrows its user interface from the real object) (Bolter and Grusin, 2000, pp. 44–45). Still **f** from *Scia Fobia* (N. Uthe, B. Böhm, 2010) illustrate this aspect of remediation in the context of the fulldome. The reader familiar with the opening sequence of the film *Catch me if you can* (Kuntzel + Deygas, 2002) will recognize similarities in the jazzy soundtrack and the art deco graphic style

* for each pixels a value was probably computed using a formula such as $L = \alpha*Red + \beta*Green + \gamma*Blue$

inspired by Saul Bass (1920–1996) posters, but also in the theme of this short animation where a man carrying a brief case is chased by its own shadow. Borrowing or repurposing is perhaps the most common form of remediation.

3 A Software Toolkit for Fulldome Production

I have taken a hands-on approach since the beginning of the project, and while the previous chapter is much more abstract in its approach, here every issues will be of a concrete nature. Starting from simple experiments in fulldome content production using analogue and digital tools, I have worked toward the specification and implementation of a solution for the creation of dome masters that does not employ any proprietary tools. I hope that sharing my experience with working with the medium will help anyone starting fulldome production, especially someone considering creative and alternative approaches to high-end production solutions.

Inspired by the methods of practice based design research (Findeli, 1998, p. 69), I have initiated a self-reflection on my process. I have carried out a research into design using the metaphor of bricolage to analyze my practice and gain valuable insights. This approach to design has motivated a practical exploration of the medium which led to the proposition of alternative solutions. Hence, I have used the activity of design as a research tool. This is reflected in this chapter by presenting the different experiments as iterations of bricolage. Examining my process through the lens of bricolage has not only changed my perspective on the fulldome medium, but it has also revealed the usefulness of the metaphor as a practical tool to identify contingencies and evaluate solutions. This supports Findeli's (1998, p. 68) observation on the effects of practice based research that “the project field will be “disrupted”, altered, but so will the theoretical model in return”.

For the purpose of evaluating what has been produced, other existing solutions will be discussed. Thanks to the cooperation of members of the fulldome industry, this discussion includes the point of view of professionals, hence ensuring that the argumentation reflects reality (appendix C). I have tried to position my design inside the bigger context of a fulldome production, and offer some ideas on how it could benefit future users as new immersive video recording equipment are being researched and developed.

3.1 Experiments in Content Production

I propose to describe and analyze my own design process with the assumption that the activity of design is a form of bricolage. A definition of what bricolage is and how it works as an analogy to describe how a designer proceeds has been given in the introduction. This definition established that design is not bricolage but a form of metaphorical bricolage, however here for brevity the term "bricolage" stands for "design as bricolage" and "bricoleur" will refer to "the designer working like a bricoleur".

Until now the explanation of bricolage has been mostly abstract. Since I employ the analogy to analyze the design process that I was engaged in during this thesis, it is first necessary to explain how I understand the steps involved in bricolage (Figure 18) from a practical stand point. Since much of what follows is inspired by Louridas (1999), it seems appropriate to reproduce his own summary of the idea here:

"It is a hermeneutic process, a process of iterative understanding. The designer proceeds by interpreting the effects his actions have on the situation. He tries to understand the effect of his materials and of his tools, to define their place in a structure. He wants to create a structure out of his means and the results of his actions. He tinkers with the materials, takes stock of the results of his tinkering, and then tinkers again. He takes stock by seeing the situation in specific ways. He subsumes the situation in normative positions that allow him to see it in a special light and under special norms, values, and expectancies, and interpret it and judge it accordingly. In effect, he translates the situation; he perceives the situation as something else. The design is at a metaphorical level, since it is a model, and the designer uses metaphors on it in order to understand it. He modifies it and then tries to understand it again. The activity is a kind of metaphorical bricolage."

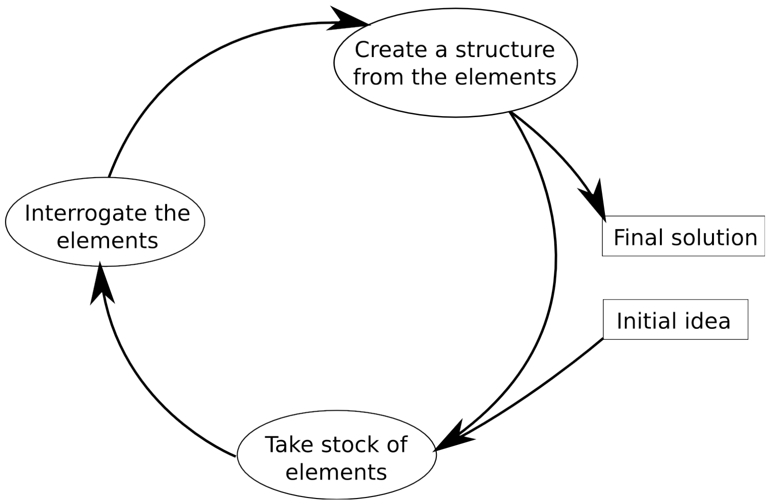

Figure 18: The bricolage process

1) Inception phase, initial idea.

Design starts when a problem that can be solved through design has been identified. These kind of problems are typically wicked problems (Buchanan, 1995, p. 16), they are hard to define and their solution are complex and amount to formulating the problem. The situation puzzle given in the introduction would be such a problem if no other information would be available, and it is this degree of wickedness that makes it an interesting riddle. Thus the designer starts by formulating a solution which evolves throughout the process. This is consistent with the understanding that design thinking works by abduction rather than induction.

2) Evaluation of the stock of available elements, creation of an inventory.

It involves recognizing and selecting from heterogeneous fields an inventory of concrete and abstract elements that can potentially be integrated in a solution to solve the design problem. This step reflects the designer's decisions on how to work and what to work with and it is also influenced by constraints such as availability, cost or regulations. Depending on which discipline design is applied to, an element can be something of the concrete world, the choice of material in furniture design for instance, or something more abstract, like the choice of programming language in software design.

3) Dialogue between the bricoleur and the inventory of elements.

By working with, combining and modifying the elements in his inventory the designer creates previously unforeseen meaning out of them. It is a dialogue in the sense that an understanding emerges from an inquiry through the elements, which in turn changes the meaning of the elements. In other words, it changes how the designer perceives them in relation to each other and the design problem. Practically it means engaging with the elements, sometimes manipulating them in unorthodox ways, sometimes creating combinations of several elements. How this dialogue is conducted reflects the character, taste, experience and knowledge of the designer.

4) Synthesis of the elements in the elaboration of a structure.

The design solution is created by combining elements into a structure that is meaningful in the context of the design problem. The solution is evolved by adding, removing or re-organizing the elements of the structure as the result of the dialogue between the designer and the stock of elements. Hence at every iteration the design problem changes in some aspect as each new solution diverges from the previous one. By evaluating this new structure against the original problem, the designer can then identify successful decision s and parts of the solution that do not perform. This evaluation will then guide the decision made in the next iterations of the process.

5) Iteration of steps 2, 3 and 4 until a satisfactory solution is created.

If the former inventory does not prove to be satisfying, the designer has to adapt the elements it contains to better fit his need, or if it is not possible simply change them. The latter option has a cost that increases at each iteration since changing elements means that the designer has effectively decided to work in a different way, and thus the previous solution and the investment of resources that went into it could be completely lost. Accordingly it is better to make radical change early. Likewise, the more the designer commits to an inventory, the more closed the inventory becomes.

3.1.1 Fulldome Content Production: a Bricoleur's Approach

The story is divided by iterations of bricolage, and each iteration divided into steps of bricolage indicated with the corresponding number from 1 to 5. This narrative enables one to lay out the evolution of the design problem and highlights not only what decisions led to a solution, but also why these decisions were made. Furthermore, by identifying the contingencies and discussing how they were integrated into the structure, it is possible to evaluate and learn from the whole process and initiate at new iteration of bricolage.

First iteration:

(1) The initial idea came some months after a screening at the Heureka Planetarium when I decided that this thesis would deal with the fulldome medium. This decision was made with the

hypothesis that this medium and its immersive property had great artistic potential.

(2) In order to explore its possibilities, I then decided to work on the production of one or a few short creative video experiments that would combine the use of different media such as photography, video, drawing and computer generated graphics.

(3) The first concrete step was to investigate what the specifications of the fulldome frame are and ways to acquire content from different sources that would fit this format. The outcome of this enquiry was an understanding of the equiangular fisheye projection and the discovery of the dome master and its large resolution.

(4) Based on these discoveries and using the Processing programming environment, I started experimenting by creating a program for generating fisheye-like images. Additionally, I made a simple procedural 3D animation using Processing and rendered in 2 versions: one without the fisheye projection, and one with a virtual 180° fisheye camera setup using the ray-tracer **POVRay**.

(5) The animations were tested inside Heureka's production environment (i.e. a single projector with a fisheye lens inside a small dome). The result was far from what I expected and revealed important misconceptions about visual composition inside a dome master, which I had treated naively like a flat circular frame. The experience also highlighted the need for a way to visualize a dome master on a computer not as a flat circle but as projected on the inner surface of a virtual hemisphere. This was particularly important as physically going to the production mini dome for every test would be impractical and time consuming. Luckily, there was already a free tool called **DomeTest** written in C++ using the Cinderlib framework that enables viewing images and videos textured inside an hemisphere and interactively change the point of view (Warnow and Ruszev, 2010).

Second iteration:

(2) After the first experiment I decided to move from the computer to the physical world and research how to use photography and drawing in this context. A constraint of using a do-it-yourself (DIY) approach was placed on the process, because I believed it would encourage a more explorative approach. At that moment, I also decided that my solution should be affordable and favor the democratization of fulldome production tools.

(3) Because panoramic photography requires to capture a field of view larger than what a common rectilinear camera lens can record even for a very short focal length, most photographers fragment the field of view by taking several shots at different angles. To avoid parallax distortion between shots, the photographer must be careful to keep the focal center at the same position, typically using a special kind of tripod. A fisheye lens is often used for panoramic photography since it is only necessary to combine 2 or 3 photos taken with the lens to create a 360° panorama, and only one for a single dome master. However it produces images that seem distorted, or curved compared to usual photographs. The fragments of the panorama must then be combined in a final image using specialized software which corrects distortions and merges, or *stitches*, the photos together.

