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Visual Science: An Emerging Discipline[1]

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Abstract. The emergence of computer graphics as a powerful medium to communicate information is one of the primary reasons graphics is playing a larger role in engineering, science, and technology. Such a powerful medium has emerged from many sources. The author suggests that there is a philosophical foundation and a unique body of knowledge necessary for a discipline called visual science.
This emerging discipline has as its foundation spatial cognition, imaging, and geometry. These three areas when combined provide the knowledge base for visual science. The applications for visual science can be grouped into two areas: artistic and technical.
It is only through the development of this emerging discipline that all graphics related activities will be viewed within the context of a common discipline: visual science. All those professionals and practitioners in the many graphics related fields can, for the first time, share their common interests. It is hoped that an international effort can be started to further define and validate the emerging discipline of visual science.

1 Introduction

There has been a renaissance in graphics brought on by the emergence of computers and computer graphics. This renaissance is directly related to some of the ideas proposed by Nicholas Negroponte in his book *"Being Digital"* [10]. Negroponte believes that the world has fundamentally changed with the introduction of the computer. More importantly computers now give everyone access to very powerful tools that can be used to create, edit, and present information visually.

For the first time it is easier to create graphics or convert text-based information into graphics which is a powerful medium for communications. Communicating visually is becoming the norm rather than the exception in technological societies.

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Converging technologies, such as computer graphics, information technology, and the web, are contributing to a renaissance in graphics. This renaissance in graphics is coupled with the emerging re-thinking of the role of visualization in basic human intelligence. Converging technologies, a renaissance in graphics, and better understanding of the role of visualization in human cognition are the catalyst for an emerging discipline called *visual science*. This discipline is interdisciplinary in nature but has all the attributes of any other discipline, including a unique body of knowledge, research agenda, and powerful applications that are having a profound effect on humanity.

There are many well recognized disciplines that have developed beginning with the ancient Greek society. Educators and laymen recognize mathematics, physics, biology, language, and others. There is little argument that these disciplines have a basic body of knowledge that most societies feel are an important part of their respective educational systems. The same cannot be said of graphics or visual science.

Why is learning a mathematical equation more important than learning about descriptive geometry and visualization? One reason can be traced to the ancient Greek philosophers who emphasized the importance of thinking skills over hand skills. Anything done with the hand was considered menial and fit only for slaves. This attitude was carried forward into the Middle Ages and later, as more formal systems of education were developed. As the knowledge base for graphics began to develop it was done by many different people scattered throughout Europe. No center for graphics knowledge seemed to emerge that could have promoted the development of a formal discipline.

This has resulted in graphics having no single home in higher education today. If you look at where graphics is taught and how it is used on a typical college campus in the USA, you will find many fields of study teaching some form of graphics or using it for their own reasons. Typically, you can find graphics being taught in engineering, art, architecture, technology, science (medical illustration), and others. This diversity indicates that graphics is an important part of many disciplines. However, what is most distressing is that there is no graphics department that makes an attempt to integrate these activities and serve as the knowledge base for all.

2 Why now?

Anyone involved in computer graphics can agree that a certain amount of knowledge of computer graphics is valuable not only in engineering but for most if not all other disciplines, such as science, medicine, art, and entertainment. In fact, it is a challenge to find where computer graphics is not or could not have some significant impact. More importantly, computer graphics is the key technology that is driving important new trends in computer and information science, such as multimedia, scientific and industrial visualization, virtual reality, and simulation and animation of real-time events to name a few (Brown et al., [7]).

We are in the midst of a radical new way of thinking, behaving, and working. We are moving from a print- and verbally-dominated culture to a visual culture. Of course print media and verbal communication will remain an important part of our culture, but the future will be impacted to a great extent using the visual mode. This change is fundamental and impacts the very essence of many of our societal institutions, such as education, business, and industry.

The invention of the printing press by Gutenberg in 1400's shaped education in the

Western World because of the emphasis placed on writing. It has shaped our literature and monopolized our education process for the last 400 years. This influence is so powerful that it has inhibited society's ability to comprehend and integrate the visual tools available today. Yet many disciplines, especially engineering and science, are much better represented and described visually (Murr [9]).

Many engineering programs regard a course in visual thinking as an aberration instead of a discipline that should be part of any engineer's education. Many engineering professors find it difficult to present a problem that requires non-verbal thought, does not have a single unique solution, and cannot be solved in rigorous mathematical steps. Much of our technological world exists not because of geometry, mathematics, or physics but because they were literally pictures in the minds of those who visualized them (Ferguson [8]).

West [14] suggests that we need to reconsider widely held ideas about smartness. He suggests that we need to have a higher respect for visual and hands-on approaches. Computer graphics is leading us back to our visual and non-verbal roots and away from abstractions. West envisions that computer graphics will promote a greater balance between words and images. In some cases the core of the work will be in understanding the images and the words will be used for comment. West also sees the day when visualization technologies will be used in areas that in the past were the exclusive domain of words and numbers. He also sees a higher regard for people who are unusually good with images.

