

3D-оптика на английском языке

Саратовский государственный университет имени Н. Г. Чернышевского

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3D Optics in English

ENGLISH TEXTBOOK FOR STUDENTS OF PHYSICS

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3D-оптика на английском языке

Учебное пособие по английскому языку
для студентов и аспирантов физических факультетов университетов

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Т 67 **3D-оптика на английском языке:** Учебное пособие по английскому языку для студентов и аспирантов физических факультетов университетов /В.В. Петров, К.А. Гребенюк, Н.И. Иголкина, Е.В. Карпец – Саратов: Изд-во Сарат. ун-та, 2013. – с.: ил.

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Данное учебное пособие предназначено для формирования и развития у студентов умений читать англоязычную литературу по физике и принимать участие в обсуждении профессиональных тем.

В учебном пособии «3D Optics in English» использованы современные аутентичные тексты по проблеме трехмерной оптики. Содержание текстов позволяет студентам получить представление об одном из активно развивающихся направлений современной физики: регистрации и воспроизведении объемных изображений.

Для студентов и аспирантов физических факультетов университетов.

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PREFACE

Dear Reader,

On behalf of the authors' team I would like to highlight the target of our book. Science in general is a cosmopolitan subject and there are no borders for scientific ideas and discoveries. There are many and many scientific laws which are known to have been discovered simultaneously by independent researchers in different countries. That happened even during the existence of the well-known Iron Curtain around the Soviet Union. Nowadays communication between scientists of different countries has become more and more indispensable. Multiple ways of collaboration have been developed between various institutions of different countries. That is why the knowledge of foreign languages is necessary for communication between people in the modern world.

Three dimensional (3D) displays find more and more applications in modern systems for information representation as 3D imaging allows transferring far larger amount of information to the observer. But the creation of 3D displaying system reconstructing the image approximate to the reality is not an easy task. In fact, the best bulk image can be reconstructed in bulk media. So, a question of great importance for scientists is how to create the artificial volumetric media. Nevertheless, the modern level of science allows inventing various systems based on different physical principles for reconstruction of 3D scenes.

This book is a handbook for students who study Physics and Optics in particular and who strive for having a good command of English. Here we have used the original texts created by the native speakers of English. Only the texts of two units belong to the scientists whose native language is not English but who have been living and working in English-speaking countries for many years. The texts used in this book are not written for educational purposes but they have been taken from original scientific papers. By kind permission of the authors we use the original materials for learning purposes. All scientific sources of the texts are modern (from 2000 – to 2006) and reflect the up-to-date state of the English language.

The book consists of four parts. In the first one the principles of spatial vision are discussed. The rest three are devoted to the main methods of 3D displays. The authors tried to build the book in a uniform way that is why each unit has the same structure which makes it easier and clearer to work with the material.

The topic of the book concerns the most popular and developed of known methods of 3D image reconstruction such as stereoscopy, multi-view displays, holography, and volumetric displays. The stereoscopic system consists of two separated channels which translate the optical signals to the left and right eyes simultaneously but separately. Then due to the parallax effect the observer's brain reconstructs the image as a 3D scene. The multi-view displays have narrow angle zones each of which directs the optical flow to the right and left eyes separately. The holographic approach allows reconstructing the most realistic 3D images but the creation of a display using this method requires very big velocity and very big memory of a computer to process a large amount of information. Nevertheless, such systems are becoming more and more perfect. The volumetric method foresees the presentation of volumetric media in which the 3D image is reconstructed.

The main aim of the book is to develop such essential language skills as Reading and Speaking. It also gives the opportunity to improve students' abilities to translate texts on Physics

and Optics in particular. It is necessary to point out that the use of the book helps students both broaden their range of vocabulary and gain profound knowledge of Optics.

We hope that the book finds a lot of readers among university students learning English for special purposes. We wish you good luck, perfect knowledge of English and interest to science and its actively developing part – registration and representation of three dimensional images.

Vladimir Petrov

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PART ONE

SPATIAL VISION

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UNIT 1

LIGHT PERCEPTION AND EYE PHYSIOLOGY

READING

I. Read the following words paying attention to their pronunciation.

Particular [pɑː'tɪkjʊlə], either ['aɪðə], adequate ['ædɪkwɪt], distinguish [dɪs'tɪŋɡwɪʃ], attribute ['ætrɪbjʊːt], cornea ['kɔːniə], choroid ['kəʊrɔɪd], fovea ['fəʊviə], iris ['aɪərɪs], infinitesimal [ɪnfɪnɪ'tesəml].

II. Try to guess the meaning of the words in bold type.

translucent *adj* allowing light to pass through but not transparent: Frosted glass is translucent./ Light entering the human visual system originated on the other hand from the light transmitted through some translucent object./ Images are perceived to be translucent./ Delia's skin has a translucent quality so that you can almost see the veins under it./ This china is so fine and delicate that if you hold it up to the light it's translucent.

perceive *v* become aware of, esp through eyes or the mind: A human being viewing each of the light sources will perceive the sources differently.

dim *adj* not light, not seen clearly; not able to see clearly: the dim outline of buildings on a dark night/ dim memories/ This eyesight is getting dimmer.

pure *adj* unmixed with any other substance: pure air, free from smoke, fumes, etc/ The laser produces an extremely light and pure red beam.

hue *n* (shade of) colors: the dark hue of the ocean/ There are three common perceptual descriptors of a light sensation: brightness, hue, and saturation.

slit *n* long narrow cut or opening: A prism and slit arrangement can produce narrowband wavelength light of varying color.

encounter *v* find oneself faced of (danger, difficulties etc); meet (a friend, unexpectedly): Some colored lights encountered in nature are not contained in the rainbow of light produced by a prism.

infinitesimal *adj* infinitely small: Such a task is presently beyond human abilities because of the large number of infinitesimal small elements in the visual chain.

vicinity *n* nearness, neighborhood: There isn't a good school in the vicinity./ There are no rods and cones in the vicinity of the optic nerve.

III. Skim the text quite quickly to get a general understanding and answer the questions given. Consult the vocabulary after the text.

Tip! You can understand a lot about a text by reading the title, the sub-heading, the introduction, conclusion and the first and last sentences of the other paragraphs. Skim the text for the answers, rather than reading for detail.

1. What is this text about?
2. What are the names of three common perceptual descriptors of a light sensation?
3. What does the saturation describe?

4. Are rods or cones more sensitive to light?

LIGHT PERCEPTION AND EYE PHYSIOLOGY¹

Light, according to Webster's Dictionary, is "radiant energy which, by its action on the organs of vision, enables them to perform their function of sight". Much is known about the physical properties of light, but the mechanism by which light interacts with the organs of vision is not as well understood.

Several common sources of light encountered in imaging systems are sunlight, a tungsten lamp, a light-emitting diode, a mercury arc lamp, and a helium-neon laser. A human being viewing each of the light sources will perceive the sources differently.

Sunlight appears as an extremely bright yellowish-white light, while the tungsten light bulb appears less bright and somewhat yellowish. The light-emitting diode appears to be a dim green; the mercury arc light is a highly bright bluish-white light; and the laser produces an extremely bright and pure red beam. These observations provoke many questions. What are the attributes of the light sources that cause them to be perceived differently? Is the spectral energy distribution sufficient to explain the differences in perception? If not, what are adequate descriptors of visual perception? As will be seen, answers to these questions are only partially available.

There are three common perceptual descriptors of a light sensation: brightness, hue, and saturation. The characteristics of these descriptors are considered below.

If two light sources with the same spectral shape are observed, the source of greater physical intensity will generally appear to be perceptually brighter. However, there are numerous examples in which an object of uniform intensity appears not to be of uniform brightness. Therefore, intensity is not an adequate quantitative measure of brightness.

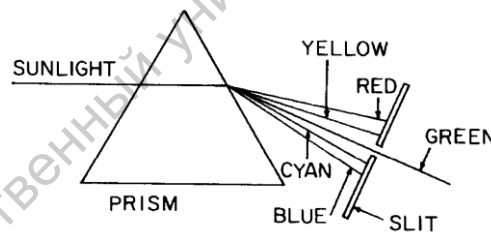


Figure 1.1. Refraction of light from a prism [1].
(Permission for Reprint, courtesy of John Wiley & Sons, Inc.)

The attribute of light that distinguishes a red light from a green light or a yellow light, for example, is called the hue of the light. A prism and slit arrangement (Figure 1.1) can produce narrowband wavelength light of varying color. However, it is clear that the light wavelength is not an adequate measure of color because some colored lights encountered in nature are not contained in the rainbow of light produced by a prism. For example, purple light is absent. Purple light can be produced by combining equal amounts of red and blue narrowband lights. Other counterexamples exist. If two light sources with the same spectral energy distribution are observed under identical conditions, they will appear to possess the same hue. However, it is possible to have two light sources with different spectral energy distributions that are perceived identically. Such lights are called metameric pairs.

¹ The text was adopted from the original book of W.K. Pratt, "Digital image processing: PIKS inside" [1], by courteous permission of John Wiley & Sons, Inc.

The third perceptual descriptor of a colored light is its saturation, the attribute that distinguishes a spectral light from a pastel light of the same hue. In effect, saturation describes the whiteness of a light source. Although it is possible to speak of the percentage saturation of a color referenced to a spectral color on a chromaticity diagram, saturation is not usually considered to be a quantitative measure.