I also learned that a similar technique, called *cube map* rendering, is used in computer graphics to simulate reflection or calculate lighting. It involves several rendering of a 3D scene (up to 6 times), using a viewing frustum defined by an angle of 90° and planes of 1:1 aspect ratio. For each new render, the view frustum is rotated +/-90° on each axis while keeping the apex of the frustum at the same position, effectively capturing a cube (Figure 23 a). If we imagine that the resulting cube is a box that contains a sphere and with its faces tangential to the surface of the sphere, it is possible to project the pixels of the cube on the sphere. (Wright, Lipchak and Haemel, 2007)

A dome master is then obtained by looking directly towards the center of the sphere. This process is illustrated on Figure 19. Note that in the figure only 5 faces are shown for clarity, and although the cameras are shown as stacked, in reality they would share the same focal center. This technique is easily implemented using common 3D graphics libraries such as OpenGL, but can also be used inside a 3D modeling software by creating a set of cameras with the appropriate settings. As a rule of thumb, the width of each face should be about a 1/2 to 3/4 the width of the target fisheye (Bourke, 2010). Additionally, since cube maps are made of rectilinear projections they are easier to edit than images created from a curvilinear projection such as the fisheye.

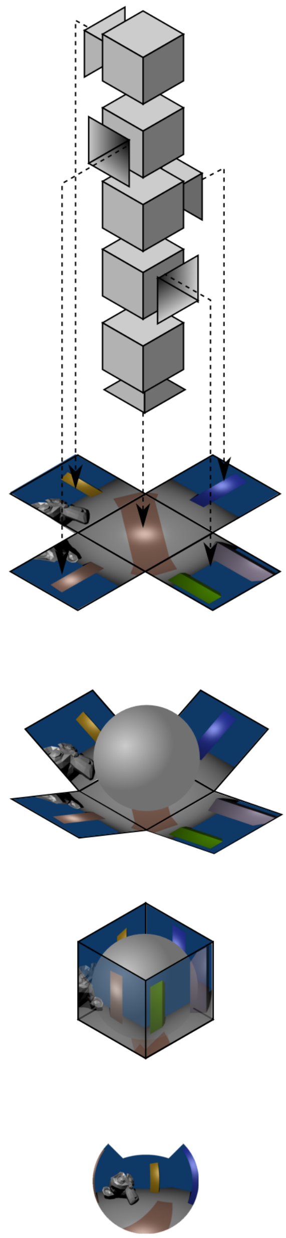

Figure 19: Cube map rendering

(4) I built a DIY fisheye lens using a door viewer – a wide angle lens that is installed for security purposes on a door to give its user the ability to view who or what is behind it – fixed to a section of a plastic pipe to be attached on a digital camera (Figure 20). This is not an original design, the instructions to build such a contraption are available online. Because the door viewer is only a few centimeters from the camera lens, the camera must be set to a macro mode in order to get a suitable depth of field. While building the lens adapter, I also had a "bee eye" kaleidoscope lens that was lying around, which I also tried out.

Figure 20: A DIY fisheye lens

I found a plastic container in a supermarket which resembled cube. By fitting a low heat light bulb inside it and by wrapping an A4 sheet of paper around it, a kind of cubic drawing light table was created (Figure 21). Drawings done on this 'light cube' can then be digitized with a scanner and turned into a dome master by projecting it as a cube map on a sphere.

Figure 21: A cubic light table

(5) The DIY fisheye produces photos that lack sharpness (Figure 22 a), especially near the edge of the lens. Although the door viewer packaging indicates a field of view of 180°, the actual field seems smaller. The photos produced by the bee eye lens reveal very interesting patterns (Figure

22 b) from inconspicuous objects such as a computer keyboard. The biggest problem with digital photography and its application in fulldome is the need for a high resolution image which requires a high-end camera.

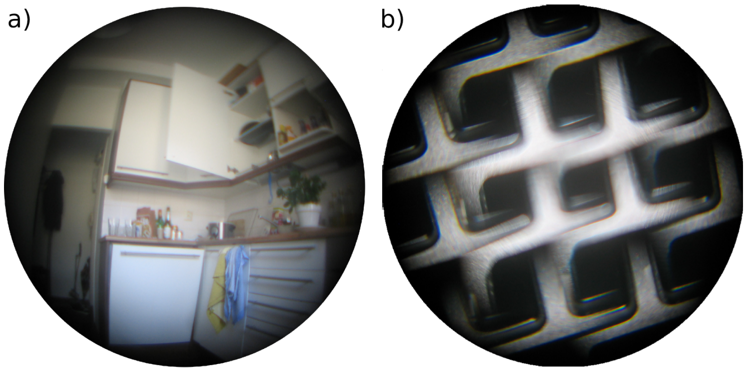

Figure 22: Photos taken with a DIY fisheye lens and a bee eye lens

The light cube helps in visualizing the spatial relation between each face of the drawing. However it is not very practical to use and its surface is too small. Furthermore, the process of scanning and processing the image into a suitable cube map is time consuming.

Third iteration:

(2) Experimenting with these tools revealed that the main difficulty inherent to using the analogue medium for fulldome content production is the high definition of the image. Although this obstacle can be solved either with time consuming processes or high-end equipment, I concluded that for my purpose would be best used with parsimony.

While drawing on the cube light demands inevitably more time, and requires draftsmanship as well as a good understanding of the spatial and angular relations between each faces of the cube, it produces high definition images and can be useful for sketching ideas. After being drawn and digitized, the cube map requires a software for projecting the cube on a sphere to create a dome master. In fact only half of a cube, also called hemicube in computer graphics, is needed to cover the 180° field of view of a dome. The cubic light box with its 5 faces covers a 270° field of view, 90° more than necessary. However, this extra information is useful as it gives flexibility to the framing of a cube map into a dome master. Furthermore, it provides enough margin to compensate for the tilt of some dome which is usually around 15°.

I also realized that there is an extensive database of 360° panoramic pictures that can be accessed through Google Street View. Unfortunately, Google does not allow the images to be used in a project that does not directly access the panorama through their dedicated application programming interface (API) and also prohibit caching these images (Google, 2011). Moreover, these photos are watermarked. Due to these limitations, Google Street View panoramas can not be used directly in a fulldome production. However, as long as these conditions are respected, they are still interesting as reference material and inspiration to create sketches of urban environment, which could prove useful in the pre-production phase (see appendix D).

It was then decided to return to the computer and focus the investigation on projections used in panorama photography and particularly on cube maps as they are easy to produce and manipulate. The DIY constraints was extended to include open source software.

(3) Part of the routine of panorama photographers to manipulate projections, and to this end a group of developers have created **Hugin**, an open source software tool chain based on the Panorama Tools library that can be used to stitch and correct deformation created by wide angle lenses. Looking at some panoramas created with this tool, it seems that the *equirectangular* projection is also popular among photographers. This projection pre-dates Renaissance (Snyder, 1993, p. 5) and in mathematical terms maps a complete sphere to a rectangle in the cartesian plane using the following formulas:

$$x = \lambda \cos(\phi_1) \quad \text{and} \quad y = \phi$$

Where λ and ϕ are angular values. λ is the longitude from the central meridian of the projection, by convention in the range [-180°, 180°] and positive east of the central meridian; ϕ is the latitude in the range [-90°,90°], where 0° is the equator and +/- 90° are respectively the north and south pole; ϕ_1 is the standard parallel, that is the latitude north and south of the equator where the scale of the projection is true. A special case of equirectangular projection called *plate carrée* is commonly used in computer graphics. For a plate carrée, the aspect ratio is 2:1 and ϕ_1 is set to zero – making the equator the standard parallel – cos(0) being equal to 1, x and y are respectively equal to the longitude and the latitude. The straightforward and easy to compute mapping from pixel to spherical coordinates makes it a popular choice for computer applications that deal with a world map but also for panorama viewer such as Google Street View.

A plate carrée can be turned into a cube map using the command line tools **erect2cubic** and **nona** from the Hugin package. However it appears that they are no open source tools to convert the cube map to a fisheye projection.

(4) A virtual camera setup, or rig, was created following Figure 19 using the open source 3D modeling and animation software **Blender** (see appendix D). Figure 23 a) is a cube map created with this setup. Fulldome video uses high definition frames, and since the edges of the cube map should be at least half as big as the resulting dome master width, any fairly complex fulldome project produced this way would require an extremely long render time on a single personal computer. It is possible to distribute the rendering tasks among a large number of processing units, also known as a render farm. Most render farms are commercial services, charging their customers on the base of the processing power in gigahertz that will be needed to compute all the images. Fortunately, users of Blender can use a free service called **Renderfarm.fi** in which processing power is provided by a network of volunteers using the Berkeley Open Infrastructure

for Network Computing (BOINC). To test this service, a 500 frames animation of traveling through a simple simulated solar system with its orbiting planets and a meteor belt was created. This animation contains images as well as procedural textures, particles (the meteors) on a star field background, which are elements often found in fulldome shows. The target dome masters for this test are 4096 pixels in width which is suitable for small to medium domes, and for each frame a complete 6 faces cube map with edges of 2000 pixels is rendered. Although only a hemicube is needed to produce a dome master, rendering the full cube affords more flexibility since it makes it possible to decide which angle of the scene to show after the render has been completed. Table 5 details how long it took Renderfarm.fi to calculate the 3000 frames - 6 times 500 frames, each 2000 by 2000 pixels - that compose this test.

Faces	Distributed Render time (hours:minutes:seconds)	Render time on one average CPU core (hours:minutes:seconds)	Time between work submission and rendering (hours:minutes)
Top	02:55:45	09:58:49	00:50
Left	03:13:11	11:03:19	01:01
Front	03:10:50	09:48:01	14:01
Right	03:00:31	12:18:28	03:08
Back	04:03:43	10:24:42	00:56
Bottom	01:59:26	09:07:55	00:52
Total	**18:23:26**	**62:41:14**	**20:48**

Table 5: Render times of 500 cube maps (edges of 2000 pixels) using Renderfarm.fi

It is clear that the render time is considerably improved by using Renderfarm.fi, however there is an important additional time cost induced by the submission process, in this case it even surpasses the time spent in rendering the images. Moreover, submission time can not be determined beforehand since the acceptance of a rendering session is at the discretion of the administrators of the system.

I found out that Blender does not support rendering using multiple cameras, thus each frame needs to be rendered separately for each camera. This is an issue especially when using Renderfarm.fi because a new rendering request must be made for each camera, and every request can potentially add a considerable amount of time to the total render time. Another point to consider before using this service is that this kind of system performs best when rendering an animation with a high processing to data ratio (Renderfarm.fi, 2011). Since data is being transferred around the network to many nodes, a large file will generate a bigger transfer time. If a big file needs minutes to be transferred but only requires a few seconds for each frame to be rendered, the transfer time will exceed the rendering time, thus the system will perform poorly compared to a render job on a single machine. This is typically the case of an animation using a lot of detailed pre-rendered textures and highly tessellated models. Conversely, a lean file that requires heavy computation of lights, shadows reflection or procedural textures and materials will maximize the processing to data ratio and thus the system will perform well.

