Three-Dimensional Representation in Visual Communication of Science

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Abstract. Technology has been used to communicate complex information and brought opportunities for science development and science communication. Three-dimensional representation systems allow design to use image and video in innovative ways and enable organization of more suitable content for effective understanding. This paper addresses the use of three-dimensional representation systems to disseminate complex concepts related to science. We reviewed its course from scientific illustration of natural species, to the use of detailed infographics as direct communication in newspapers. We also undertook visual experiments to demonstrate the use of such three-dimensional representation systems in science communication, and proceeded with an evaluation from experts. This research allowed us to find connections between visual communication and complex concepts coming from science. Three-dimensional representation systems have features which generate benefits for science communication and understanding.

Keywords: Science communication · Three-dimensional representation systems · Theoretical photorealism · Visual communication

1 Introduction

Throughout history, design has found ways to produce content suited for audiences with whom it communicates. This study sought to understand the evolution of three-dimensional representation systems in visual communication, gathering examples related to cinema and image production, as well as audiovisual media, with its focus directed towards visual communication of science. Based on the need to explore through images, a universe as vast as that of science, the study pursued to find examples and to understand the role of three-dimensional representation systems in visual communication of scientific areas, nowadays and throughout recent history. A small experiment was carried out and an evaluation was made to assess the relevance of three-dimensional representation systems in scientific communication, with positive results.

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2 Theoretical Framework

2.1 Big Data

Our days are filled with technological advances which enables production of large amounts of information. According to Gadepally and Zachary [1], sources of information are also derived from social behavior on the internet and social networks. They depend on our present context to become a more visible flow. An explicit problem arising from technological ambition, according to Chavez [2] is the unbearable amount of information produced which has to be stored and archived in an accessible way for later use. The problem of information production and its consequent management is called 'big data'. This problem triggers other concerns related to communication in general. Based on the excessive volume of knowledge from most diverse areas, population stands exposed to a dense variety of information which is sometimes not authentic or beneficial. Chavez [2] suggests we live in a period where data grows further critical and where several times it goes unnoticed. The design action on problems of large amounts of information for a broad public is called information design. This area of design finds ways to act and present society with means to organize its communication. It has been growing and attending the 'big data' problem.

2.2 Visual Communication of Science

Science communication can be defined as the transmission of complex concepts of rigorous detail, derived from analytical study, to the public through accessible language. By consequence it should encourage an easy understanding. For communication to be effective, different communication agents, such as journalists, researchers, politicians, but also design professionals need to filter contents generated by everyone in the scientific community. These several agents also need to define key points, transmitted afterwards to the public through written, scientific papers, or magazine articles, posters or conferences; or by images as infographics and scientific illustrations [3].

The concept of scientific illustration is closely linked in its origin to detailed design of animal species, associated with biology. Since the beginning of scientific exploration, scientists have felt the need to represent, through illustrations, natural phenomena related to their fields of study, such as, botany or geology [4]. Scientific illustrations have assumed ever since, the importance of a scientific document, as they complement written descriptions and visually document information regarding the object of study. Such illustrations were like proofs of the discoveries [4], they became essential to knowledge in a time where photography still did not exist as a way of register reality. For that reason, these drawings served the purpose of recording in an analytical and impartial way, the object of study [5].

Before the 1970s, NASA visual communication artists worked in conjunction with Disney and other entities such as Chesley Bonestell, designer and illustrator, to engage readers in exploring themes as space. Images can function by themselves, by presenting something that attracts attention and creates interest or curiosity. For this reason, innovative representation systems are used in visual communication of science. The use of three-dimensional images for exploration of a concept has been gaining a presence in visual communication of science for the advantages these systems present.

2.3 Reach for Realism

The use of digital technologies for imaging has been a trend, as reported by Trivedi [6]. The digitization of the world and creative ideas have been codified in increasingly complete digital software. However, since the beginning of the 21st century, an initiative has taken place to introduce three-dimensional representation of objects as a way of visual communication. One of the main characteristics associated with these technologies is the close representation of our observed reality. This sense of realism as obtained by three-dimensional generated images known today is the result of advances in technology. According to Wong [7], software has experienced accelerated evolution, accompanied by exploration of computers and their capabilities.

The relationship between three-dimensional representation systems and science communication depends on the ability to represent a method in a realistic, precise and objective manner. It is necessary three-dimensional systems can guarantee this requirement with rigor, for this connection to be established. Nowadays, technical capacity is able to produce photo realistic quality content, as there was certainly a need to overcome past problems in representation.