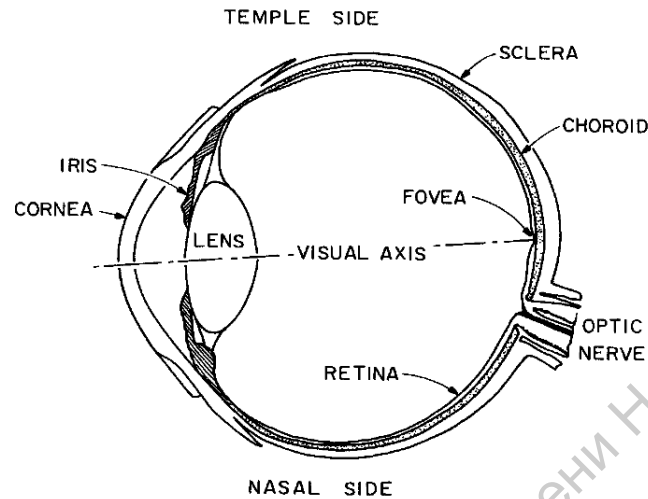


Figure 1.2. Eye cross section [1].
(Permission for Reprint, courtesy of John Wiley & Sons, Inc.)

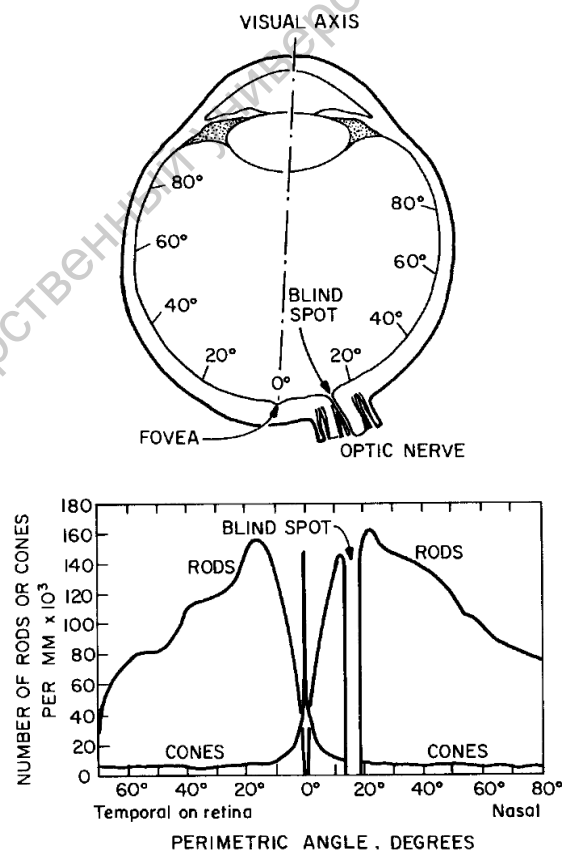


Figure 1.3. Distribution of rods and cones on the retina [1].
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A conceptual technique for the establishment of a model of the human visual system would be to perform a physiological analysis of the eye, the nerve paths to the brain, and those parts of the brain involved in visual perception. Such a task, of course, is presently beyond human abilities because of the large number of infinitesimally small elements in the visual chain. However, much has been learned from physiological studies of the eye that is helpful in the development of visual models.

Figure 1.2 shows the horizontal cross section of a human eyeball. The front of the eye is covered by a transparent surface called the cornea. The remaining outer cover, called the sclera, is composed of a fibrous coat that surrounds the choroid, a layer containing blood capillaries. Inside the choroid is the retina, which is composed of two types of receptors: rods and cones. Nerves connecting to the retina leave the eyeball through the optic nerve bundle. Light entering the cornea is focused on the retina surface by a lens that changes shape under muscular control to perform proper focusing of near and distant objects. An iris acts as a diaphragm to control the amount of light entering the eye.

The rods in the retina are long slender receptors; the cones are generally shorter and thicker in structure. There are also important operational distinctions. The rods are more sensitive than the cones to light. At low levels of illumination, the rods provide a visual response called scotopic vision. Cones respond to higher levels of illumination; their response is called photopic vision. An eye contains about 6.5 million cones and 100 million rods distributed over the retina. Figure 1.3 shows the distribution of rods and cones over a horizontal line on the retina. At a point near the optic nerve called the fovea, the density of cones is greatest. This is the region of sharpest photopic vision. There are no rods or cones in the vicinity of the optic nerve, and hence the eye has a blind spot in this region.

Vocabulary Notes:

radiant energy – энергия излучения; лучистая энергия

imaging system – система формирования или обработки изображений

tungsten lamp – вольфрамовая лампа накаливания

bulb – лампочка

narrowband wavelength light – почти монохроматический свет

cyan – голубой (один из цветов системы CMYB – Cyan – Magenta – Yellow – Black)

metameric pair – метамерическая пара

chromaticity diagram – график цветностей

cornea – роговица (роговая оболочка глаза)

outer cover – наружная оболочка

sclera – склера (белочная оболочка глаза)

choroids – сосудистая оболочка глаза

iris – радужная оболочка глаза

visual response – реакция зрительной системы

scotopic vision (night vision) – скотопическое (ночное) зрение

photopic vision (day vision) – фотопическое (дневное) зрение

Active Vocabulary:

sensation – ощущение; восприятие

attribute – свойство; отличительная черта

uniform – одинаковый; однородный; равномерный

hue – цветовой тон

saturation – насыщенность

quantitative measure – количественная мера

slit – щель
 arrangement – механизм; приспособление
 refraction – преломление
 under identical conditions – в одинаковых условиях
 infinitesimally small – бесконечно малый
 cross section – поперечный разрез
 bundle – связка; пучок
 respond (to) – реагировать (на)
 light-emitting diode – светоизлучающий диод
 retina – сетчатка (сетчатая оболочка глаза)
 rods – палочки (сетчатки)
 cones – колбочки (сетчатки)
 eyeball – глазное яблоко
 lens – хрусталик глаза
 fovea – центральная ямка (сетчатки)
 blind spot – слепое пятно
 mercury arc lamp – ртутная дуговая лампа

IV. Read the text attentively for detail and answer the following questions.

1. Which attribute of light distinguishes a red light from a green light?
2. What are the attributes of the light sources that cause them to be perceived differently?
3. Which spectral energy distributions should two light sources have in order to possess the same hue when observed under identical conditions?
4. How many perceptual descriptors are there?
5. What lights are called metameric pairs?
6. What does the saturation describe?
7. What does figure 1.2 show?
8. At what point is the density of cones greatest?

VOCABULARY EXERCISES

I. State the part of speech of the following words pointing out the word building elements. Give their Russian equivalents.

Differ – different – difference; part – partial – partially; describe – description – descriptive – descriptively – descriptor; identical – identifiable – identification – identify – identity; equal – equality – equalization – equalize – equalizer – equally.

II. Make nouns and adjectives from each of the verbs in the table.

Verb	Noun	Adjective
radiate		
represent		
measure		
intensify		
distribute		

III. Use the correct form of the word in capitals at the end of each sentence to fill the gap.

1. Light is energy which enables the organs of vision to perform their function of sight. **RADIATE**
2. It's not difficult to represent the spectral energy of light emitted from some primary light source. **DISTRIBUTE**
3. The source of greater physical intensity will generally appear to be brighter. **PERCEIVE**
4. There are three perceptual of a light sensation. **DESCRIBE**
5. It is possible to have two light sources with spectral energy distributions that are perceived identically. **DIFFER**
6. A photochemical transition occurs a nerve impulse. **PRODUCE**
7. The of the three types of cones provides a physiological basis for the trichromatic theory of color vision. **EXIST**
8. The monocular depth cues are experiential and over time learn the physical significance of different retinal images. **OBSERVE**
9. Stereo depth in the natural world is illustrated in this picture. **PERCEIVE**

IV. Combine the words in bold with those in brackets. Translate the combinations into Russian.

light (the ~ of the sun, the ~ of a candle; to stand in sb's ~, in a good ~, to rise with the ~, to strike a ~, in the ~ of past events, to do one's best according to one's lights, to get out of the ~, the ~ of my eyes, by the ~ of nature; polar ~)

perform (~ function of sight, task, useful work, operation, experiment, obligation, the part of the host, the part of Hamlet, tricks)

interchange (~ of letters, of greetings, of civilities, of gifts, of opinions, of ideas, of commodities between two countries, of light and darkness, of hills and valleys)

perceive (~ the sources differently, the futility of the attempt, some light in the distance; ~ that he is a poor teacher)

view (~ house and grounds, pictures, each of the light sources, the matter, sth in a different light, the future with misgiving, proposal)

produce (~ passport, railway ticket, proofs, five pounds from one's pocket; ~ in evidence; ~ Shakespearian plays, woolen goods, steel, heavy crops, small income, pictures, book, rise in prices)

V. Match the words in column A with their meanings in column B.

A	B
attribute <i>n</i>	see, understand well the difference
distinguish <i>v</i>	become aware of especially through the eyes or the mind
saturation <i>n</i>	flexible line of connected rings or links for connecting ornament
concept <i>n</i>	well - defined, distinct
invisible <i>adj</i>	complete with everything needed
perceive <i>v</i>	quality naturally or necessary belonging to a person or thing
chain <i>n</i>	process by which we become aware of changes through seeing, hearing, etc
perfect <i>adj</i>	number of things fastened, tied together

bundle <i>n</i>	idea
sharp <i>adj</i>	state of being saturated
perception <i>n</i>	that cannot be seen

VI. Fill in the gaps in the sentences below using words from column A of Exercise V in the correct form.

1. Such a task is beyond human abilities because of the large number of small elements in the visual 2. The α cones are primarily responsible for blue light 3. Points in space are to lie at the same depth. 4. I have no of what he means. 5. When applied to nuclei, the snapshot is theoretical. 6. A person with good eyesight can distant objects. 7. In a normal metal dynamic and static in the crystal lattice are responsible for the scattering of de Broglie waves. 8. The electrons of lower energy follow a path of radius than the full-strength electrons do. 9. What are the of the light sources that cause them to be perceived differently? 10. describes the whiteness of a light source.