3 Visual Science

Universities divide knowledge into various disciplines and form colleges, schools or departments for those disciplines that have common attributes. Normally, the visual disciplines are scattered throughout the university. For example, graphic design departments are sometimes located in an art school or department, engineering graphics in schools of engineering or technology. Even when graphics is placed in departments, such as engineering, the subject and the faculty are viewed as being somehow different from the rest of the faculty and discipline. The same could be said for graphics in schools of technology and in schools of art. Graphics is recognized as important in engineering, technology and the arts, but not on the same level as other disciplines within that school.

Approximately eighty percent of our sensory input comes from our visual system. Studies have shown that one-half of the population has a preference for visual rather than verbal learning style. Much of what we learn and experience is through our visual sense. Much of our technological world could not exist without the use of graphics to plan, produce, market, and maintain goods and services. There is a tremendous amount of information that is associated with producing good graphics. Color theory, projection theory, cognitive visualization, and geometry are a few examples of what is needed to plan and produce graphics. Graphics is used to communicate and store information, solve problems, and affect the senses. Graphics is an integral part of the human experience.

Graphics and all that it encompasses is a unique body of knowledge that should be studied, practiced and scientifically verified. This body of knowledge, called *visual science*, can be defined, is significant, and is mutually exclusive from other disciplines and should be placed with the sciences as a secondary domain of knowledge. The term *graphic science* is not used because the word *graphic* by definition is limited to text and pictures. The word *visual* was chosen because it is a broader term that encompasses not only text and pictures but anything that is seen or able to be seen by the eye.

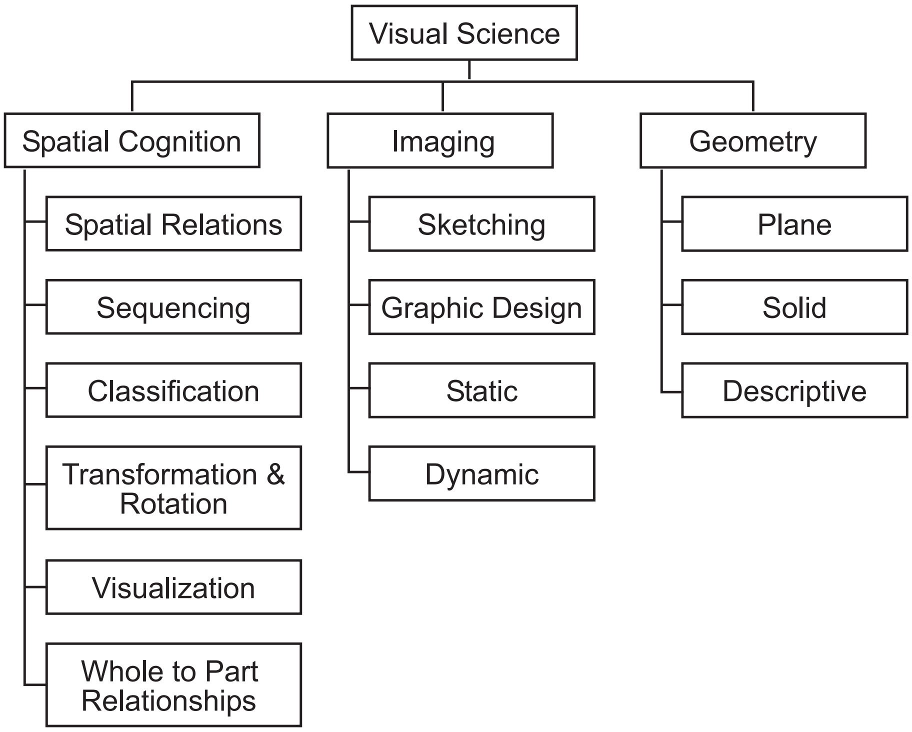

Figure 1: The Visual Science Subject Matter

Visual science is defined as the study of the processes that produce images in the mind. Visual science has at least three major categories: *geometry*, *spatial cognition*, and *imaging* (Fig. 1). These three categories form the foundation for any field of study related to the visual sciences. For example, an engineering design graphics course should have elements of all three areas.

3.1 Spatial Cognition

Spatial cognition is an important building block to general cognition. Spatial cognition is the mental process used to perceive, store, recall, create, edit, and communicate spatial images. It is generally agreed that the ability to think quickly and to recognized complex mental models are signs of intelligence and important prerequisite to learning. Mental imagery is not a core cognitive process but a medium; models for thinking. Zimler and Keenan [16] believe that visualization is a naturally occurring event based on their studies of people who have been blind from birth. This leads one to wonder why there is not more formal instruction in schools and universities that emphasis the visual mode. It also presents a very strong argument for a discipline that addresses such a fundamental part of human intelligence.