Moreover, rendering through this free render farm currently imposes some technical limitations due to the images being split up in multiple parts to be rendered in parallel. For instance, parallel distributed rendering makes its impossible for a frame to depend on a previous frame to be calculated first because there is no guarantee that the frames will be rendered in the order of the timeline of the animation. Since not only images but also parts of images are distributed for rendering, post-processing effects that happen at the pixel level and use information about

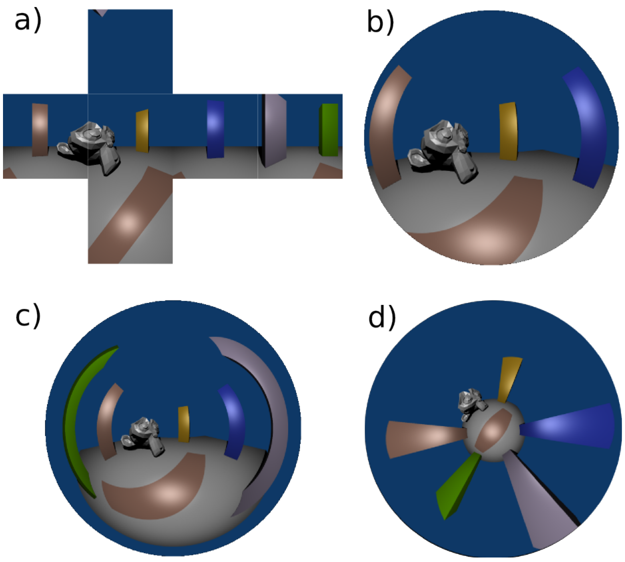

Figure 23: Cube map to fisheye conversion

surrounding pixels will not work properly for the same reason. Finally, the animation data and resulting rendered frames are publicly shared, hence the artist must provide appropriate copyright information regarding the content of the animation but also agree to one of the Creative Commons license supported by the service governing the usage of the output images. (Renderfarm.fi, 2011)

Using information about the angular fisheye projection found online (Bourke, 2001) and the source code of Fisheye Quake (van Oortmerssen, n.d.), I created a software that converts cube maps into dome masters. It was first prototyped in the Processing environment and then adapted in C++ for better performance and to be used as a command line utility. I called this software CubeAnimator (see appendix D). It takes up to 6 images as inputs as well as projection angles and outputs a dome master of the specified size and provides some simple anti-aliasing functionality. While it uses a default aperture of 180° to suite the dome projection (Figure 23 b), it is possible to specify smaller or bigger angles (Figure 23 c). Furthermore, there is a 'zoom' value that can be changed to deform the projection. This last parameter is the result of accidental modifications of the fisheye projection function which created interesting effects such as 'wee planets' (Figure 23 d). Although this functionality is beyond the scope of a cube map to fisheye converter, it was decided to give the user the possibility to experiment with this parameter.

(5) The cube map approach provides several affordances. To begin with, it is easy to produce cube maps either by writing one's own program or using a 3D software, and it is also fairly simple to create dome masters from cube maps. Secondly, cube maps are easier to work with when it comes to post-processing because most image editing software are designed to cope primarily

> with rectilinear projections (i.e. most photographs). Finally, because they can capture a 360° field of view cube maps are more flexible than fisheye renders as the final angle of view of the dome master can be chosen after the image is rendered.

The cube map technique provides a way of creating dome masters that is easy to implement and flexible enough to accommodate the use of several media without having to turn to proprietary solutions. For these reasons, this method can be judged satisfactory with respect to the initial goals and constraints that started the design process. At that point, the bricolage process can end because there is no need to modify the stock of elements. The last task is to assemble all these elements meaningfully from what is now known about them in the context of the design problem. Before going into the proposed solution, for the purpose of evaluating the bricolage approach to design I shall discuss what I have gained from this exercise.

3.1.2 Learning from Bricolage

The most interesting insight I gained from looking at my process under this particular light is what Lévi-Strauss (1962, p. 21) called *the poetry of bricolage*. He was referring to the fact that the bricoleur always put something of himself in his work, and that this personal contribution is visible in the dialogue he has with the elements. From the previous story, it is clear that I have a strong connection with the computer as a tool. I always try to translate what I learn to the computer, either by finding a software that embodies this knowledge, or by writing code that exhibits the same behaviour. From this remark, it is not surprising that I appreciate cube map as good solution since it is embodies most of what I have learnt about geometry and fulldome in an object that is very easily produced and manipulated on a computer. Incidentally, the light cube is an attempt to make physical this abstract model.

Another interesting outcome is a clear sense that design is a path finding process as described by Herbert A. Simon (1996, p. 121). It is commonly admitted that design as a creative activity requires an explorative approach, but this should be done always towards a goal. Bricolage also illustrates how this target is moving as every iteration modifies the previous solution or the understanding of the problem. Hence it might not be possible to search for an optimal solution, but by following a target it is possible to reach a *satisfacing* result. In the process different paths are being evaluated, and while some are dropped along the way (e.g. the DIY fisheye lens), others are almost discovered by accident (e.g. the 'bee eye' lens). In bricolage terms path finding is a dialogue with elements. I believe this is consistent with Simon's view that the complexity comes from the external environment and not from the human mind. Bricolage shows that as soon as meaning is created from interacting with the elements, the future design decisions are made clearer and new elements can be added to the structure more easily. This, I think, is the creation of structure out of event afforded by bricolage, or the process of evaluation of Simon's science of design.

In the previous subsection I only described the higher level of bricolage, but the process can be further broken down into more specific occurrence of bricolage. The creation of CubeAnimator for instance is one of those smaller scale design processes inside the bigger project. Coincidentally, I used a style of bricolage to write this software much like the one described by Sherry Turkle (1995, pp. 54-59). I did not have to carefully plan the implementation, as a matter of fact the only formalization of the design for this first version of the software are a few sketches describing the user interface. However, my notebook contains pages of doodles, formulas, logical expressions, random numbers and reference to lines of code provided by the debugger that together create a record of the development process. The software was created over a period of 4 months, but I remember particularly a intense period of code writing when I could mentally recall every details of all the module that compose the software. I am inclined to think that other programmers, or for that matter anyone working intensely on complex structures, experience the same sensation of having a map of the project in their head. This would tend to show that the thinking process involved creates a mind structure that connect all the elements in the bricoleur's stock. In a way it is surprising that all this complex information can be committed to memory unconsciously. I presume that it is made possible because this method is similar to inventing a story by connecting elements meaningfully. Since a story is much more easier to remember than disconnected elements, the bricoleur can exploit this to integrate the metaphorical manipulation that

3.2 Open Source Fulldome Production Pipeline

Returning to the definition given in the introductory chapter, design is "a specification of an object, manifested by an agent, intended to accomplish goals, in a particular environment, using a set of primitive components, satisfying a set of requirements, subject to constraints" (Wand and Paul, 2007). It has been determined that the subjects of design are wicked problems, hence they can not be formulated before a solution has been found. Prior to the investigation that has been detailed in the last section, the question seemed to be how to include analogue and digital media in a fulldome show. Hence, it is only after experimentation, evaluation and research that I was able to formulate the design problem as how to create content using available tools adapted to the need of the medium.

3.2.1 Specification

In this case the object that is specified is not a physical one but rather a series of tools that if used together in a certain sequence can create dome masters. Thus the object of this design can be seen as an information processing pipeline, in which primitive elements are technics but also tools and services (Figure 24). Itself an element of a possibly bigger production setup, this solution should find its place between the creation of the content — by photography, filming, computer generated graphics or any other means — and other post-production tasks such as compositing and editing. Therefore, the pipeline must allow heterogeneous visual media at one end and output dome masters suitable for fulldome video projection. It is in particular intended to be applied in a production where the use of proprietary solutions might not be possible due to cost or copyright constraints, thus the use of proprietary and commercial elements should be kept at a minimum in its implementation.

Bricolage has been defined as the creation of structure out of events. While the previous section of this chapter has been mostly dealing with events and how they where understood, producing a specification requires to detail the structure that emerged from giving meaning to these events. Since the object is a pipeline, it makes sense to start from its inputs and work up to its output. It has been shown that acquiring photographs or video was problematic and that the process could only be simplified by using high-end equipment. Furthermore, using drawings is easier and essentially requires skills rather than equipment. Finally, it was established that computer graphics where the most suited for fulldome production. However, the solution should be agnostic of the process needed to create the input media as much as possible if it is to be useful. Therefore, this pipeline shall be only dealing with digital input since any of the cited medium can be digitized in one way or another (Figure 24, A).

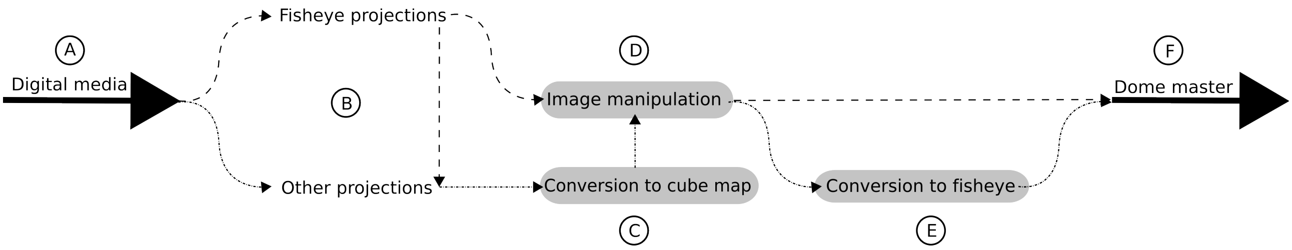

Figure 24: A fulldome production pipeline - Specification

From panoramic photography we know that they are many possible projections that should be accounted for. Following a similar logic that led to consider only digital images as input, these images should be mapped to a single projection before proceeding further in the pipeline. Of course, since a fisheye projection can be used directly as a dome master, images which where created using this projection can be allowed to the next stage (Figure 24, B). A good choice for a common projection would be a compromise between the target fisheye projection and the most common rectilinear projections, as most image manipulation software are designed to deal with this type of input. Cube maps offer such a compromise (Figure 24, C).