VII. Arrange the words given in a. and in b. in pairs of antonyms.

- a. Narrow, light, free, reflect, appear, solid, top, finite.
- b. Dependent, absorb, vanish, liquid, wide, darkness, infinite, bottom.

VIII. Give the English equivalents for the following using the text.

Согласно, лучистая энергия, зрение, свойство, источник света, солнечный свет, пучок света, яркость, отличительная черта, щель, механизм/приспособление, зрительная система человек, поверхность, гелий-неоновый лазер.

IX. Give the Russian equivalents for the following.

Light-emitting diode; mercury arc lamp, imaging system, bulk visual perception, visual axis, optic nerve, bundle, visual axis, optic nerve, bundle, visual response, photonic vision, scotopic vision.

PRACTICE

I. Translate the following noun groups according to the pattern.

thermoelectric generator design problem

проблема чего? (какая?) → конструирования

конструирования чего? → генератора

генератора какого? → термоэлектрического

проблема конструирования термоэлектрического генератора

psychophysical vision properties

a wavelength band

light spectral energy distribution

narrowband wavelength light
 a constant perceptual color difference
 a micron-scale computed tomography apparatus
 regeneration process

II. Correct the following statements.

1. The mechanism by which light interacts with the organs of vision is well understood nowadays.
2. A human being viewing the light sources will perceive these sources identically.
3. There are five common perceptual descriptors of a light sensation.
4. Intensity is an adequate quantitative measure of brightness.
5. It is impossible to have two light sources with different spectral energy distributions that are perceived identically.
6. Saturation is usually a quantitative measure.
7. Up to now we have learnt almost nothing from physiological studies of the eye that is helpful in the development of visual models.
8. The rods in the retina are short receptors, the cones are long and thicker in structure.
9. Cones cannot respond to higher levels of illumination.
10. In the vicinity of the optic nerve there are a lot of rods and cones.

III. Translate the following text into English.²

В последние годы было экспериментально установлено, что существуют три основных типа колбочек сетчатки. Эти колбочки имеют различные спектральные характеристики поглощения с максимальным поглощением в красной, зеленой и голубой областях оптического спектра. На рисунке 1.4 приведены типичные кривые спектрального поглощения пигментов сетчатки. Эти кривые имеют две особенности. Во-первых, колбочки типа α , поглощающие в основном синий свет, имеют относительно низкую чувствительность. Во-вторых, кривые поглощения значительно перекрывают друг друга. Существование трех типов колбочек служит физиологическим обоснованием трехцветной теории цветового зрения.

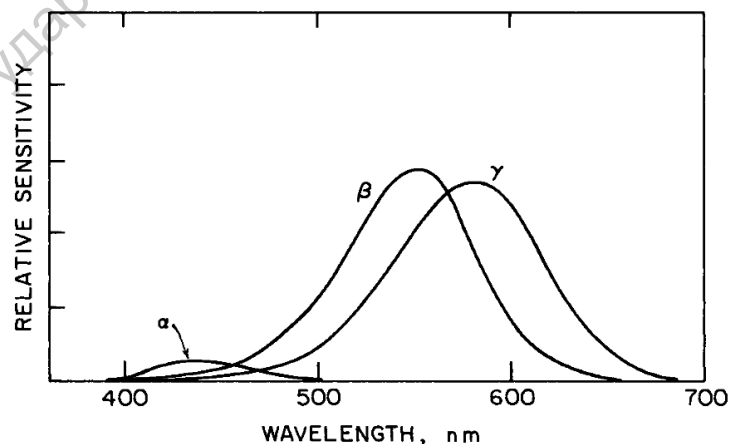


Figure 1.4. Typical spectral absorption curves of pigments of the retina [1].
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² The text was translated from the original book of W.K. Pratt, "Digital image processing: PIKS inside" [1], published by John Wiley & Sons, Inc.

Vocabulary Notes:

absorption characteristic as a function of wavelength – спектральная характеристика поглощения

peak absorption – максимальное поглощение

absorption curve – кривая поглощения

pigments in the retina – пигменты сетчатки

primarily – в основном; главным образом

sensitivity – чувствительность

to overlap – перекрывать

trichromatic theory of color vision – трехцветная теория цветового зрения

IV. Read the text and say what it is about.³

Light is known to be a form of electromagnetic radiation lying in a relatively narrow region of the electromagnetic spectrum over a wavelength band of about 350 to 780 nanometers (nm). A physical light source may be characterized by the rate of radiant energy (radiant intensity) that it emits at a particular spectral wavelength. Light entering the human visual system originates either from a self-luminous source or from light reflected from some object or from light transmitted through some translucent object. Let $E(\lambda)$ represent the spectral energy distribution of light emitted from some primary light source, and also let $t(\lambda)$ and $r(\lambda)$ denote the wavelength-dependent transmissivity and reflectivity, respectively, of an object. Then, for a transmissive object, the observed light spectral energy distribution is $C(\lambda) = t(\lambda)E(\lambda)$, and for a reflective object $C(\lambda) = r(\lambda)E(\lambda)$.

Vocabulary Notes:

electromagnetic spectrum – спектр электромагнитных волн

radiant intensity – интенсивность излучения

self-luminous - самосветящийся

transmitted light – прошедший свет

translucent - полупрозрачный

transmissivity – пропускательная способность

reflectivity – отражательная способность

transmissive object – предмет, пропускающий свет

V. Read and translate the text.⁴

When a light stimulus activates a rod or cone, a photochemical transition occurs, producing a nerve impulse. The manner in which nerve impulses propagate through the visual system is presently not well established. It is known that the optic nerve bundle contains on the order of 800,000 nerve fibers. Because there are over 100,000,000 receptors in the retina, it is obvious that in many regions of the retina, the rods and cones must be interconnected to nerve fibers on a many-to-one basis. Because neither the photochemistry of the retina nor the propagation of nerve impulses within the eye is well understood, a deterministic characterization of the visual process is

³ The text was adopted from the original book of W.K.Pratt, "Digital image processing: PIKS inside" [1], by courteous permission of John Wiley & Sons, Inc.

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unavailable. One must be satisfied with the establishment of models that characterize, and hopefully predict, human visual response.

Vocabulary Notes:

photochemical transition – фотохимический переход

deterministic characterization – полное описание

VI. Reproduce the main text.**VII. Write an annotation on the text.****VIII. Topics for discussion.****1. What is light?**

Light, according to Webster's Dictionary, is 'radiant energy which, by its action on the organs of vision, enables them to perform their function of sight'. What other definitions of light do you know? Try to make several definitions of light using your knowledge of its physical properties.

2. Rods and cones.

What is the sense of having two types of receptors on the retina? Does possession of two types of receptors enhance human vision abilities? Use information from the article. Supply your viewpoint with arguments.

UNIT 2

HUMAN DEPTH PERCEPTION

READING

I. Read the following words paying attention to their pronunciation.

Binocular [b(a)r'nɒkjʊlə], homologous [hə'mɒləgəs], precise [prɪ'saɪs], occlude [ɒ'klu:d], muscle [mʌsl], geometry [dʒi'bɒmɪtri].

II. Try to guess the meaning of the words in bold type.

perception *n* process, act, by which we become aware of changes (through seeing, hearing, etc: Stereo depth perception in the natural world is illustrated in Figure 2.2.

derive *v* have as a source or origin: Thousands of English words are derived from Latin.

advantage *n* sth useful, helpful or likely to bring success: the advantages of a good education/ Binocular vision provides humans with the advantage of depth perception.

precise *adj* exact, free from error: This can provide precise information on the depth relationships of objects in a scene.

depth *n* distance from the top down, from the front to the back, from the surface inwards: Water was found at a depth of 10 meters./ The snow is one meter in depth.

texture *n* the arrangement of the threads in a cloth; the arrangement of the parts that make up sth: A texture of constant size objects, such as pebbles or grass, will vary in size on the retina with distance.

loose *v* not held, tied up, fastened: That day is too dangerous to be left loose.

verge *n* edge, border: to be on the verge of – be close to, on the border of/ The country is on the verge of disaster.

vision *n* power of seeing or imagining, looking ahead, grasping the truth: They will move on to consider how human binocular vision works.

extract *v* take or get out (usually with effort); obtain by force; obtain by pressing: have a tooth extracted/ extract money/ information from a person who is unwilling to give it/ 47 tonnes of gold have been extracted at the mine./ The nuts are crushed to extract the oil from them./ He read out a brief extract from his book./ Extracting 3D information about the world from images received by the two eyes is a fundamental problem for the visual system.

III. Skim the text quite quickly to get a general understanding and answer the questions given. Consult the vocabulary after the text.

1. What is this text about?
2. What does binocular vision provide us with?
3. What are the relations of different retinal images to objects in the real world?
4. What provides our brain with a powerful cue to 3D spatial relationships?
5. How is the binocular disparity processed?

HUMAN DEPTH PERCEPTION⁵

Binocular vision provides humans with the advantage of depth perception derived from the small differences in the location of homologous, or corresponding, points in the two images incident on the retina of the eyes. This is known as stereopsis (literally solid seeing) and can provide precise information on the depth relationships of objects in a scene.

The human visual system also makes use of other depth cues to help interpret the two images incident on the retina and from these builds a mental model of the 3D world. These include monocular depth cues (also known as pictorial or empirical cues), whose significance is learnt over time, oculomotor cues in addition to the stereoscopic cue. We consider these in turn and introduce in detail binocular vision in the natural world.