Spatial relations is an understanding of the relationship between static or dynamic objects in space. Sequencing is the ordering of both objects and events. Classification is the ability to comprehend relationships between objects and to develop meaningful groups. Transformation is the ability to mentally change an object from one state to another. Rotation is the ability to mentally rotate an object and still maintain orientation and attributes. Whole-to-part relationships are needed to construct and deconstruct complex objects. Visualization is the ability to construct, manipulate, and interpret images in the mind.

An individual's visual literacy at any level has a compounding effect that directly influences competency at higher levels. So visualization should be a continuous goal of formal graphics education throughout all stages of visual learning. Just as language can be broken into various aspects such as grammar and semantics, and mathematics into algebra and calculus, the visual language must be broken into discrete elements that can be learned and manipulated to bring about desired results. Modern tools and techniques make it more important for those in engineering graphics to study the principles of visual communications, such as line, shape, color, value, contrast, repetition, etc., that are common to other visual fields.

3.2 Imaging

Imaging is the process of producing, and reproducing ideas. A knowledge of imaging processes is used to create graphics that are easily visualized or recognized by the user. This area would include animation, color theory, projection theory, graphic design principles, photography, videography, typography, reprography, lighting theory, and computer graphics. Much of the body of knowledge for any visual science course will come from the imaging area.

3.3 Geometry

Geometry is the branch of mathematics that deals with the properties, relationships, and measurements of points, lines, planes, and solids. There are three primary areas of geometry: plane, solid, and descriptive (see Fig. 1). Plane geometry is concerned with planar figures, such as circles and polygons, and their relationships. Solid geometry is concerned with three-dimensional objects, such as cylinders, cones, and cubes, and their relationships. Descriptive geometry is concerned with analyzing and solving space distances and relationships. Much of the study of engineering design graphics has dealt with these topics. However, it must be recognized that the study of geometry has a much wider application than just engineering. Artists, animators, illustrators, and anyone who creates graphics have a need to learn about geometry.

3.4 Visual Science Research Base

It is through scientific inquiry that disciplines move forward and new knowledge is discovered. In visual science, research is conducted in spatial cognition, imaging, and geometry. All of these areas currently conduct research but it is not focused toward a single goal, which is the advancement of visual science. The emergence of visual science as a discipline will promote a focused research approach that will lead to more new knowledge and a more refined discipline.

4 Applications

There are many applications of visual science, which is another way of validating its importance as a formal area of inquiry. All of these applications share the common core knowledge of spatial cognition, imaging, and geometry. The application of visual science is divided into two broad categories: *artistic* and *technical*. Although both categories share some of the same knowledge, skills, and technique, the final products are different both in content and style.

4.1 Artistic

Artistic applications are primarily concerned with the conscious production or arrangement of color, form, and other elements that affect the sense of aesthetics. The primary purpose of art is for personal expression and not to solve problems. Artistic applications include sculpting, painting, and drawing. A good foundation in visualization, geometry, and imaging will make a better artist because those are the foundations for sculpting, painting, and drawing.

4.2 Technical

Technical applications are primarily concerned with the conscious production or arrangement of color, form, and other elements used to communicate information or solve problems. The primary purpose of technical graphics is to present information in such a way as to make it easier and faster to assimilate and understand than could be done using other forms of communication, such as writing and speaking. Technical graphics is a huge area of study that includes engineering design graphics, architectural graphics, medical illustration, printing/publishing, scientific visualization, presentation graphics, technical illustration, industrial design, interior design, multimedia production, and others.

4.3 Techniques

Of course, the applications for visual science must also include the systematic procedures necessary to accomplish a task. These techniques would include the processes, tools, and skills used to create the visual, such as sketching, 3D modeling, computer programming, math, and physics. These processes, tools, and skills are integrated into the artistic and technical applications of visual science.

5 Multidisciplinary Nature of Visual Science

Spatial cognition, imaging, and geometry are unique areas of study that requires visual science to be interdisciplinary. Visual science requires knowledge of cognitive psychology, geometry, imaging science and technology, art and design, and computer science. Related disciplines such as computer science leave out cognitive psychology and art and design topics. Art and design curricula have little or no exposure to computer science and imaging science. The development of visual science as a discipline must be lead by visionaries who are willing to break the barriers of established disciplines to form an interdisciplinary team.

6 Conclusions

To formalize a discipline takes a great deal of effort and time from many individuals. Visual science can be recognized as a discipline if like-minded people work together to further refine its subject matter and begin implementing it through organized research and a defined curricula. The development of visual science as a formal knowledge has to be accomplished by an international group who share the same vision. This international group must work together to create the vision, define the subject matter, perform related research, develop the curriculum, and teach the courses. This effort has begun at Purdue University and by other members of ISGG (for example SUZUKI [12]) but must be expanded throughout the world by others who share the vision of making visual science a recognized discipline.

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