At this point the pipeline only contains cube maps or fisheye images. Using conventional graphics manipulation softwares, any particular effect, correction or other manipulation can be carried out on cube maps (Figure 24, D). Fisheye images can be edited by the same means to a certain extent, but if their curvilinear projection proves to be problematic, they should also be converted into cube maps. Finally, cube maps are converted into dome masters by applying the correct fisheye projection (Figure 24, E). The outcome of this process being correctly formatted dome masters (Figure 24, F) which can be used in a fulldome projection system.

3.2.2 Implementation

The described pipeline can be implemented in multiple ways, but using only open source software is a way to minimize costs and gives the possibility to make custom modifications to fit one's need. The example implementation detailed here (Figure 25) was created for this thesis with the intention to use it in short 3D animation production. Most of the open source softwares used have been found online. In the rare case where no open source solution was available, the missing tools have been implemented and their sources released publicly under the *MIT/X11* license (see appendix D). The motivations behind the choice of this particular license are that its is permissive to use in proprietary software, and secondly that it is compatible with the *Lesser General Public License* (LGPL) v2.1 which applies to the QT Framework v4.7.4 on top of which the software what built. As before, the description will follow the direction of the flow in the pipeline.

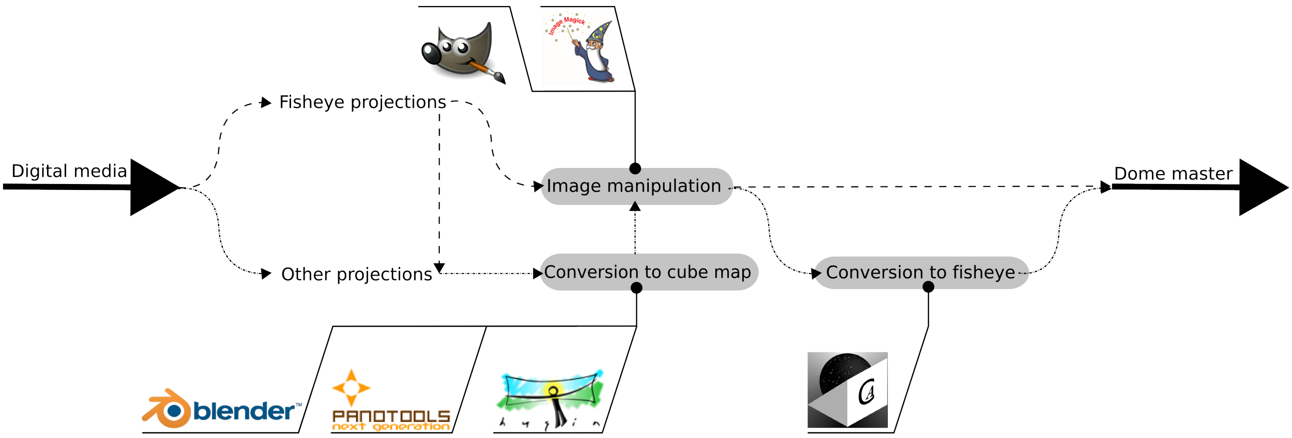

Figure 25: A fulldome production pipeline – Implementation

When it comes to manipulating the projection of raster graphics, especially photographs, into a panoramic image **The Panorama Tools** (Panotools) — a collection of software to create panoramas — is the best open source solution there is. It is still being actively developed by a small core of developers and its user community can be helpful in case of problems. Moreover, another open source project called **Hugin** makes its functionalities more accessible by providing a GUI. The tool is also very versatile, thus it would be impossible to describe all the possible use-scenarios to create cube maps, however one approach that can be applied in most case is outlined.

To begin with, cube maps in the documentation of Panotools are called cubic projection. Hugin comes with a set of utility scripts that perform some projection transformation operation. Many of them take equirectangular projections as input since they are very easy to work with due to the simple mapping function of this kind of projection (see subsection 3.1.1). One script called **erect2cubic** converts equirectangular projection to cubic projection. The script actually produces a description of the mathematical operations that need to be applied to the image. This description needs to be fed to another program called **nona** which will actually perform the conversion and produce the 6 faces of the cube map in separate files. Other tools can be chained to create the equirectangular projection. For instance, for my own private usage, I wrote a script for the Bash command shell that automatize the process of downloading panoramas from Google Street View and converting them to cube maps using the method described above.

Regarding computer graphics, and especially 3D scenes, they are several possibilities to create cube map. One would be to render an equirectangular projection and use the previous solution. However, in most case it might be easier to implement cube map rendering. Any modern 3D graphics library such as OpenGL can perform the required operations that were outlined in $1 (see Wright et al., 2007). Similarly, if the images are created from a 3D modeling and animation software such as Blender, it should be possible to simulate the 6 camera setup. To this end, I wrote a Python script that extends the functionality of Blender, by adding a simple user interface to work with cube map rendering. In this context of use, a 3D content creation software could be also an interesting solution to create text titles or animate pictures slide shows by adding planes textured with text or images to the scene.

Be it fisheyes or cube maps, bitmap image manipulation such as colour adjustments, applying filters to part of the picture or compositing elements together is not different from working with other rasters. Hence, any bitmap editing tools such as **Gimp** can be used. However, since an animation may require thousands of images to be modified the same way, for correcting colour balance for instance, using a software that supports batch processing is highly recommended. **ImageMagick** is a suite of open source programs available for most platform. These programs can perform all sorts of bitmap image manipulation and since they are all designed to be run by a command line, complex manipulation can be scripted and applied automatically to thousands of images. My Google Street View script for instance use ImageMagick to re-create a single image from all the image tiles downloaded.

The last piece of this implementation is the cube map to circular fisheye converter. This could also be achieved by chaining utilities of Panotools. However this requires more computation than is actually required and since a great number of images might need to be converted it would be better if the process was as fast as possible. Thus a better solution would allow to convert directly from cube map to fisheye without intermediary steps. To my knowledge, such software are not available with an open source license, thus I wrote cubemap2fisheye, a command line tool that take up to 6 images of a cube map and outputs a projection of a circular fisheye. This software covers the core functionalities of similar softwares called cube2dome written by Paul Bourke for Mac OS X (Bourke, 2008) and GLOM for Windows (Copyright 2003 Spitz, Inc). Namely, the angle of view in terms of yaw, tilt, pitch and roll can be specified. Additionally, it is possible to show more than 180° if desired and a zoom setting can be used to deform the projection. Command line scripts can be written to batch process cube maps, this also allows to animate a cube map by interpolating between yaw values for instance.

In order to make the most of cubemap2fisheye possibilities, I also wrote a graphical tool to animate cube maps which I named CubeAnimator. After loading images in the software, manipulation of the angle parameters happens through a real-time interactive low resolution fisheye preview and an interpolation curve editor. The workflow paradigm is similar to animation tools such as Blender, Flash or After Effects where values of animated properties are set, or keyed, at certain frames on a timeline. The animation in between these frames is then created by interpolating from one keyed value to the other. While the fisheye preview lets the user change angles by dragging with the mouse, or entering values in number boxes, the curve editor allows better control of the interpolation by moving animation keys in a graph which horizontal axis represents the timeline and vertical axis the value of the parameter at a particular frame. The user can choose the type of interpolation — linear, constant or bezier — between two keys. The bezier curve interpolation is useful to create smooth interpolation and is controlled by two additional control points. An animation project can be saved in a text file where information is structured in JSON format. Incidentally, cubemap2fisheye accept such file as input, hence it is possible to render an animation simply by running cubemap2fisheye with the path to the file as a parameter. This functionality is also accessible within CubeAnimator.

3.2.3 Integration into Production

The entire pipeline would require to be tested as part of a reasonably complex fulldome production to judge its relevancy. This has not be done yet, but it is possible to infer what could prove to be problematic by evaluating the proposed solution against production pipelines used during previous productions. While I have not taken part in the making of any existing fulldome shows, a few show creators have kindly shared their own experiences and work flows, hence enabling me to contrast my concept against the practical realities they face in their work with the medium.

To begin with, it appears that most professionals work nearly exclusively with fisheye images when it comes to content created in 3D software. While some have in the past used the cube map approach, they have abandoned it, preferring other techniques that allow them to directly render using a fisheye projection. This can be achieved by a special camera rig inside the animation software, or implemented as a shader, that is a program that can perform manipulation on vertices and pixels as part of a customizable rendering pipeline. Since it is not natively supported by most 3D software suit, it appears that cube map rendering is problematic because there are no easy ways to pre-visualise a scene as a fisheye projection using the technique. Furthermore, because it is possible to use information about depth, light and material which is not available anymore after rendering, it is common to apply some of the post-processing effects already in the rendering pipeline. Since cube map rendering fragments the scene into several independent render jobs, this type of post-processing can introduce undesirable seems between faces of the cube map due to how most rendering engine work and specifically how they optimize calculation.

Another complaint regarding cube map is about the time wasted in rendering parts of the scene which will not appear in the final dome master. As a matter of fact, rendering a full cube map (360° horizontally and vertically) to create a fisheye (360° horizontally but only 180° vertically) amount to wasting 50% of the render time. So far, my counter argument have been that this extra information could be used to create different versions of the same animation to accommodate dome theaters with different tilts. In practice, it is sufficient to render 5 faces only since the tilt of most domes rarely go beyond 30°, hence only 25% of render would be wasted. According to Ron Proctor, production coordinator at the Ott planetarium, "Remapping / tilting after render is a strength of the cubic method, but in 6 years of planetarium show production and distribution, I have never been asked to re-tilt a scene." (Proctor, 2011). This is surprising considering how the tilt can drastically affect how things are perceived (see Figure 2). Interestingly, according to Ron Proctor's experience, the public seem to accept these deformations. However, his advice is to keep the horizon of the scene 30° to 40° above the spring line of the dome master. It should also be noted that the main stream shows are set in space, where horizon as such does not exists. Watching *Black Holes: Journey into the Unknown* (see 2.3.2) inside a dome tilted by 15°, I did not really mind the tilt in the dragonfly pond scene. However, in a later scene where a rather large boat is shown sailing towards the back of the dome, I clearly remember finding this rather strange as it felt that the ship was climbing up a hill.

My opinion is that direct fisheye rendering and cube map rendering should be combined to profit from their strength while minimizing their weaknesses. Should be rendered directly as fisheye frames scenes without horizon, or scenes representing a space that would not be affected significantly by a different tilt. However, scenes that will be disturbed by a tilted dome should be rendered as cube map. The idea is that when the show is distributed to diverse venues, only cube maps scenes need to be 're-tilted', which is a very simple process. For this strategy to be as efficient as possible, further research should try to establish how to identify scenes that require cube map rendering.