Redundancy is built into the visual system and even people with monocular vision are able to perform well when judging depth in the real world. The monocular depth cues are experiential and over time observers learn the physical significance of different retinal images and their relation to objects in the real world. These include:

- Interposition: objects occluding each other suggest their depth ordering.
- Linear perspective: the same size object at different distances projects a different size image onto the retina.
- Light and Shade: the way light reflects from objects provides cues to their depth relationships, shadows are particularly important in this respect.
- Relative Size, an object with smaller retinal image is judged further away than the same object with a larger retinal image.
- Texture Gradient: a texture of constant size objects, such as pebbles or grass, will vary in size on the retina with distance.
- Aerial Perspective: the atmosphere affects light travelling through it, for example due to fog, dust or rain. As light travels long distances it is scattered, colours lose saturation, sharp edges are diffused and colour hue is shifted towards blue.

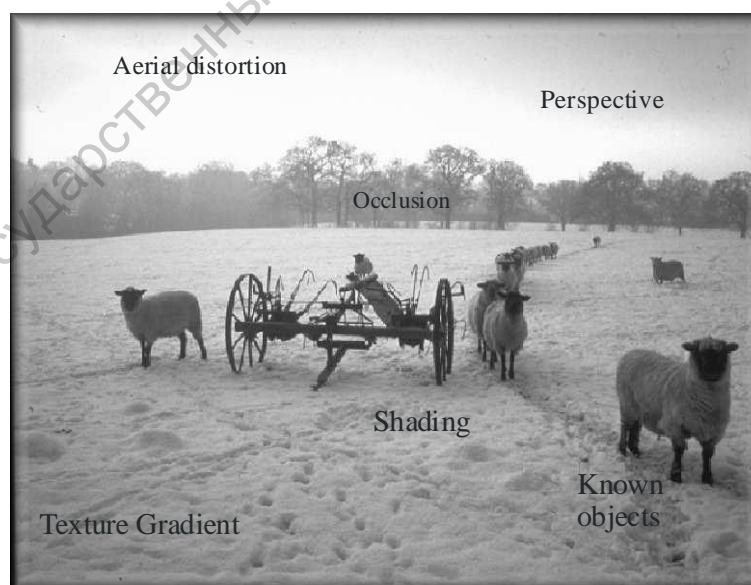


Figure 2.1. Picture illustrating the depth cues available in a 2D image [2].
(photographer David Burder)

⁵ The text was adopted for language learning purposes from preprint of the original work of N.S. Holliman "Three-dimensional display systems"[2].

Many of these cues are illustrated in figure 2.1 and can be considered to be 2D depth cues since they are found in purely monoscopic images. Two other non-binocular depth cues are available: motion parallax and oculomotor cues.

Motion parallax provides the brain with a powerful cue to 3D spatial relationships without the use of stereopsis and this is the case when either an object in the scene or the observer's head moves. Motion parallax does not, however, make stereopsis redundant, as comprehending images of complex scenes can be difficult without binocular vision. Yeh and others have shown that both stereopsis and motion parallax combined result in better depth perception than either cue alone.

Oculomotor depth cues are due to feedback from the muscles used to control the vergence and accommodation of the eye. They are generally regarded as having limited potential to help depth judgement and we will move on to consider how human binocular vision works when used to view the natural world.

Extracting three-dimensional information about the world from the images received by the two eyes is a fundamental problem for the visual system. In many animals perhaps the best way of doing this comes from the binocular disparity that results from two forward facing eyes having a slightly different viewpoint of the world. The binocular disparity is processed by the brain giving the sensation of depth known as stereopsis.

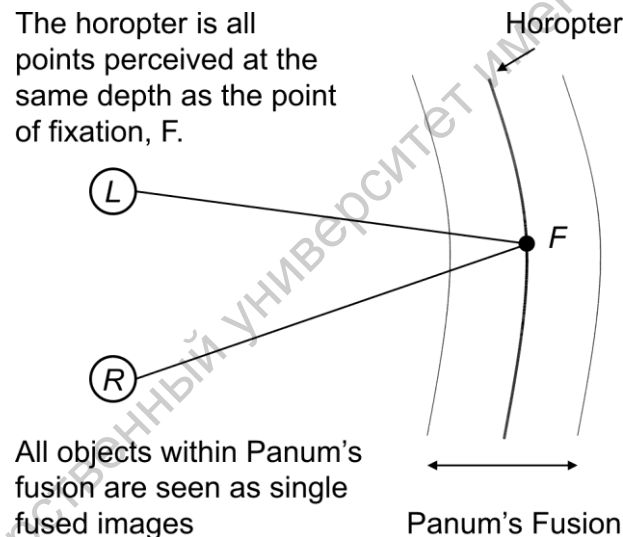


Figure 2.2. The geometry of the binocular vision when viewing the natural world [2].

Stereo depth perception in the natural world is illustrated in figure 2.2. The two eyes verge the visual axes so as to fixate the point F and adjust their accommodation state so that points in space at and around F come into focus.

The vergence point, F , projects to the same position on each retina and therefore has zero retinal disparity, i.e. there is no difference between its location in the left and right retinal images. Points in front or behind the fixation point project to different positions on the left and right retina and the resulting binocular disparity between the point in the left and right retinal images provides the observer's brain with the stereoscopic depth cue. Depth judgement is therefore relative to the current vergence point, F , and is most useful to make judgements on the relative rather than absolute depth of objects in a scene.

Points in space, other than F , which project zero retinal disparity are perceived to lie at the same depth as the vergence point, all points that project zero retinal disparity are described as being on a surface in space known as the horopter. The shape of the horopter shown in figure 2.2 is illustrative only it is known in practice to be a complex shape and to have non-linear characteristics.

To summarise the above, binocular vision uses the stereoscopic depth cue of retinal disparity to perceive an object's depth relative to the fixation point of the two eyes. At close and near range this provides a high degree of depth discrimination and even at tens of metres from the observer enables relative depth perception for larger objects.

Vocabulary Notes:

homologous points – одноименные точки; соответственные точки (изображений)
 stereopsis – бинокулярный стереоэффект
 oculomotor cues – окуломоторные (глазодвигательные) факторы стереоскопического видения
 stereoscopic depth cues – бинокулярные факторы стереоскопического видения
 monocular vision – монокулярное зрение (видение)
 monocular depth cues; 2D depth cues – монокулярные факторы стереоскопического видения
 texture gradient – изменение текстуры
 aerial perspective – воздушная перспектива
 color hue – цветовой тон; оттенок цвета
 motion parallax – параллакс движения
 vergence point – центр конвергенции (осей глаз)
 retinal disparity – сетчаточная диспаратность (изображений на сетчатке)
 horopter – гороптер
 depth sensation – ощущение глубины (пространства)

Active Vocabulary:

cue – сигнал; намек
 depth cues – признаки глубины; факторы стереоскопического видения
 incident – (физ.) падающий
 solid – (матем.) пространственный; трехмерный
 pictorial – изобразительный; графический
 redundancy – избыточность
 experiential – основанный на опыте; эмпирический
 interposition – вставка; нахождение между чем-то
 occlude – преграждать; закрывать
 scatter – рассеивать
 diffuse – рассеивать
 vergence (convergence) – конвергенция; схождение в одной точке
 comprehend – понимать
 disparity – диспаратность; несоответствие

IV. Read the text attentively for detail and answer the following questions.

1. What did the author mean saying about redundancy built into the visual system?
2. What is aerial perspective?
3. Which monocular depth cues can you name?
4. Why is the stereoscopic depth cue most useful to make judgements on the relative rather than absolute depth of objects in space?
5. Which focus of points in space is called the horopter?
6. What retinal disparity do left and right projections of the vergence point have?

VOCABULARY EXERCISES

I. State the part of speech of the following words pointing out the word building elements. Give their Russian equivalents.

deep – deepen – deeply; judge – judgement – judgeship – judgmatical; perceive – perceptibility – perceptible – perception – perceptive – perceptivity; perfect – perfectibility – perfectible – perfecting – perfection; complex – complexity; dispose – disposal – disposed – disposer – disposition.

II. Make nouns and adjectives from each of the verbs from the table.

Verb	Noun	Adjective
inform		
add		
observe		
reflect		
illustrate		

III. Use the correct form of the word in capitals at the end of each sentence to fill the gap.

- As light travels long distances it is scattered, colors loose, sharp edges are diffused. SATURATE
- Motion parallax the brain with a powerful cue to 3D spatial relationships without the use of stereopsis. PROVIDE
- The binocular disparity by the brain. PROCESS
- There is no between the location of the vergence point in the left and right retinal images. DIFFER
- The shape of the horopter in figure 2.2 is only illustrative. SHOW
- Binocular vision uses the stereoscopic depth cue of disparity. RETINA
- The stereoscopic depth sensation could by showing each eye a separate 2D image. RECREATE
- The left and right eye views should be 2D planar images of the same scene from different viewpoints. SLIGHT
- Depth judgement is relative to the current point. VERGE
- All points that project zero retinal disparity are described as on the horopter. BE

IV. Combine the words in bold with those in brackets. Translate the combinations into Russian.

perception (organ of ~, stereo-, color; ~ of beauty)

derive (~ benefit from sth, pleasure from sth, income, character from father, knowledge)

advantage (~ of a good education, of smb's good nature; to get (to have) ~)

precise (~ measurements, meaning, rules of conduct, definitions)

depth (~ of the river, of the snow, of penetration, of knowledge, of sound (feeling), of color; a foot in ~; in the ~ of despair, in the ~ of poverty; a man of no great ~)

extract (~ bullet, cork, tooth, juice, information)

vision (the field of ~; the organ of; glasses for far ~, glasses for close; back ~, forward; the ~ of natural objects; ~ of power, of wealth, of fame)

V. Match the words in column A with their meanings in column B.

A	B
depth <i>n</i>	process by which we become aware of changes through seeing, hearing, etc
precise <i>adj</i>	distance from the top down
perception <i>n</i>	power of seeing of imagining, looking ahead
loose <i>adj</i>	obtain by force, by pressing
vision <i>n</i>	understand fully
extract <i>v</i>	go in different directions
comprehend <i>v</i>	not tied up, not fastened
scatter <i>v</i>	free from error

VI. Fill in the gaps in the sentences below using words from column A of Exercise V in the correct form.

1. The human system also makes use of other depth cues to help interpret the two images incident on the retina. 2. As light travels long distances it 3. 3D information about the world from the images received by the two eyes is a fundamental problem for the visual system. 4. Points in space which project zero retinal disparity to lie at the same depth. 5. judgement is therefore relative to the current vergence point, F. 6. The smallest change in angular disparity between two small objects is referred to as stereo acuity. 7. depth is inversely proportional to individual eye separation. 8. This can provide information on the depth relationships of objects in a scene.