Lack of realism in representing objects occurs directly linked to the problem posed by Masahiro Mori, which he defined as 'uncanny valley.' Mori [8] presents the concept of robotics and the construction of mechanical models of human figures. Mori describes construction of robots with human attributes runs the risk of causing repulsion when contacting real users. Like Wong [7], Mori [8] mentions that the human being is very incisive to find details and characteristics, both of form and behavior, of other individuals. For this reason, details which are not genuine are assumed to be non-real or simulated. Like human behavior, the concept of 'uncanny valley,' introduced by Mori, also applies to other transpositions, mechanical or artificial, in the real world.

To illustrate the problem, Mori elaborated a graphic, which we adapted in Fig. 1. It is possible to identify that the basis of proximity between humans and machines, considered by the author, are industrial robots (A).

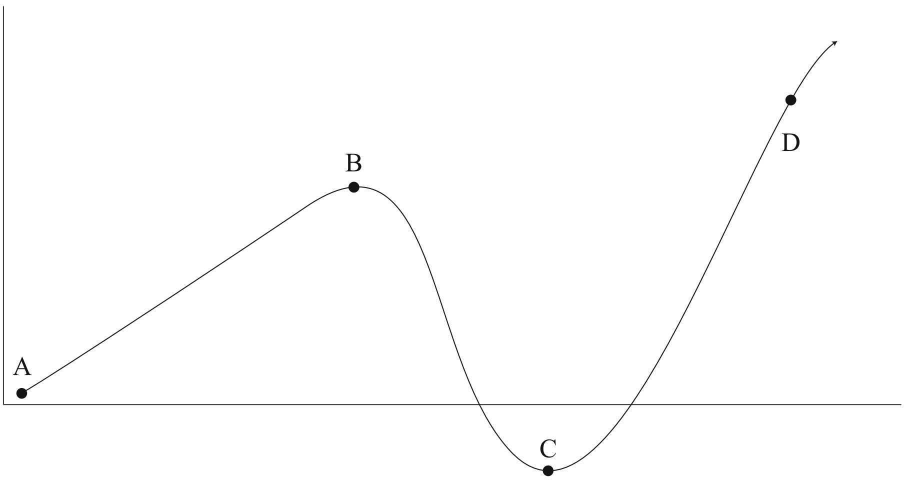

Fig. 1. Index of realism, adapted from Masahiro Mori.

They do not have any direct relationships with humans as their function completely dictates their construction, behavior, and appearance. At a second level we can find stylized and unrealistic robots or representations such as dolls and toys (B). There are anatomical relationships recognized but exaggerated, such as the ASIMO robot, and placed outside real understanding. Finally, there is a peak where human/machine relationship is lost, which is interaction with another human individual (D). However before this, is where 'uncanny valley' appears. The relationship between mechanisms and their objectives is very close but very distant concerning similarity between themselves and their users. The perception of reality and its transformation into something material has been the subject of a change on the part of artists.

According to Scott [9], engineers and visual artists will constantly have the will to achieve a replica of human characteristics. Taking a specific case, it is possible to verify that robot Sophia presents a set of factors associated with the human figure, the relationship between its mechanisms and its objectives are very close, but very distant in terms of similarity between it and its users (C).

The same objective is sought in the field of visual communication. Conceptual artists who produce visual elements for films also encounter the problem of transposing real-world details into digital environment. As Scott [9] points out, the connection between general public and cinema easily denounces a weaknesses which digital representation still presents. Nowadays, many effects are invisible, and software produces photographic quality images. However, reaching this level required creative and technological decisions.

2.4 Evolution of Three-Dimensional Representation Systems

Three-dimensional representation systems owes part of their growth to cinema. An example of the importance of using three-dimensional representation systems is observable in the 1993 film 'Jurassic Park'. Under the direction of Steven Spielberg, animatronics were first used to represent dinosaurs. However, it was necessary to produce more complex movements which required a rethinking of how to provide them. Three-dimensional representation systems were used to create a product that could not be made otherwise. Throughout the history of modern cinema, over the last two decades, three-dimensional representation systems have gained more visibility and importance as a way of creating illusions and providing innovative experiences to the public.

In 2009, another milestone was reached in the use of digital animation in three dimensions with the film 'Avatar' under the guidance of its director James Cameron. In the film an essential improvement was introduced to blend real actors with digital elements. In this way, it became possible for the director to instantly understand the relationship between his actors and their future interactions, when the film was delivered to the digital effects team. According to Wong [7], approximately 70% of the film was produced thanks to introduction of real-time rendering in digitally recorded scenes. Afterwards, actors interacted with each other as characters, while the camera captured digital environments around them, and from a real-time channel, the director could have a low-quality simulation of how the scene would be, before of it being rendered. The effect, called real-time rendering, has been increasingly used in film, advertising, and video games.

In 'Avatar,' James Cameron used yet another innovative method called 'motion capture' that allows real actors to play animated characters. This effect is created through a point triangulation system drawn on the face and clothes of actors, are recorded by a series of cameras and localization sensors which map their movements. All movement data is applied in a three-dimensional system, and a simulation of character gesture is generated in conjunction with real-time rendering system.