A final concern of fulldome show creators is that the cube map format is not handled directly by leading post-production softwares, hence they have to implement ad-hoc solutions to their usual work flow, which can possibly impair productivity. Arguably there is a gap in the technology here, which I believe could be easily filled by developing special software or extending existing ones as cubic projection is rather simple to implement. However, because most productions prefer the fisheye format, there is not a strong motivation from the industry to produce such tools. Perhaps personal initiative or establishing an open source community around the production of such tools could remedy this problem. CubeAnimator for instance offers limited post-processing capabilities but they are specific to cube maps, and as such it could be a base to implement more powerful features. Besides software solutions, it would also be worthwhile to research and share best practices regarding working with cube maps in post-production.

The resources of most fulldome production are much more constrained than those of mainstream cinema because the dome theaters shows market is much smaller. Paradoxically, the fulldome technology demands higher definition than other video media which requires expensive and particular production tools. Nowadays the most practical way of capturing video for fulldome application is based on using a fisheye lens mounted on a high definition digital camera, hence it would appear that productions which use a lot of footage would not benefit from using a cube map pipeline. As the image definition of fulldome video is increasing — most recent fulldome projection systems can work with dome masters that are roughly twice the size of the 4K dome masters used in most commercial productions of the last 2 years — it becomes increasingly expensive to acquire high-end digital cameras that can deliver this kind of definition. According to Tom Casey, president and creative director of Home Run Pictures, a professional RED ONE camera is the best choice for fulldome production in terms of image resolution and cost but it current price of about 25 000 dollars is still expensive for most dome theaters (Casey, 2011). However, cheaper and alternative solutions using several independent cameras are being researched and developed.

Those systems are in essence physical implementations of camera rigs. This was actually the first approach to immersive cinema (see section 2.1.1), but what was technically difficult 80 years ago is now well within the technological capabilities of our times. For instance, the Lady Bug camera, created by Point Grey Research Inc., captures spherical panoramic images from 6 cameras mounted on a pentagonal prism casing, one pointing up from the top base, while the others are arranged on the 5 other faces capturing a 360° horizontal field of view. Some projects also use a more do-it-yourself approach and obtain good results. For the production of an immersive film about the Versailles castle, the company Aloest created a special rig composed of 8 HD captors each pointing at one face of a diamond shaped 8-sided mirror, enabling them to record 12000 by 1080 pixels video frames of a 360° horizontal panorama (Aloest, 2010). With an even simpler setup, using 4 digital cameras priced 300 dollars attached to a square plastic table leg, Ryan Jackson was able to capture an immersive video of a dodgeball game from 3561 by 1308 pixels spherical panoramic frames (Jackson, 2011).

While the image resolution of these alternative solutions might not rival with professional cinema equipment, they do however afford the creation of immersive live footage to modest budgets. This is probably the strongest argument in favor of developing more multiple cameras setups. These methods will usually output panorama in the equirectangular projection format which is very easily converted into a cube map. Hence, having the possibility to work with this format would make the type of solutions presented here an asset to a production team.

4 Propositions for Open Source Productions

The fulldome industry operates in a situation where its technology provides a great degree of immediacy at the cost of complexity. The technical requirements of the medium exceed the needs of mainstream audiovisual production and demands particular tools and skills. However, this complexity is not matched by the resources available to most fulldome productions because the market is rather small in comparison to mainstream cinema. At the moment, there is a mismatch between the expressive potential of the medium and the amount of resources that the society allocates to its use and development. This situation seems rather paradoxical as it is rational to think that since a new fulldome system is expensive and more of these systems are being installed every years, there would be also money spent in creating content to be shown in these new dome theaters.

However, this paradox does not survive a simple look at what is the common usage of this medium. Since dome theaters are traditionally used in planetariums and other cultural institutions to teach science, producers focus on delivering content that fits in this context. Furthermore, as fulldome video replace opto-mechanical stars projectors, the medium is also often used in an interactive fashion to show models of astronomical phenomena that can be navigated in real time. This means that content can actually be created 'on-the-fly' by the planetarium operators. If the medium is solely seen as a teaching tool, the need for fulldome video content, real-time shows or planetarium softwares can be matched by a small number of producers. Planetarium, astronomy, education, this is how most of us think about this medium. If I'm asked to describe fulldome, I'm most likely to answer that it is the system used by planetaria to project digital video because most people know what a planetarium is. I could also say that it is immersive video projection inside a dome screen, but in my experience this answer is harder to grasp for the layman; although descriptive, it does not refer to common knowledge and experiences like the first one. What happens if the image of fulldome changes? What if its value as a provider of immersive experience starts to exceed its educational value? Would it affect how financing is allocated and how shows are produced? These are questions that are at the heart of the discussions of the fulldome community and which will probably be answered in a near future as the medium gets wide spread and more familiar to the public.

In the previous chapter it was shown that, through their online advertisement strategy, new fulldome theaters have made the choice to put forward the technological and expressive aspects of the medium, while more traditional venues emphasize education. Furthermore, fulldome festivals award prices to alternative and even purely artistic productions that propose novel interpretation of the fulldome experience. So far in this thesis, the focus has been exclusively on pre-rendered shows. However, real-time interactive works must be included in a discussion about the change in the image of the medium since they are an important part of recent researches and development in production. The program of the last FullDome-Festival that took place in Jena, Germany, in May 2011 reflect this state of affair as it featured a workshop about the creation of performances using live generated images and sound under the label "Showcasing Real Time Footage – The Revolution of the Full Dome" that involved fulldome experts but also VJs, designers and other media artists. Actually, the performance of live entertainment shows in a dome theater is not an original concept if one takes into account the Vortex Concerts of the 1950s and the laser shows that are still programmed in some theaters. The revolution of course here is technological, the digital medium affording performers to achieve feats that were not imaginable sixty years ago. The american artist J-Walt is emblematic of this trend. Since 2006, he has been performing what he calls *Spontaneous Fantasia* in diverse dome theaters in the U.S.A. and in Europe. In his performances, he uses a drawing tablet and a color controller to live paint in a 3 dimensional space rendered in real-time that he also navigates using a joystick. The artist is clear about his motivations, "My goal is to create a wholly integrated experience for the eye, ear, and mind." (J-Walt, 2011), which are very much in tune with the claim of immediacy of the fulldome medium.

If the medium is to become equally represented in its traditional use as a teaching tool and in its artistic form, artists need to acquire the skills and the means to create in the particular technical context of fulldome. Most importantly, in the struggle of remediation, the newcomers have to make their vision of authenticity recognized by the public. At the moment, the audience is largely unaware of alternative shows that are often constrained to the particular venue that participated to the production and a few festivals. Furthermore, owners of dome theaters who consider the medium mostly as an education tool are understandably less likely to invest in a show that does not directly refer to the culture they are promoting. On the one hand, investing resources in creating alternative fulldome is a risky business, especially if you are not affiliated with a planetarium. On the other hand, even traditional planetaria must accept remediation. They have to advertise immersion and state of the art technology because that how they can keep interested an audience that has come to expect more from digitally mediated experience. However, there is no need for antagonism between the two visions of the medium, and judging from the exchange I had with planetarian and other professionals, members of the fulldome community are rather open minded and are mostly trying to build bridges between tradition and the new possibilities offered by the technology.

It is my belief that the role of the designer is to think the future not only in terms of new artifacts but also in regards to how society is organized. My assumption is that novel technical solutions can only be successful if they are supported by a will to work differently. In this chapter I am proposing a strategy for new independent productions to reach the public, but also for dome theaters to regularly provide their audience with new and exciting content. While I have previously advocated the use of open source solutions as a way for producers with modest budget to creatively realize their projects, I propose that an open organization of production can raise these projects to the level of quality necessary to establish themselves among traditional shows.

4.1 Thinking Open

Fulldome as a technological development should be understood in the context of other changes that have been associated with the dissemination of other digital audiovisual equipment — the personal computer paving the way — and the invention and popularization of the Internet. The combination of both phenomena has provided the adequate environment for new kind of social organization. Traditional social structures, such as the political state or the family, are somehow arbitrarily imposed on the individuals by factors that are mostly independent of one's will, such as where on Earth and in what culture one is born in. New technologies do not directly oppose those organizations. They cannot replace our need for institutions that create and nurture us, but they can sometimes shortcut or expand them because they allow people to organize in ways that are not possible in a world where they are physically constrained. This changes are fairly new* and we just only start to have enough experience living with those technologies on a day to day basis to see how they are changing our society. However, as controversies about social media illustrates (Turkle, 2011), it might still be hard to tell if we are gaining or losing from the change.

There is one instance were the change has arguably been and is still beneficial. The *Open Source* (OS) movement, initiated by software developers, offers a new perspective not only on software design and production but also on economics and politics:

> *"Open source is an experiment in building a political economy—that is, a system of sustainable value creation and a set of governance mechanisms. In this case it is a governance system that holds together a community of producers around this counterintuitive notion of property rights as distribution. It is also a political economy that taps into a broad range of human motivations and relies on a creative and evolving set of organizational structures to coordinate behavior." (Weber, 2004, p. 1)*

The word Open in this case is to be opposed to Proprietary. Proprietary software or hardware restricts the user by usually granting her only the right of usage, the company that created the product keeps the right to modify and redistribute it and retains its inner working secret. Proprietary is the traditional model that most people are accustomed to. For instance, when a car is bought, it is rarely the case that the blue print of the automobile and a permission to reproduce and re-distribute it be handed over with the keys. In some cases, where security of physical persons or data matters, this approach is perfectly adapted. It can also be felt as a frustrating loss of autonomy and freedom. At the moment, the production of Fulldome shows is primarily dominated by the proprietary model where only the right to project the show in a particular theater is granted (Bruno, 2010). This licensing scheme and the corresponding pricing which can vary with the size of the theater and its attendance, is more or less similar to what is custom in the film theater industry. It is certainly a valid way of doing business when using traditional production methods and distributing traditional content as it allows to share the production costs.

This is only adapted for educational shows targeted at the planetarium type of dome theaters, or artistic work commissioned by these institutions (e.g. Voices in the dark). Independent small productions and especially artistic experimentations which have little or no commercial value at the moment can not usually

* around 40 years old considering the ARPANET went online in 1969. (Leiner et al., 1995)

profit from the same support and distribution network. With the prohibitive costs of professional grade hardware and software used for fulldome production, these are the factors that limit the development and dissemination of alternative productions. I have shown that already solutions exist that can potentially reduce the cost of productions. The cube map pipeline and its open source implementation I have described is one of them, and multiple camera rigs looks like a promising approach to reduce costs of live action capture.