VII. Arrange the words given in a. and in b. in pairs of synonyms.

- a. Precise, advantage, scatter, quantity, return, prominent, neglect, much.
- b. Diffuse, magnitude, come back, well-known, exact, merit, a lot, disregard.

VIII. Give the English equivalents for the following using the text.

Трехмерный; объемный (стереоскопический); падающий; сетчатка; (радио)сигнал; основанный на опыте (эмпирический); рассеивать; насыщенность; обратная связь; зрительная ось; фиксируемая точка.

IX. Give the Russian equivalents for the following.

Homologous points; pictorial; redundancy; stereoscopic; retina; human visual system; cue; monocular vision; occlude; saturation; texture gradient; diffuse; motion parallax; feedback; visual axis; fixation point; depth sensation; vergence (convergence).

PRACTICE

I. Translate the following noun groups.

depth perception
 screen disparity, monocular depth cues
 display design
 color hue
 surface material perception
 3D display systems, surface curvature

II. Correct the wrong statements using the following as phrase-openings: *on the contrary, I don't believe that, to my mind, it is considered that.*

1. Binocular vision can't provide humans with the advantage of depth perception.
2. People with monocular vision are unable to perform well when judging depth in the real world.
3. The monocular depth cues are not experiential.
4. Objects occluding each other don't suggest their depth ordering.
5. The way light reflects from objects can't provide cues to their depth relationships.
6. A texture of constant size objects such as pebbles or grass won't vary in size on the retina with distance.
7. The shape of the horopter is known in practice to be a simple shape and to have linear characteristics.

III. Translate the following text into English.⁶

Некоторые исследователи выделяют три основных подхода к созданию 3D-дисплеев. Это метод на основе стереоскопии, метод на основе голографии и использование объемной среды.

В методе, основанном на стереоскопии, ощущение глубины пространства воссоздается путем предъявления каждому из глаз зрителя отдельного плоского изображения. Изображения, предъявляемые левому и правому глазам зрителя должны быть изображениями одной и той же сцены, полученными с незначительно отличающихся точек зрения.

Различие точек зрения приводит к различиям в полученных изображениях. Впоследствии, при раздельном бинокулярном наблюдении этих изображений, у зрителя появляется ощущение глубины пространства, так как различия в изображениях приводят к возникновению сетчаточной диспаратности подобной той, что имеет место при непосредственном наблюдении реальной трехмерной сцены.

Vocabulary Notes:

single out – выделять
 approach (to) – подход (к)
 stereoscopy – стереоскопия
 volumetric medium – объемная среда
 recreate – воссоздавать
 separate – отдельный
 subsequently – впоследствии

⁶ The text was translated from preprint of the original work of N.S. Holliman "Three-dimensional display systems"[2].

IV. Read the text and say what it is about.⁷

Geometrically we can define angular disparity, α , as the difference between the vergence angle at the point of fixation, F and the point of interest. Considering figure 2.3:

Points behind the fixation point, such as A , have positive disparity.

$$\alpha_a = f - a$$

Points in front of the fixation point, such as B , have negative disparity.

$$\alpha_b = f - b$$

The smallest perceptible change in angular disparity between two small objects is referred to as stereo acuity, δ . The advantage of defining stereo acuity as an angle is that it can be assumed to be constant regardless of the actual distance to and between the points A and B .

Considering figure 2.4 when points A and C can just be perceived to be at a different depth then stereo acuity will be:

$$\delta = a - c$$

Various studies show the eye is able to distinguish very small values of δ , as little as $1:8''$ (seconds of arc). As the exact limits vary between people Diner and Fender suggest that a practical working limit is to use a value of stereo acuity $\delta = 20''$. Using this value we can calculate the size of the smallest distinguishable depth difference at a given distance from the observer.

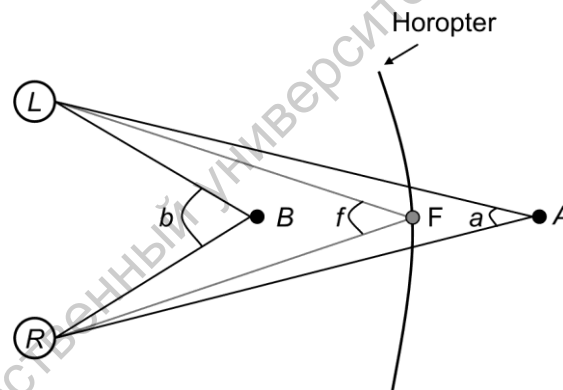


Figure 2.3. Angular disparity is defined relative to the current fixation point [2].

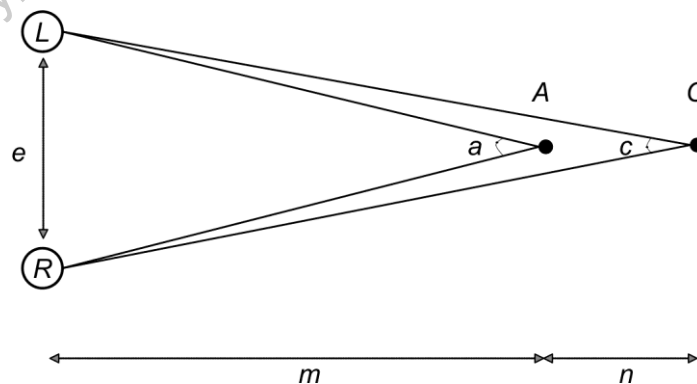


Figure 2.4. Stereo acuity defines smallest depth difference an observer can perceive [2].

⁷ The text was adopted for language learning purposes from preprint of the original work of N.S. Holliman "Three-dimensional display systems"[2].

V. Read the text and render it in Russian.⁸

An important question is what advantages does binocular vision provide in the real world? As a visual effect it clearly fascinates the majority of people when they see a 3D picture. Beyond the attractive nature of stereoscopic 3D images they provide the following benefits over monocular vision:

- Relative depth judgement. The spatial relationship of objects in depth from the viewer can be judged directly using binocular vision.
- Spatial localisation. The brain is able to concentrate on objects placed at a certain depth and ignore those at other depths using binocular vision.
- Breaking camouflage. The ability to pick out camouflaged objects in a scene is probably one of the key evolutionary reasons for having binocular vision
- Surface material perception. For example, lustre, sparkling gems and glittering metals are in part seen as such because of the different specular reflections detected by the left and right eyes.
- Judgement of surface curvature. Evidence suggests that curved surfaces can be interpreted more effectively with binocular vision.

These benefits make three-dimensional image display of considerable benefit in certain professional applications where depth judgement is important to achieving successful results.

VI. Reproduce the main text.

VII. Write an annotation on the text.

VIII. Topics for discussion.

1. Depth judgement with conventional 2D display.

Can video viewed with conventional 2D display provide any additional depth cues in comparison with painting pictured on the sheet of paper? Prove your viewpoint using information about depth cues from the reading text. Compiling list of depth cues may be helpful for finding right answer and arguing your position.

2. Concept of volumetric image.

As Lenny Lipton has rightly noted in his book 'Foundations of the Stereoscopic Cinema: a Study in Depth', 'all filmmaking is three-dimensional in the sense that motion pictures provide many cues to depth that also help us perceive the visual world'. Nevertheless we say that image provided by conventional display is not a volumetric image, but planar one. In this context how can you define the term 'volumetric image'? Use information about depth cues to formulate the definition.

⁴ The text was adopted for language learning purposes from preprint of the original work of N.S. Holliman "Three-dimensional display systems"[2].

PART TWO

STEREOSCOPY

Саратовский государственный университет имени Н. Г. Чернышевского

UNIT 3

POLARISED STEREOSCOPIC PROJECTION

READING

I. Read the following words paying attention to pronunciation.

Available [ə'veɪləbl], purify ['pjʊəɪfaɪ], percentage [pə'sentɪdʒ], accuracy ['ækjʊrəsi], attribute *v* [ə'trɪbjʊ:t] – attribute *n* ['ætrɪbjʊ:t], distinguish [dɪ'stɪŋɡwɪʃ].