The detail achieved by advances and decisions made throughout history has allowed a spectrum of uses of three-dimensional systems to be expanded and exploited in other areas: from advertising and graphic design to science communication.

2.5 Representation of Scientific Concepts

It is worth introducing a critical concept to establish the link between three-dimensional representation systems and science communication. Alan Warburton [10] presents the idea of 'theoretical photorealism', which is based on image composition to simulate, predict or represent concepts that do not have photographic records. According to Warburton, there are elements beyond the reach of human vision, and whose presence is confirmed, which can be represented according to this theory. Planets and celestial bodies, cells and microscopic features can be represented, but also atmospheric effects such as the presence of wind or temperature. The need to present images about these phenomena is a matter of science communication. The importance of three-dimensional representation of images related to science has been evident in the last decade since digital systems have had their growth and evolution.

Between Design and Science. In the science fiction film 'Interstellar' (2014), directed by Christopher Nolan, a black hole, called Gargantua, which assumes the central dramatic tension of the film is represented. Nolan, known for using practical effects in his movies, conducted the recording in real-world spaces, using different locations to represent different moments of the film. However, due to the lack of real images of this space phenomenon, Nolan used three-dimensional rendering technologies to generate black hole images.

As in previous cases, the lack of capacity to respond to a creative need was the driving force for advances in digital technology. Huls [11] states that the way we visually represent scientific concepts tells a lot about how we think of them at the moment they are represented.

From a scientific point of view, this is an initiative to represent phenomena still to be explored visually and hence generate material for dissemination of its respective area. The scientific community, according to Wong [7], has features which are not accurate enough to present compelling visual conclusions. All communication in the film, whether dialogues or astronauts suits, were thought to convey confidence to the viewer, to give the impression everything being transmitted was a representation of the real world [12]. In this way, the presence of any effect would have to be as real as the rest of the film. Special effects studio Double Negative was in charge of space plans and black hole views. Mathematical knowledge of astrophysicist Kip Thorn was used, which was committed to build scientific facts, which in turn, led to special effects being made.

This case demonstrates the importance of using special effects as a way of producing realities, but also how three-dimensional representation systems assume significance in science communication to the public. Collins [13] refers to the effects of 'Interstellar' as the bridge between art and science.

In the same way, Warburton [10] points out the development of three-dimensional computation and that the 'Interstellar' case is part of his 'theoretical photorealism' category. It describes mathematical theories with tested and validated fundamentals may be subject to visual interpretation by digital artists. According to Warburton, representation of the black hole as presented in the film exposes a phenomenon scientifically proven, but never observed or captured by a conclusive image. The interpretation of the concept is presented as a visual simulation, not as a real proof.

3 Experiment and Evaluation

A small three-dimensional system for visualizing scientific communication was developed. This experiment used the presented concepts and consisted of creating images of planets, produced according to Warburton 'theoretical photorealism' and based on an applied study of 'procedural textures'. Composition of complex materials for application in a spherical model allows the design of various profiles and representation of planets, specifically controlling their factors and relations.

According to Hurt [14], the method to generate representations related to astronomy, namely planets, is based on association and knowledge collected during research done in this scientific area. Taking into account the requirements to represent planet Earth, we have considered mandatory aspects to be present in the model, namely oceans and continents, rivers, poles, mountains and valleys, as well as simple effects such as clouds and atmosphere. The system allows users to change any value to produce a completely different result, depending on communication needs.

For this study, we developed 24 images, to test the use of three-dimensional representation with visual communication of science. Figures 2 and 3 are examples of this procedure.

In essence, the obtained results from image creation should demonstrate benefits when compared to current production process. In other words, it intends to make clear that the use of functions found in three-dimensional representation environments are beneficial.

After creating such images, we conducted an evaluation on the relationship between three-dimensional systems and science communication carried out by visual means. Based on literature review and on the development of this images, it was important to evaluate this relation by a group of specialists. This evaluation was done through questionnaires and placed our images for representation of planets, elaborated using procedural textures, before the understanding of these specialists. As evaluators of this development, we invited experts from two areas, who collaborate. We selected 5 researchers working in astronomy and in science, in broad terms and design

Fig. 2. Render of a planet according to planet Saturn reference.

professionals who regularly work with three-dimensional representation systems. All collaborated to evaluate the system as a technical resource for creating quality results for visual communication. The expert's assessment followed a two-part script: an introduction to the research subject, followed by an explanation of the research problem and design solution; and in a second moment, evaluation of developed visual elements. We intended to evaluate the system in specific situations, where communication of scientific concepts depends on visual rigor. We also tried to observe, for all images, the most relevant limitations. The results of the questionnaires helped establish an understanding of the two areas together, commenting on a beneficial procedure for both. For design, the existence of an automated model, capable of obtaining a result with high detail, implies acceleration of production processes. The change of one or more variables, using three-dimensional representation systems, is beneficial because the generated model can be observed from multiple angles and perspectives. For science, it is essential to produce images that accompany scientific proof or speculation. Collaboration with design, in constitution of more incisive communication, is the main idea extracted from this evaluation.