However, it is not tools but skilled and creative people that create quality content. The fulldome community is aware of this. When I asked about the opinion of professional fulldome content creators on open source production tools, this was well summed up in the remark that “No one ever asked Michelangelo what paint brush he used to paint the Sistine Chapel ceiling.” (Casey, 2011). The challenge is then to bring together creativity and skills. Some institutions already offers training in fulldome productions. The Ott Planetarium (Weber State University, Utah, U.S.A.), producers of commercial fulldome shows, is an interesting case because it hosts a workshop where participants create a short fulldome video using the open source 3D animation software Blender. The files necessary to render the resulting productions are then made available for download under the term of the Creative Common license, which means that the work might even be used commercially as long as it is made clear who the authors are. This initiative was inspired by the open source 3D animations productions supported by the Blender Foundation (Ott Planetarium, 2011).

The Blender foundation has released three short open animated films in the past five years. Their productions were all organized the same way. A small team — *Elephants Dream* in 2006 was created mainly by 6 people, *Big Buck Danny* in 2008 by 7 and *Sintel* in 2010 by 12 — is gathered under one roof in Amsterdam, Holland, during seven to twelve months and the work is financed and coordinated by the Blender Foundation and other sponsors. Every time the team members were different but they were all selected for their contributions to the open source project and skills at using the tool. Every film and all the digital materials that participated into the production are licensed under a Creative Common license; the Blender Foundation sells DVDs which can be freely copied and distributed under the term of the same license. The motivation of the Blender Foundation, which is also at the core of the development effort behind Blender, is to submit the software to a stress test applied through a real production scenario contributing to a better product. Indeed, during these open productions problems are found and many improvement are implemented which benefit all the users. Furthermore, by allowing the outcome to be freely shared, the project gets considerable advertisement so more sponsors are attracted and people can improve their knowledge of the tool by studying the source files. (Blender Foundation, 2010)

Blender Foundation's open projects are particularly interesting because most of the team members creating the films are not professionals. It seems that in the selection process the will to create and commit to an ambitious project is as important as competences. For instance Colin Levy, the director on Sintel, is an undergraduate student in film and television (Levy, 2011). In these projects there is opportunity for the participants to learn hands-on how to work on a close to professional production. While the outcome is not perfect, considering the risk induced by hiring an un-experience team to work with a tool that still needs improvements, the result is impressive. The value of open production is not in making money from the box office, but rather to benefit a community by contributing a show, explore possibilities, improve the skills of artists and technicians and make the project popular to attract more support. Since it allows shows to be produced more or less experimentally by minimizing the effect of failure and maximizing the outcome in case of success, this approach seems to answer some of the problems that alternative fulldome shows face. Furthermore, making it possible for any dome theater to program open content, and even charge the public for a screening without having to pay for a license, is a strong incentive for education oriented venues to participate in the dissemination of alternative shows.

The narrative behind open 3d animations is significant because it shares three fundamental similarities to open source software development. At the very core of open projects there is a similar belief that property is not the right to exclude others to use what you produce but rather the right to distribute it (Stallman, 1985; Weber, 2004). Secondly, the individuals that take part in the development are also the users and their merit is not judged on their place in a hierarchy, but on their skills and contribution to the project. Thirdly, while a hierarchy exists in the sense that a core of users-developers drives and manages the project, most of the organization happens through negotiations driven by expertise between networks inside the community and not so much by enforcing decisions from the top to the bottom (Raymond, 2000; Weber, 2004, p.173).

However, they are also notable differences in the two implementations of the open model. While the members of open software projects are usually scattered around the world and use Internet for coordination, this is at the moment not practical in an audiovisual production and people must be able to work in the same space. Likewise, the number of participants must be kept low since having people physically working together for a long period of time increases costs and needs for fundings.

The OS model has received considerable interest from researchers of different horizons but notably from the fields of software design, economics, sociology and politics. While open audi-visual production is a rather new phenomenon, there is already empirical data about what made projects such as Linux so successful. Since they share fundamental traits, it makes sense to use what is known about open source software to infer how an open fulldome production could be implemented. I have identified two documents which contains particularly interesting information about the open source project from two complimentary perspectives. The first is the essay *The Cathedral and the Bazaar* by Eric S. Raymond. It is the author's self-reflection on software design and project management based on his experience being the project owner of the *Fetchmail* open source program. The second is a book called *The Success of Open Source* written by Steven Weber, professor of political science at Berkeley (California, U.S.A.). It is an outside view of the phenomenon which attempt to understand open source from the point of view of its political organization.

4.2 Motivations, Coordination and Economic Logic

The definition of Open in contrast to proprietary falls short to address the social and organizational aspect of the OS movement which pre-dates its opposition to proprietary licensing. In 1969 Ken Thompson, a computer science researchers at Bell Labs, created in a month a small and simple operative system called

Unix. This famous piece of software became massively popular and successful for three reasons. To begin with, its simple design and the fact that it is distributed in the form of source code readily modifiable, allows it to be installed on a wide range of hardware. Secondly, Unix has a built in modularization mechanism, the pipe, enabling users to interface different programs with each others. This feature created a paradigm shift, as simple programs could now work together like a versatile toolbox instead of being complex and specialized but incompatible. Finally, a community of users, mainly made of researchers and students at the beginning, started contributing and sharing programs and bug fixes. By giving each other support they helped spreading the operative systems around the world to other academic institutions and later to businesses. (Weber, 2004, pp. 25–33)

Unix, however, is not an open source software as its source code is distributed by vendors who can make proprietary modifications to the code without sharing it with the users. It is only later, mainly through initiative such as GNU and Linux, that the Open Source software movement was born. However, while their is a strict difference regarding copyright and property issues between the proprietary Unix and other OS softwares, the organization of the development effort is very similar in both cases and revolves around three principles:

1. The core of the project is created by one person or a small team.
2. The system is modular, so that functionalities can be worked on separately by multiple developers.
3. The users, by contributing in more code, fixes or support to other users become developers and form a community.

In the case of OS, there is an additional fundamental:

4. The source code is shared freely, it can be modified and its distribution is encouraged.

4.2.1 Initial Development and Motivating Participation

To my knowledge there is no OS project that was built from the beginning by a heterogenous group of scattered developers. There is always a smaller group of people that work closely together (e.g. Ben Fry and Casey Reas for Processing), and in some case a single individual (e.g. Linus Torvalds and Linux), to originate the project. Like any designers, they do it out of the need of creating something that is not available, or because they are not satisfied by the existing tools. For diverse reasons, often ideologic or financial, the original authors decide to release the source for free so that others can use it and build upon the work. If users find the solution interesting and see potential in pursuing its development then a community starts to form around it. Sometimes the original authors remains the leader, also called the owner of the project, usually by implicit agreement, and supervise the development effort (e.g. Ton Roosendaal and Blender). Some other times they can decide to pass on the responsibility to another person or group (e.g. Fetchmail originated from the program *popclient* by Carl Harris before being passed on to Eric S. Raymond (2000)).

If the model is to be transferred to audiovisual production, this organizing principle would still apply as someone must originate an idea for a production and the idea needs to be interesting to others so that they would accept to take part in the project. An OS project is not self-organized by a state of nature (Weber, 2004, p. 132), but is allowed to grow if it attracts enough users to make it relevant and volunteering developers to keep it alive. Thus, the viability of an OS project is first a question of vision and leadership (Raymond, 2000). This of course is not limited to OS but applies to any projects that requires a certain amount of resources to be invested in its creation. However, OS does not compensate its contributors with a salary like conventional work organization models, hence the project must provide something else in return.

The personal motivations to take part in an OS project seems to come first from the enjoyment of solving challenging problems and sharpening skills in the process. This motivation is also present in proprietary projects, but OS offers the freedom to actually choose what kind of challenge to take on. As a corollary, the prospect of proving yourself that you can match new challenges while being able to share your creation plays an important motivational role. It is also a reason for participant to try and come up with the best solution, and not only a working solution, in order to build a reputation as a talented practitioner. There is of course also the satisfaction of participating in a project that others can benefit from. (Raymond, 2000; Weber, 2004, pp. 135-144)

These motivations, and especially the 'ego-boost' of solving a difficult problem and the building of a reputation, are relevant in the context of innovative fulldome shows. Since they are fewer fulldome productions than productions for more conventional media, and since only a few of them are actually programmed in many venues, this personal motivations can be leveraged as an open source fulldome project can potentially count on an a better public visibility. The economic value of reputation that is gained from participating in an OS software project needs to be downplayed because it has not been verified that in facts its plays a major role in career improvement, or that it generates a behaviour that tries to maximize reputation inside the OS project (Weber, 2004, p. 143). However in the specific context of fulldome productions since the community is small, and skilled and experienced creators are scarce, reputation might be much more valuable. Perhaps the story of Colin Levy, the young director of the latest Blender open film project, who was offered a 12 months position at the Pixar studio after his participation on the OS project can tell something about the value of reputation in the context of open source audiovisual production (Levy, 2011). Finally, working with the fulldome medium with its unique features and technical requirements is in itself a considerable challenge that can generate interest.

4.2.2 Thinking Modular

Open source project work best if people can participate at different level and find an outlet for their expertise or creativity. This is logical if one agrees on the previously described personal motivations of participants. It also seems that the work should be kept enjoyable, that is a positive frustration should come from interesting problems to be solved while negative frustration from a complex project structure should be avoided. In other words, if the organization of the work and the production design requires too much effort from the volunteers, they will loose motivation. Conversely, if the infrastructure helps the participant to solve problems it will increase the motivation. OS software projects tackle this problem by relying on a modular design inspired by the development of Unix which distribute the complexity in smaller chunks. (Weber, 2004, p. 164-165)

I believe this can also inspire open source fulldome productions in designing ambitious but manageable projects. When I asked some fulldome professionals what they thought about open source production, one concern was about having to coordinate people at different location without hierarchy when it was already hard to deal with a production team under the same roof (Fletcher, 2011). My answer was that tension and communication problems are inherent to any collaboration and that OS software projects managed to deal with the problem although most of their participants never met in person. This is made possible because the structure of the system follows the structure of the organization that is building it, a phenomenon known as Conway's law:

"organizations which design systems (in the broad sense used here) are constrained to produce designs which are copies of the communication structures of these organizations" (Conway, 1968)

OS projects are constantly facing coordination problems since they are not organized by a strict hierarchy. Hence modularization which makes explicit the need for interfaces between small semi-autonomous parts echoes the need of developers to make technical decisions that closely follow how the way they discuss to work together (Weber, 2004, p. 174). Blender open projects gather all the participants in the same studio because the coordination needs to be tighter as the tool developers must be responsive to the need of the artists and the artists must be responsive to the needs of the director. What coordination model should open source fulldome production follow?