II. Try to guess the meaning of the words in bold type.

clockwise/counter-clockwise *adv* in the same direction/ in the direction opposite to the movement of the hands of a clock: Polarized stereoscopic projection involves the polarization of the two projected images – e.g. ± 45 degrees for linear polarization, or clockwise and counter-clockwise for circular polarization.

advantageous *adj* profitable, useful: This paper points out that it is advantageous that the output of an LCD projector is already polarized./ He gained little advantage from his visit to London.

circular *adj* round or curved in shape; moving round: For round circular polarization, the two views are clockwise and counter-clockwise polarized.

purify *v* make pure, cleanse: Linear polarizers are placed at the output to purify the linear polarization in the desired direction.

assess *v* fix or decide the value of: The difference between measured and calculated figures provides some assessment of the approximate accuracy of the figures.

attribute *v* consider as a quality of, as being the result of, as coming from: He attributes his success to hard work./ The differences between the measured and calculated figures could be attributed to measurement error.

distinguish *v* see, hear, recognize, understand well the difference: The twins were so alike that it was impossible to distinguish one from the other./ The non-linear response of the eye to brightness may make this brightness difference somewhat hard to distinguish.

III. Skim the text quite quickly to get a general understanding and answer the questions given. Consult the vocabulary after the text.

1. In what directions must two views be polarized in stereoscopic projection with circular polarization?
2. Why must directions of two views in stereoscopic projection with linear polarization be orthogonal?
3. Which three categories of output polarization are available with contemporary video projectors?
4. What configurations of optical filters may be used to obtain the correct linear polarization with each of video projectors from Figure 3.1?
5. What are linear polarizers placed for in configuration from Figure 3.1c?

POLARISED STEREOSCOPIC PROJECTION⁹

Polarised stereoscopic projection involves the polarisation of the two (left & right) projected images in orthogonal directions. The defacto standard for linear polarised stereoscopic projection is ± 45 degrees from the vertical axis, however, vertical and horizontal polarisation for the two views can also be used. For circular polarisation, the two views are clockwise and counter-clockwise polarised.

In the past, projectors with unpolarised outputs were generally used, such as slide projectors or movie film projectors – hence the orientation of a polariser placed on the front of the projector didn't need to be given much thought. However, the output of projectors based on an LCD optical engine are already polarised, so some attention must be given to the possible interaction between the polarisation orientation of the projected output and the desired polarisation direction for stereoscopic projection.

The output polarisation of commonly available video projectors fall into three main categories:

- unpolarised output – as with CRT or DMD/DLP projectors.
- linear polarised output with two colours in one direction and the remaining colour in an orthogonal direction (e.g. Red and Blue vertical and Green horizontal) – most three-panel LCD projectors are in this category. For the purposes of this paper, let's call this a Type 1 LCD projector.
- linear polarised output with all colours in the same direction – as with single panel LCD projectors and some three-panel LCD projectors. Let's call this a Type 2 LCD projector.

In order for the three categories of video projectors to be used with polarised stereoscopic projection, various configurations of optical filters must be used to obtain the correct polarisation output with minimal light loss and minimal colour distortion. The various configurations for configuring projectors for linearly polarised stereoscopic projection are illustrated in Figure 3.1.

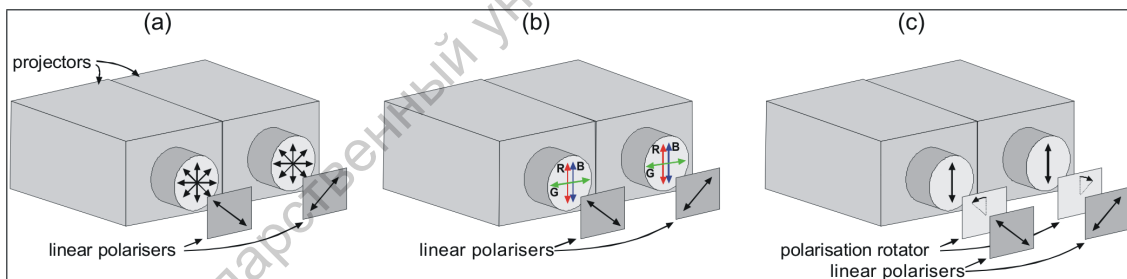


Figure 3.1. Methods for linear polarized projection for various output polarization types [3].

In the case of Figure 3.1a, the linear polarisers at the output of the projector can be oriented at any angle since the projector output is unpolarised. In the case of Figure 3.1b, the linear polarisers must be placed at either $+45^\circ$ or -45° in order for the correct colour balance to be achieved. Luckily this corresponds with the desired polarised projection orientation.

In the case of Figure 3.1c, it is desirable that the bulk of the light being output by the projectors in the vertically polarised direction be rotated into the desired $+45^\circ$ or -45° orientations – this can be achieved with a half-wave retarder. Linear polarisers are then placed at the output to purify the linear polarisation in the desired directions - to match the standard orientation. The projectors of Figure 3.1c could be configured the same as Figure 3.1b (i.e. without the retarders) however the image is brighter when the retarders are used.

⁹ The text was adopted for language learning purposes from preprint of the original paper of A.J. Woods "Optimal usage of LCD projectors for polarised stereoscopic projection" [3].

The relative efficiency of each of the projection methods illustrated in Figure 3.1 have been calculated and measured and the results are summarised in Table 3.1. The percentage figure quoted for each configuration represents the amount of light that reaches the screen from the projector's output lens – i.e. 0% efficiency represents no light reaching the screen (100% light loss in any optical components between the output lens and the screen) and 100% efficiency would mean that all light emitted at the projector's output lens reaches the screen (0% light loss).

Table 3.1. Relative optical efficiency of the various polarised stereoscopic projection methods [3].

Projector Type and Configuration	Efficiency	
	Measured	Calculated
(a) Unpolarised output (CRT/DMD)	~25%	~35%
(b) Linear polarised with colours non-co-linear (Type 1 LCD)	~32%	~50%
(c) Linear polarised with all colours co-linear (Type 2 LCD)	~57%	~62%

Both measured and calculated figures are listed because the difference between measured and calculated provides some assessment of the approximate accuracy of the figures. However, both the measured and calculated figures show the same trends therefore providing some confirmation of the overall results. The differences between the measured and calculated figures could be attributed to measurement error and/or differences between product literature and actual shipped product.

It can be seen from these figures that the least efficient projection configuration is configuration (a) (the unpolarised output projector) and the most efficient configuration is configuration (c) (where all colours are polarised in the same direction). Considered another way, if three projectors of all equal brightness were used (one of each projector type), the image from configuration (c) would be ~130% (measured) or ~75% (calculated) brighter than the image projected by configuration (a). Therefore, there is a significant advantage to using LCD projectors for polarised stereoscopic projection due to the fact that their light output is already polarised. Even configuration (b) produces an image ~28% (measured) or ~41% (calculated) brighter than configuration (a), although the non-linear response of the eye to brightness may make this brightness difference somewhat hard to distinguish.

Vocabulary Notes:

LCD (liquid crystal display) – ЖКД (жидкокристаллический дисплей)

CRT (cathode ray tube) – ЭЛТ (электронно-лучевая трубка)

DMD (digital micro-mirror device) – цифровое микрозеркальное устройство - устройство, используемое в технологии DLP

DLP (digital light processing) – цифровая обработка света; технология DLP - технология обработки света, разработанная компанией Texas Instruments

bulk – основная масса; большая часть

ship – поставлять (товар)

purify the linear polarization – повышать степень линейной поляризации

non-linear response of the eye – нелинейная характеристика реакции глаза

Active Vocabulary:

interaction – взаимодействие

match – подходить; соответствовать
 quote – приводить (в качестве примера, иллюстрации)
 achieve – достигать (цели)
 reach – достигать (места)
 assessment – оценка; определение ценности
 approximate – приблизительный
 accuracy – правильность; точность
 trend – общее направление; тенденция
 confirmation – подтверждение
 overall – суммарный результат
 attribute (to) – объяснять (чем-либо)
 distinguish – различить; разглядеть
 distortion – искажение
 orient at any angle – располагать под произвольным углом
 co-linear – коллинеарный
 retarder – фазовая пластинка
 half-wave retarder – полуволновая (фазовая) пластинка

IV. Read the text attentively for detail and answer the following questions.

1. What does polarized stereoscopic projection involve?
2. What are the two views for circular polarization?
3. Into what categories do video projectors fall?
4. What does Figure 3.1 show?
5. What can you tell us about the non-linear response of the eye to brightness?

VOCABULARY EXERCISES

I. State the part of speech of the following words pointing out the word building elements. Give their Russian equivalents.

Project – projector – projection; line – lineal – lineally – linear – lineation – lineman; single – singleton – singly – singular – singularize – singularly; vary – various – variously – variability – variable – variance – variant – variational; retard – retardation – retarder.