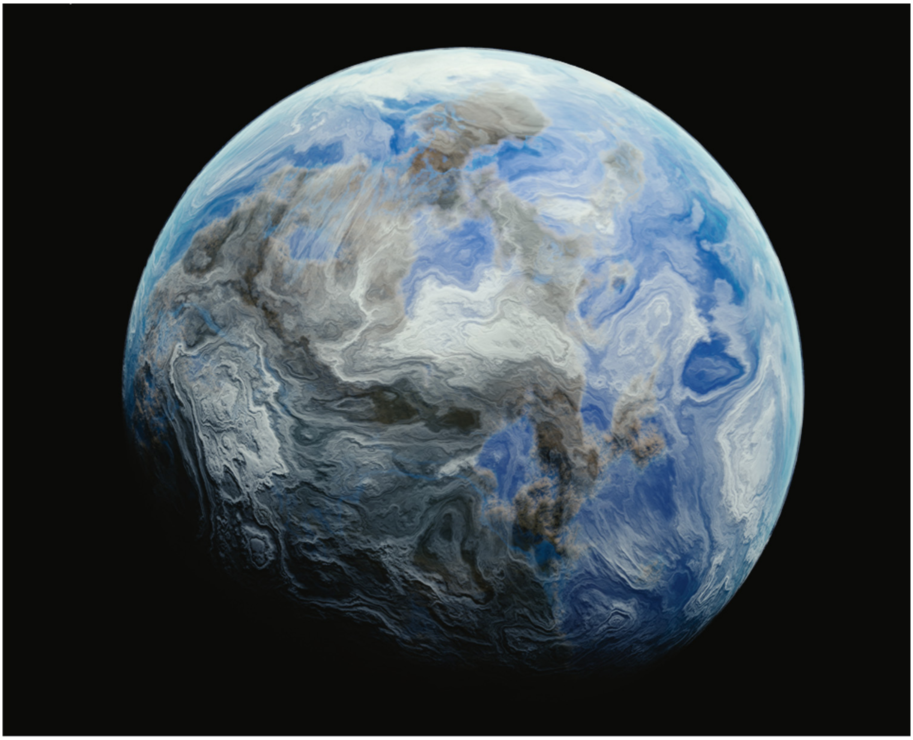

Fig. 3. Render of a planet according to planet Earth reference.

4 Conclusion

Based on obtained results during research, and gathered knowledge, it is essential to recognize, that three-dimensional representation systems are prevailing tools for visual communication and understanding of concepts related to science. In this context, accelerated evolution of technology, means of information and the amount of data generated consequently, dictates communication is transformed and adapted to reach different audiences.

Since its growth and use in cinema, as a means of reproducing available realities and drawing on the interest of general public, the notion of 'uncanny valley' and breaking barriers between digital and photographic production, three-dimensional representation systems have gained increasing presence in visual communication. In the same way, we can verify its continuous use in design, assuming the importance of images in advertising. In another phase, cinema assumed responsibility of exploiting three-dimensional representation systems capacities and presented, in the last century, more and more realistic results. According to creative needs, more innovative production processes were also adapted to reduce the difficulty between understanding real and digital content, while also including benefits in production stages. Functionalities with motion capture and real-time rendering arise with the goal of integrating procedures designed to solve a problem, culminating in an increasingly realistic and fearless result, raising the bar for possible following advances.

Three-dimensional representation systems presents an instrument for visual communication on two levels: on the one hand, by producing a realistic result of a creative idea, bringing real and digital closer. On the other hand, for design, the use of three-dimensional systems is benefited by a community to solve problems and find innovative methods and processes. The process combines with creativity and a visual environment which creates everything from real to unreal.

Science thus uses design to simulate complex concepts that are the result of technological progress. From scientific illustration, through infographic composition until the extensive use of three-dimensional representation systems, it is important to conclude that the means of visual communication production are as current as the information being transmitted by them.

One key to relate science to visual design is, in the light of research, the so-called concept of theoretical photo-realism introduced by Warburton [10]. It establishes the advantage of using a visual medium to generate realistic images, with the need to present public with evidence of an innovative, supposed or invisible concept. Combination between both areas results in something that, as evaluated, has advantages in visual result and in production process.

An interesting phenomenon observed during research is the fact that most referenced authors are published their articles in the last decade. The community regarding three-dimensional representation in general and its applications in design and science have increasingly found motivations, supports, and means to explore details that define new systems of visual communication.

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