I was suggested an interesting possibility by Tom Casey, which pointed out that Hollywood productions such as *Independence Day* sometimes get special effects done in parallel by multiple studios because of time constraints. However, to ensure that the outcome is consistent with one artistic vision, rather than looking like it comes from various producers, it is crucial that the creative side of the production guides the realization (Casey, 2011). Thus, it seems possible to have a modular and distributed approach to audiovisual production as long as the leadership remains in the hand of the creative. As it has been noted in previous subsection, an open source project in order to federate participants requires a vision, and leadership is often granted implicitly to the person or group which initiate the project. However, this does not mean that a dictatorial model should be enforced as it would not work in an open source context. On the contrary, the creative side should be responsible to provide the technical side with interesting challenges.

4.2.3 Users, Contributors and Sponsors

In the particular context of fulldome production, tools are costly, access to a dome theater is necessary and a particular skill set is needed to work with its particular screen. The consequence for an open source project is that it must be overseen by an organization that can provide monetary support and qualified personnel. For this reason, a business model must be developed in order to recover production costs and finance future projects. They are many possibilities. For instance, the Blender Foundation gets funding by selling DVDs of the open films, but also documentation and tutorials on how to use Blender as well as other accessories. It also receives funding through donations and sponsors. While the Blender Foundation is a non-profit organization, open source does not mean it has to be that way. Red Hat is one of a number of companies that make money by packaging and distributing Linux. The authors of the open source hardware project Arduino, an electronic prototyping board, retain the brand name and manufacture and sell ready to use boards.

I must admit lacking the knowledge that would allow me to present a solid business model adapted to open source fulldome production, but I can make some suggestions. From the success of productions created by partnering organizations (Bruno, 2010), bringing several institutions with different skills and perspective into the production, and thus sharing not only the initial cost but also authorship seems like a good idea. Furthermore, these institutions will be the developers but also the end users in this model, and as such they would be in the best position to influence what is being produced and can profit fully from the result of the production in terms of know-how and publicity. An open source fulldome production can also be seen as a first step towards a commercial production, and a way to attract interest from investors.

A possible source of income could come from accessorizes to the shows, such as posters, DVD of the show formatted for regular screens, etc... It could be agreed that major dome theaters provide those items in their gift shop in exchange for the right to program the film. This type of negotiations that implicate the end user of course demand that the show be of high quality. Other possibilities include selling post-production services, such as rendering in higher definition and re-tilting or translating the show for a specific venue. Besides the necessity of collecting funds, an open source project needs the contribution of its users. Large theaters house several powerful computers as part of their projection system. One idea would be to set up a distributed rendering system for fulldome production and volunteer some of the processing power of these units to calculate 3D renders. However, to be implemented this might require a degree of cooperation between dome theaters that does not exists yet.

The type of venues that has the strongest growth is the portable dome. Since it does not have the image definition of a solid large dome theater, less resources are required to create content for these venues. Hence, first open source productions could start by targeting this market as it allows to relax the technical constraints while still potentially touching a large public. Since the principal goal is to develop and disseminate an artistic proposition for fulldome content, it is important to not forget the lower scale of theaters. Furthermore, it is probable that an experience that is successful inside a small dome will probably be amplified by a larger projection surface.

5 Conclusion

Although this project started as an animation production, my interest gradually shifted to fulldome production tools and organization. I discovered through my research that fulldome is part of an ongoing mutation of the planetarium culture. Using the theory of remediation as a probe, I was able to examine and understand what was happening not only at a technological level but most importantly in the more complex contexts of culture and society. What I gained from this study is a broad understanding of the environment fulldome operates in, who are the people that are most affected by it, how this new medium challenges traditions and what are its affordances. In parallel, I followed a hands on approach to fulldome production instigated by my original goals, involving a combination of do-it-yourself experimentation and open source practices. This resulted in the design of a production pipeline based on the cube map technique, and also the design and implementation of CubeAnimator, an open source software to assist the manipulation and animation of cube maps. Synthesizing my knowledge of the context and the understanding of the technology, I proposed an open source strategy for alternative productions to sustain artistic research of the medium by making its outcome attractive and featured in the programs of dome theaters, and thus helping the dissemination of a new genre.

Approaching the subject from the point of view of design allowed me to reflect about creative thinking. In particular, I took the opportunity to use this thesis as a case study to evaluate a model of design as an activity. This model, which has been called bricolage in reference to the analogy formulated by the anthropologist Claude Lévi-Strauss, came about by thinking about creativity and do-it-yourself, or how being constrained fosters the exploration of new possibilities and can lead to successful designs. I discovered that this model had been further developed as a metaphor for design by Panagiotis Louridas, and thus I used his work as a base to develop my own understanding of design as bricolage. In order to evaluate its relevancy, I used bricolage to analyze and discuss my own process. Not only did bricolage provide a good mental framework to gain knowledge on how I approach design, it also helped me formulate the design problem. I believe this model is helping me become a better designer as I can rely on it to get a clear image of how design happens. On a more academic note, getting to know some of the trends in design research made me aware of the questions design researcher are trying to answer which makes current discussions on the topic of teaching design much clearer and interesting.

This thesis shows that fulldome is a very complex phenomenon, and I have had to work under many assumptions because I am not involved in the industry. On the one hand, as an outsider I have provided a different point of view on the medium. On the other hand, since I cannot claim that my logic is based on facts, the implications of my arguments are very sensible to my hypothesis being correct. In particular, the question of the viability of alternative productions is pivotal in supporting my proposition of an open source strategy. I can foresee that my propositions will be received with skepticism by many. However, I am sure it will be considered and discussed by the fulldome community, as I found it to be very open and aware that its culture is at a turning point. For every members of the fulldome industry, this is a moment of negotiations and adaptation from one model to the other and therefore I look forward to the coming years as they will reveal which of my assumptions proved to be facts.

I have sent an early version of CubeAnimator to Paul Bourke, associate professor at the University of Western Australia, who has contributed several papers on the subject of fulldome, notably on a projection system using a projector and a spherical mirror, and whose web site has been a tremendous help in writing the software. His first comments have been very positive and he has already suggested some improvements to my original design, such as supporting equirectangular projection in addition to cube maps to make its use easier for people working with equipment like the LadyBug camera. He has also mentioned that he is working on a production where the tool might prove useful. At the moment, only a handful of people are aware of this project and thus my next step will be to announce its beta release, an invitation for others to test the tool and comment on its functionalities. I hope it will receive the same positive feedback and attract other developers.

I am still contemplating the production of a short fulldome video, and now that I have been able to setup a production pipeline free from proprietary software I can start to experiment with different ideas. My goal is to present the result as open source project at the next Fulldome festival, but much work remains to be done in terms of artistic research. In a way, I am back where I started but with the advantage of being able to count on a much better understanding of the medium, not only from a technical stand point, but also in terms of visual composition. I have completely omitted the question of sound in this thesis, hence additional technical research will be required, but since dome theaters surround sound systems are common to other theaters, it should be easy to find skilled people to help me.

Sound is not the only aspect of fulldome that I have not investigated. Interactive and real-time generated content are among the subject that are highly relevant to the medium and would really benefit from practical research. If alternative content comes to play an important role in the future market of fulldome shows, then interactive performances will certainly be among the most successful ones. I believe that at the moment this type of content is still very experimental, and not only in the context of fulldome, and a stylistic language coherent with and specific to the medium needs to be developed further. There is an opportunity for interested artists and designers to participate in shaping the future of this new medium.

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A: Word Count Analysis

The words found by the text analysis software are manually sorted into themes. A score for each theme is calculated. This score is represented by the size of the text in the figure. Table 6 and 7 illustrate how the words have been sorted and the scores calculated based on the number of words per category and the number of occurrences of the words.

Themes	Technology	Architecture	Experience	Audience	Education	Astronomy	Total
Words(occurrences)	technological(2), instrument(2), equipped(2), multimedia(2), technology(2), machine(2), modern(2), screen(2), latest(2), realistic(2), precision(2), animation(2), panorama(2), image(2), brightness(2), light(3), music(3), projected(3), computer(3), laser(3), slide(4), zeis(5), projection(5), effect(6), video(6), system(6), projector(10)	capacity(2), theatre(2), domed(3), seat(3), building(3), diameter(3), Dome(8)	motion(2), wonder(2), recreation(2), enjoy(2), visual(2), entertaining(2), flight(2), gazing(2), real(2), live(2), dazzling(3), entertainment(3), movement(4), experience(5), journey(5), unique(5), special(8)	audience(2), youth(2), children(3), group(4), people(5), visitor(6), public(10)	classroom(2), teacher(2), history(2), historical(2), information(2), understand(2), taught(2), book(2), lecture(2), learn(2), campus(2), preschool(2), illustrate(2), dissemination(2), finding(2), natural(2), talk(2), geography(2), physic(2), discovery(2), explain(2), question(2), course(2), exploration(2), observe(3), research(3), observation(3), discover(3), learning(3), education(3), teaching(4), knowledge(4), presentation(5), educational(5), student(6), school(8), science(8)	ecliptic(2), horizon(2), nasa(2), saturn(2), coordinate(2), lunar(2), eclipse(2), mars(2), celestial(3), milky(3), space(9), moon(9), world(5), universe(5), solar(4), starry(3), scientific(3), telescope(3), earth(5), constellation(6), sun(6), astronomical(7), planet(7), night(7), sky(10), astronomy(12), star(12)	
Words count	27	7	17	7	37	27	122
Combined occurrences	92	24	53	32	106	135	442
Average occurrences	3.41	3.43	3.12	4.57	2.86	5.00	
Normalized combined occurrences	0.21	0.05	0.12	0.07	0.24	0.31	1
Weighted average occurrences	0.71	0.19	0.37	0.33	0.69	1.53	
Score	46	12	24	22	45	100	