II. Make nouns and adjectives from each of the verbs from the table.

Verb	Noun	Adjective
imagine		
polarize		
direct		
measure		
calculate		
differ		
assess		

III. Use the correct form of the word in capitals at the end of each sentence to fill the gap.

1. More light is when DLP and CRT projectors are used for linear polarized stereoscopic projection. **LOSE**
2. The paper has only considered polarized stereoscopic projection. **LINE**
3. Similar principles to circular polarization. **APPLY**
4. The optical filters can change the color balance of the projected image. **VARY**
5. Unfortunately, this paper comes at a time when very few Type 2 LCD projectors
PRODUCE
6. This will depend upon the quality of the filters being used. **OPTICS**
7. The figures shown in Table I should therefore be used to re-date of the projectors you are considering. **BRIGHT**
8. The paper also points out that it is that the output of an LCD projector is already polarized.
ADVANTAGE

IV. Combine the words in bold with those in brackets. Translate the combinations into Russian.

involve (~ some assumptions, the polarisation of images, expense, a nation in war, sb in a crime)

attention (to attract ~, to draw sb's ~ to sth, to give one's ~ to sb, to redouble one's ~)

form (~ a piece of wood into a certain shape, sth in accordance with a pattern; an idea, an opinion, habit)

decide (~ question, battle, matter to sb's favour, against sth, between two alternatives, on a course of action)

end (~ one's labor on a book, the cold war, testing now and for all time, in disaster; in success)

hollow (~ ball, tree, tooth, cheeks, threats, victory)

V. Match the words in column A with their meanings in column B.

A	B
output <i>n</i>	device which separates alternating current of one frequency from others; colored glass which allows light of certain wave-length to pass through
in bulk	repeat, write (words used by another, from a book, an author)
match <i>v</i>	allow
filter <i>n</i>	sth useful, helpful or likely to bring success
permit <i>v</i>	to be equal to, correspond (with) (in quality, color, design, etc.)
advantage <i>n</i>	in large amounts
quote <i>v</i>	quantity of power, energy, etc produced; information produced from a computer

VI. Fill in the gaps in the sentences below using the words given in brackets making any necessary changes.

1. More light is lost when DLP and CRT ... are used for linear polarized stereoscopic projection. (project)
2. It is ... that the output of an LCD projector is already polarized. (advantage)
3. Projectors with unpolarised outputs are generally (use)

4. It is ... that the bulk of the light be rotated into the desired $+45^\circ$ or -45° orientations. (desire)
5. Both measured and calculated figures are listed because the difference between them provides some ... of the approximate accuracy of the figures. (assess)
6. Even configuration (b) produces an image $\sim 28\%$ (measured) or $\sim 41\%$ (calculated) ... that configuration (a). (bright)

VII. Arrange the words given in a. and in b. in pairs of synonyms.

- a. Involved, output, desire, various, rotate, pair.
- b. Different, move round a central point, information produced in a computer, two things of the same kind used together, complicated in a form, wish.

VIII. Give the English equivalents for the following using the text.

Линейная поляризация; круговая поляризация; по часовой стрелке; против часовой стрелки; световые потери; искажение света; подходить, соответствовать; излучать; коллинеарный.

IX. Give the Russian equivalents for the following.

Retarder, bulk, to achieve, to reach, approximate, confirmation, non-linear response of the eye, to distinguish, light loss; to orient at any angle, half-wave retarder, to purify, to match.

PRACTICE

I. Translate the following noun groups into Russian.

liquid crystal display
cathode ray tube
digital micro-mirror device
digital light processing
light loss
color distortion
LCD projectors
price/performance ratio figures
stereoscopic projection configurations
polarisation process

II. Correct the wrong statements using the following as phrase-openings: *on the contrary, I don't believe that, to my mind, it is considered that.*

1. Polarized stereoscopic projection involves the polarization of left projected images.
2. Vertical and horizontal polarization of the left views can also be used.
3. For circular polarization, the two views are counter-clockwise polarized.
4. The output polarization falls into two categories.
5. Various configurations of optical filters must be used to obtain the correct polarization output without light loss and color distortion.
6. The linear polarizer at the output of the projector can be oriented only at half-angle.

7. Without the retarders the image is weaker.

III. Translate the following sentences into English.

1. Поляризационная стереоскопическая проекция включает в себя поляризацию световых потоков, идущих от двух изображений, в ортогональных направлениях.
2. При использовании ЖКД-проекторов следует помнить, что свет на выходе проекторов этого типа уже поляризован.
3. В данной работе рассматривается величина световых потерь в различных системах поляризационной стереоскопической проекции.
4. Необходимо рекомендовать оптимальную конфигурацию проекционной системы.
5. Наличие определенной поляризации у света на выходе ЖКД-проектора на самом деле является преимуществом.
6. В общем, при использовании ЖКД-проектора световые потери будут меньше.

IV. Read the text and reproduce it in English in short.¹⁰

Obviously it is unlikely that the projectors you will be considering for a stereoscopic projection system will all be of the same brightness, the figures shown in Table 3.1 should therefore be used to de-rate the brightness of the projectors you are considering. This may well produce a considerably different set of price/performance ratio figures that you might have originally considered.

It should be noted that the various optical filters can change the color balance of the projected image so this may need to be corrected by adjusting the gain of each appropriate color at the projector. It should also be noted that the more optical filters that are used, the sharpness of the projected image may reduce but this will depend upon the quality of the optical filters being used.

Vocabulary Notes:

performance – эксплуатационные качества; производительность

adjust – регулировать; настраивать

gain – прирост; увеличение; (тлв.) усиление

sharpness – резкость

V. Read the text and render it in Russian.¹¹

The main point of this paper is that there can be a significant advantage in using certain LCD projectors for polarized stereoscopic projection versus using DLP or CRT projectors. More light is lost when DLP and CRT projectors are used for linear polarized stereoscopic projection versus the amount of light lost when using LCD projectors.

Unfortunately this paper comes at a time when very few Type 2 LCD projectors are being produced. A recent survey of LCD projectors revealed that almost all are of the Type 1 variety. If the value of Type 2 LCD projectors for polarized stereoscopic projection is not recognized, the Type 2 LCD projector may well totally disappear from the market. Although this paper has only considered linear polarized stereoscopic projection, similar principles apply to circular polarization but this will be left to the reader to explore or it may be the subject of a future paper.

¹⁰ The text was adopted for language learning purposes from preprint of the original paper of A.J. Woods "Optimal usage of LCD projectors for polarised stereoscopic projection"[3].

¹¹ The text was adopted for language learning purposes from preprint of the original paper of A.J. Woods "Optimal usage of LCD projectors for polarised stereoscopic projection"[3].

Vocabulary Notes:

survey – обзор

reveal – открывать; обнаруживать

VI. Reproduce the main text.**VII. Write an annotation on the text.****VIII. Topics for discussion.****1. Relative efficiency.**

Which of configurations from Figure 3.1 is the most efficient one (has the least light losses)? Explain your choice using Figure 3.1 and comparing chosen configuration with other two.

2. Color balance.

Is there any way to reduce light losses in configuration from Figure 3.1b by changing orientations of polarizers? How is it necessary to orient polarizers in Figure 3.1b in order to minimize light losses? What would happen in this case with color balance of the produced image?

UNIT 4

TIME-MULTIPLEXED 3D DISPLAY

READING

I. Read the following words paying attention to pronunciation.

Sequential [sɪ'kwɛnsjəl], transparent [træn'speərənt], gauge [geɪdʒ], transition [træn'sɪʃn], alter ['ɔ:lteɪ], angle ['æŋɡl], incident ['ɪnsɪdənt], acceptable [ək'septəbl].

II. Try to guess the meaning of the words in bold.

transparent *adj* allowing light to pass through so that objects (or at least their outlines) behind can be distinctly seen: Ordinary glass is transparent./ Place a stack of microscope cover slips in a transparent bath of water.

blur *v* make or become unclear in appearance: The writing was blurred./ The concept enables wide fields of view, sharp discrimination between views, little blurring at depth, and no repetition of views.

boundary *n* dividing line; line that marks a limit: The stream forms a boundary between my land and his./ The boundaries between the views of a field sequential display are defined by a single element which gives a sharp transition between views.

sequence *n* succession; connected line of events, ideas, etc; the sequence of events, the order in which they occur: A simple way to make a field sequential 3D display is to show a sequence of views of a solid object on a liquid crystal display.

bulk *n* quantity, volume; the bulk of – the greater part or number of: He left the bulk of his property to his brother./ The bulk of this concept arises from the space needed between light source and lens.

alter *v* make or become different, change in character, appearance, etc: He has altered a great deal since I saw him a year ago./ The angle of the injected rays can be altered by moving the spot source of light in the focal plane of the lens segment.

comprise *v* **be comprised of** consist of two or more things: The committee comprises men of widely different views./ A liquid crystal display with a frame rate high enough for field sequential 3D is likely to comprise ferroelectric liquid crystal and poly-silicon transistors./ The bulk of the film is comprised of unrelated, ridiculous set pieces./ Life is comprised of actions and reactions.

flat *adj* smooth and level; even: The lens segment and scanning source of light need be no thicker than the mirror stack, so that the whole illumination system is flat.

III. Skim the text quite quickly to get a general understanding and answer the questions given. Consult the vocabulary after the text.

1. What is the text about?
2. What do you know about 3D displays?
3. Which lenses do field sequential displays use?
4. What is the quality of image produced by field sequential 3D?
5. Do gratings alter the angle of incident rays?
6. What quality will such displays deliver?

TIME-MULTIPLEXED 3D DISPLAY¹²

A flat panel field sequential 3D display can be made by illuminating a ferroelectric liquid crystal display with scanning illumination passed through a transparent slab embossed with a grating. The concept is expected to enable wide fields of view, sharp discrimination between views, little blurring at depth, and no repetition of views.

The demand for 3D stems more from whim than necessity which makes it difficult to gauge exactly what kind of 3D image is sought. Nevertheless people talk wistfully of a display round which three or four people can sit, each seeing what they would if they were looking at a solid object instead of an image. This is not on offer from most 3D concepts because their field of view is limited by lens f-number.

Field sequential displays use compound lenses which have better f-number than lenslet arrays, so offer wider fields of view. Furthermore, the boundary between the views of a field sequential display are defined by a single element which gives a sharp transition between views. This means that there is less blurring of pixels which are either far behind or far in front of the screen of the 3D display as happens with lenslet array 3D displays. Lastly, field sequential 3D displays have the advantage that in principle they need no more pixels than a 2D display with equivalent resolution.

The quality of image produced by field sequential 3D is excellent, but the displays have tended to be bulky, and they require fast-switching ferroelectric liquid crystals which have been slow to gain acceptance. This paper will explain how to make thin field sequential 3D displays.