Table 6: Non-fulldome text analysis

Themes	Technology	Architecture	Experience	Immersion & Interactivity	Education	Astronomy	Total
Words(occurrences)	technical(2), technological(2), projected(2), mechanical(2), optical(2), software(2), advance(2), definition(3), multimedia(3), light(3), upgraded(3), fulldome(3), digistar(3), skan(3), digitalsky(3), imax(3), laser(3), movie(3), developed(4), feature(4), traditional(4), music(4), audio(4), effect(4), display(5), advanced(5), powerful(5), sound(5), computer(5), screen(5), latest(5), equipped(5), film(6), modern(6), resolution(6), visual(6), equipment(7), special(7), image(10), video(10), new(13), technology(14), projector(14), projection(14), system(16), digital(22)	hemispherical(2), dimension(2), shape(2), surface(2), surrounding(2), infrastructure(2), open(2), ceiling(2), large(2), circle(2), covering(2), sphere(2), shaped(3), big(3), building(3), facility(3), largest(4), seating(4), domed(4), surround(4), room(4), wide(5), capacity(6), around(7), diameter(8), seat(9), dome(20)	dazzling(2), fidelity(2), realism(2), natural(2), fascination(2), fascinating(2), ultimate(2), extraordinary(2), amazing(2), quality(2), entertaining(2), enhanced(2), fun(3), original(3), stunning(3), wonder(4), inspiring(4), awe(6), enjoy(6), unique(6), spectacular(6), experience(16)	explore(2), fly(2), discovery(2), interaction(2), traveling(2), panorama(2), immersion(2), seamless(2), virtual(2), imagination(2), reality(2), navigation(2), exploration(2), motion(3), movement(3), discover(3), environment(3), simulate(3), accurately(3), travel(4), feel(4), immersive(6), journey(6), interactive(6), live(7)	explanation(2), informative(2), data(2), workshop(2), didactic(2), visualization(2), observation(2), learn(2), educational(3), understanding(3), information(3), understand(3), question(3), research(3), knowledge(4), activities(4), presentation(5), education(5), science(13)	heavenly(2), mythological(2), comet(2), heaven(2), moon(3), nature(3), astronomer(3), galaxie(4), cosmic(4), starry(4), solar(5), phenomena(5), celestial(5), earth(6), constellation(7), night(7), astronomical(7), universe(12), time(12), astronomy(12), world(12), planet(13), sky(15), space(19), star(22)	
Words count	46	27	22	25	19	25	164
Combined occurrences	262	111	81	77	75	188	794
Average occurrences	5.70	4.11	3.68	3.08	3.95	7.52	
Normalized combined occurrences	0.33	0.14	0.10	0.10	0.09	0.24	1
Weighted average occurrences	1.88	0.57	0.38	0.30	0.37	1.78	
Score	100	31	20	16	20	95	

Table 7: Fulldome text analysis

To begin with, the number of words for each theme (Words count row in the table) is counted. Then the numbers of occurrences for each word are summed up (Combined occurrences row), an Average occurrences is calculated by dividing the Combined occurrences by the Words count.

$$Average\, occurences = Combined\, occurences / Words\, count$$

The reciprocal of the total of *Combined occurrences* is multiplied with the *Combined occurrences* of each theme to produce the *Normalized combined occurrences.* This value is used to weigh the *Average occurrences* for each theme by giving more importance to the number of occurrences than to the number of words. This explains why “Technology” has a higher score than “Education” although this theme contains 10 more words than the other. Multiplying the *Normalized combined occurrences* with the *Average occurrences* row gives the *Weighted average occurrences* for each themes.

$$Normalized\, combined\, occurences = \left(\frac{1}{\sum (Combined\, occurences)}\right) \times Combined\, occurences$$

$$Weighted\, average\, occurrences = Normalized\, combined\, occurences \times Average\, occurences$$

To get the final score, the theme with the highest *Weighted average occurrences* is assigned the score of 100 (in this case “Astronomy” has the score of 100). The scores for the remaining themes are then calculated by multiplying the quotient of 100 divided by the highest *Weighted average occurrences* (bordered with red) with the *Weighted average occurrences* of the theme.

$$Score = \frac{100}{Highest\, weighted\, average\, occurrences} \times Weighted\, average\, occurrences$$

B: Fulldome Show Analysis Methodology

In order to be a useful tool for the discussion, an appropriate methodology should allow to apprehend every shows using universal features as opposed to specific elements. Since fulldome shows belong to the big family of moving pictures it seems appropriate to approach the task by looking at traditional film analysis methodology. Consequently, the approach used in this work is based on a methodology for film sequences analysis developed by Laurent Jullier, professor at l'Université Paris III (Jullier, 2006).

It adopts the American logician Charles Sanders Peirce's (1839–1914) division of all that can be perceived in three fundamental categories, Firstness, Secondness and Thirdness, also known as Quality, Reaction, and Representation. Peirce created the three categories as an echo to the work of well known philosophers Aristotle, Kant, and Hegel. The original concept comes from the text "Categories" by Aristotle where he made the proposition that everything that can be experienced falls in ten groups or categories. In other words, by using those ten categories it is possible to describe all that can be experienced. Peirce would later propose that only three categories are actually necessary. The American logician gave the following definitions of his divisions (Peirce, 1904):

Firstness is the mode of being of that which is such as it is, positively and without reference to anything else.

Secondness is the mode of being of that which is such as it is, with respect to a second but regardless of any third.

Thirdness is the mode of being of that which is such as it is, in bringing a second and third into relation to each other.

While never giving an absolutely clear definition of his universal categories, Peirce would apply them all through his work. Those rather abstract definitions need an interpretation to be useful in the context of film sequences analysis and mapped to three questions the analyzer should answer.

What am I being told, what events am I witnessing? Returning to Peirce's definitions, "That which is such as it is" is the subject or phenomenon itself. In other words it refers to an image, a sequence from a film or a fulldome show. "Positively and without reference to anything else" means that the subject is seen for itself, without needing anything outside itself or even inside itself to exist. It is the pure quality of the subject, it is the answer to the question "What is it?" when the context is a frame extracted from a dome show (Jullier, 2006). They are three possible answers, depending if you are "seeing through" the picture, "seeing in" the picture or "seeing it as" it is (ibid.).

- "Seeing through" refers to the virtual worlds suggested in the picture (e.g. a spaceship floating in deep space).
- "Seeing in" refers to the model that have been used to produce the image (e.g a tridimensional textured geometry in a tridimensional scene rendered to a two dimensional image and mapped to a circle using an angular fisheye projection).
- "Seeing as" refers to the material directly in front of the viewer, namely the inner surface of a dome where beams of colored light are being projected.

For the analysis, the "Seeing through" and "Seeing in" perspectives are the most interesting as they give information about the genre of the show and the media used (2D/3D, photos, video). "Seeing as" and the technical aspect of fulldome video production is more relevant to the production part of this thesis.

How are those events presented, and what are the means of expressions employed for this purpose? Or as Charles Peirce would put it, experiencing the subject "with respect to a second but regardless of any third". The focus is on the techniques that support the narration. Elements like the usage of the space in the frame of the dome, the movement of the camera, the point of view and the lighting are combined to deliver the message of the show (Jullier, 2006).

Why are those events told this way and not another way? Finally, by combining the two previous categories, the meaning of the show can be interpreted in the context of the fulldome system "in bringing a second and third into relation to each other" and give clues as to how the medium enhances the message.

C: Questions to the Fulldome Community

I would like to have your opinion as dome theater managers, show producers and projection system vendors about some questions regarding fulldome show production and distribution. I'll first directly give you the questions and then give you some explanation that hopefully will clarify them:

A) What is you opinion on the value of non educational, non astronomical content in the Fulldome market?

B) What is you opinion towards open source fulldome production tools ? Are you using them?

C) Would you be interested in taking part in fulldome open source production (e.g. Elephants Dream (6) or Big Buck Danny (7))? Can you see any major problem that would prevent this model of production and distribution to be implemented in the context of dome theaters?

These are the main questions I'm trying to address as part of my master's thesis and it would be very valuable to have the point of view of member of the industry. I thought it would help to contextualize these 2 questions if I told you a bit more on what I have gathered so far:

Question A:

My earlier researches have made me realize that although digital Fulldome projection systems are getting more and more widespread, in major planetaria as well as in smaller ones and mobile inflatable dome theaters, it also had an impact on the organization of production (1). However, the nature of the content of main stream productions has not changed much, and it seems that mostly dome theater present educational show about astronomy.

On the other hand, the technology has facilitated the entry of new artists with a non-traditional vision on the type of content, which shows can be seen in festival like the Fulldome Festival in Jena. However, it seems that these productions are rarely programmed in other dome theaters (this is a personal observation after visiting planetaria in Finland and India and looking on the web at what was being programmed in different venues).

Question B:

For this project, my core user group is made of producers with modest resources, like university or schools that would like to create custom content. Looking at production tools, I see that they are some open source or free software that can be used for this task such as Blender which has a Dome Mode in its game engine (3) or Stellarium (4), a free open source planetarium software. They are still a lot of other tools that one would need to produce a show. However, at the moment it is still common to use quite expensive commercial package (3D software/renderer - e.g. Autodesk's Maya, editing/post processing software - e.g. Adobe's After Effects) which are not specifically designed for Fulldome, those functionalities being added by proprietary plugins (e.g. Sky-Skan's DomeXF After Effect plugin).

Question C:

I can already see that the Fulldome community is quite open and organized on-line. They are dedicated websites (e.g. http://fulldome.ning.com), how-to's and active forums (5). I'm wondering if this community could leverage the skills and expertise of its member to create show together in the spirit of those open source 3D animations given as example.

References:

(1) http://www.blooloop.com/Article/Trends-in-Fulldome-Production-and-Distribution-The-Paper/84
(2) http://www.imersa.org/index.php?option=com_content&view=article&id=199
(3) http://wiki.blender.org/index.php/Dev:Source/GameEngine/2.49/Fisheye_Dome_Camera
(4) http://stellarium.org/
(5) http://groups.yahoo.com/group/fulldome/
(6) http://www.elephantsdream.org/
(7) http://www.bigbuckbunny.org/

D: DVD Content

The data DVD that comes with this thesis contains documentation about my different experimentations in fulldome content creation and the tools I have created and used in my research.

It is divided in 7 folders:

Blender Plugin: A python script for the 3D animation software Blender. It integrates into the UI of Blender and allows to simply attach a cube map camera rig to any camera. Released under MIT license.

CubeAnimator: A C++ software that helps to animate and convert cube maps into fisheye. The code source and the QtCreator project is provided as well as a binary for Mac OS X. The folder also contains a demonstration video and the material used in the video. Released under MIT license.

DIY Fisheye: Photos taken with a do-it-yourself fisheye lens made from a door viewer.

GoogleStreetView: Panoramas and fisheye extracted from GoogleStreetView.

Processing: Processing sketches written to understand cube map to fisheye conversion and a cube map sketching prototype.

Videos: Small animations tested in a dome and visualizations of cube map conversion.

Word Count: The data collected for section 2.2 and the java program used to count words.