A conceptually simple way to make a field sequential 3D display is to show a sequence of views of a solid object on a liquid crystal display, and illuminate each view with rays of light traveling parallel to the axis of the camera which captured the view. Provided that there are enough views, and that the sequence is repeated sufficiently quickly, the result is a flicker-free three dimensional image. The bulk of this concept arises from the space needed between light source and lens – how is this eliminated?

If a ray is shone vertically up to a mirror angled at 45° to the vertical, the ray is deflected into the horizontal plane. Variations of ray angle in the vertical plane are converted into variations in the horizontal plane, as shown in figure 4.2.

If a set of rays are shone vertically so as to illuminate the entire base of a stack of mirrors angled at 45° to the vertical, and the mirrors are partially reflective, then collimated light will emerge from the whole of the front face of the stack.

Alter the angle of the injected rays in the vertical plane, and the angle of the emergent rays in the horizontal plane will alter by an equal amount. The injected rays can be formed by placing a spot source of light in the focal plane of a lens segment, and the angle of the injected rays can be altered by moving the spot source of light in the focal plane of the lens segment, as shown in figure 4.3.

The lens segment and scanning source of light need be no thicker than the mirror stack, so that the whole illumination system is flat. The lens segment and scanning source of light can in principle of course be folded behind the mirror stack with prisms in order to make a system which fits behind the liquid crystal display without overlap.

This concept was tested satisfactorily by placing a stack of microscope cover slips in a transparent bath of water whose sides were spaced so that the cover slips settled at 45° to the sides, with partial reflection taking place at each glass/water interface. However components tend to be less expensive if they can be moulded, and an alternative way of making a flat panel illuminator is to use

¹² The text was adopted for language learning purposes from the original paper of A.R.L. Travis "Time-multiplexed 3D display" [4].

gratings.

By making the lens segment circularly symmetric, this illumination scheme can be designed to have an almost unlimited field of view. Furthermore, over the last few years graphics rendering chips have become fast enough to drive liquid crystal displays at the frame rates needed for frame sequential 3D, while light emitting diodes are now bright enough to deliver the switchable illumination needed to control view direction. It is now the frame rate of liquid crystal displays which limits the field of view of frame sequential 3D. A liquid crystal display with a frame rate high enough for field sequential 3D is likely to comprise ferroelectric liquid crystal and poly-silicon transistors. In combination with the latest graphics engines and high brightness LED's, it is expected that the displays will deliver good quality 3D images at an acceptable manufacturing cost.

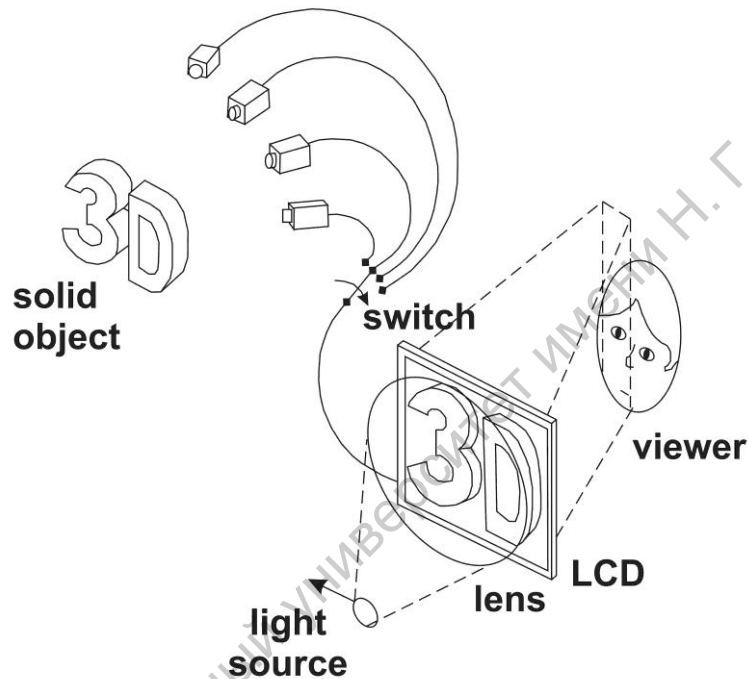


Figure 4.1. A field sequential 3D display comprises a high frame rate LCD illuminated with scanning rays of light [4].

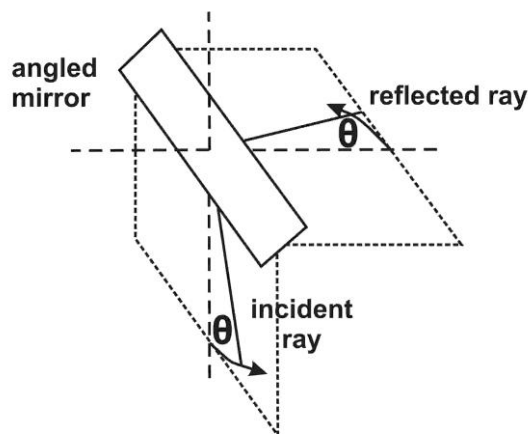


Figure 4.2. An angled mirror converts ray deflection in the vertical plane to ray deflection in the horizontal plane [4].

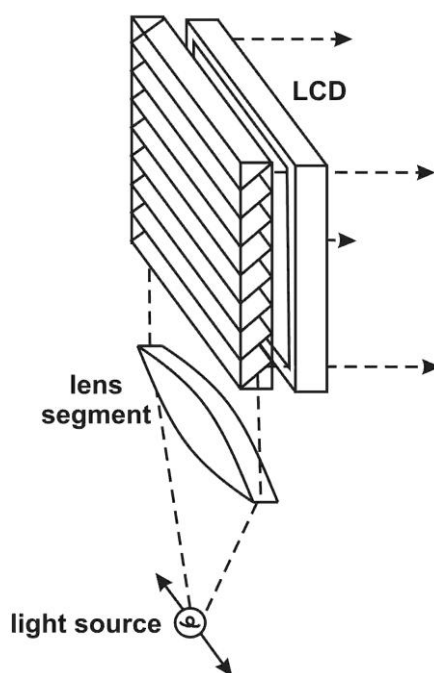


Figure 4.3. Illuminate the base of the stack with a light source collimated by a lens segment, and move the light source to scan view direction [4].

Vocabulary Notes:

time-multiplexed display (field sequential display) – дисплей с временным разделением (чередованием) изображений – название стереоскопических дисплеев, в которых изображения различных ракурсов объекта предъявляются зрителю поочередно, в различные моменты времени

ferroelectric crystals – сегнетоэлектрические кристаллы; ферроэлектрики

blurring at depth – размывание (изображения) по глубине

f-number – диафрагменное число (объектива)

compound lens – составная линза

lenslet array – линзовый растр

flicker-free image – немерцающее изображение

base of stack of mirrors – основание стопы зеркал

whim – прихоть; каприз; причуда

wistfully – тоскуя; страстно желая чего-то

mould – отливать форму; делать по шаблону

Active Vocabulary:

slab – пластина

emboss – наносить рельеф; выпуклый рисунок

grating – дифракционная решетка

discrimination – различение; разграничение

stem from – происходить от; являться результатом чего-то

gauge – измерять; оценивать

transition – переход

bulk – величина; объем

bulky – громоздкий; занимающий много места

gain acceptance – получить признание

capture – записывать (с помощью видеокамеры)
 deflect – отклонять; изменять направление
 angle – располагать под углом
 emerge – появляться; выходить
 fit – уместаться; помещаться
 overlap – наложение; совпадение; перекрытие
 settle – укладывать(ся); устраивать(ся)
 solid object – пространственный (трехмерный) объект
 partially reflective mirror – частично отражающее зеркало
 injected rays – входящие лучи
 emergent rays – выходящие лучи
 microscope cover slip – покровное стекло микроскопа
 frame rate – скорость смены кадров (частота кадровой развертки)

IV. Read the text attentively for detail and answer the following questions.

1. What kind of 3D display do people usually talk of?
2. What is a conceptually simple way of making field sequential 3D display?
3. How is it possible to eliminate the bulk of the 3D display original concept?
4. Why should the mirrors in stack be only partially reflective?
5. Why must a spot source be placed in the focal plane of a lens segment?

VOCABULARY EXERCISES

I. State the part of speech of the following words pointing out the word-building elements. Give their Russian equivalents.

Able – ability – enable; image – imageable – imagery – imaginable – imaginary – imagination – imagine; concept – conception – conceptual – conceptually; suffice – sufficiency – sufficient – sufficiently; vary – variety – various – variously; part – partial – partially; alter – alterable – alteration.

II. Make nouns and adjectives from each of the verbs in the table.

Verb	Noun	Adjective
limit		
produce		
accept		
reflect		
satisfy		

III. Use the correct form of the word in capitals at the end of each sentence to fill the gap.

1. The displays deliver good quality 3D images at an manufacturing cost. ACCEPT
2. The grating must be weak. EMBOSS
3. Light passing from air into the slab and back into air is barely by the grating. AFFECT
4. 3D display was developed in which the roles of liquid crystal and light source are

INTERCHANGE

5. The lens segment is symmetric. CIRCULAR
6. The display substrate crystalline silicon. BE
7. The lens segment and scanning source of light need be no than the mirror stack. THIN
8. The injected rays can by placing a spot source of light in the focal plane of a lens segment. FORM
9. The bulk of this concept arises from the space between light source and lens. NEED

IV. Combine the words in bold with those in brackets. Translate the combinations into Russian.

expensive (~ equipment, fuel, instrument, device)

reliable (~ information, source of information, device, measurements)

sharp (~ angle, knife, pencil, slope, fall, turn, features, outline, frost, discrimination)

compound (~ word, sentence, fracture, glass, lenses, body, cable)

gain (~ experience, strength, color, bread, information, battle, prize)

perform (~ experiment, test, procedure, analysis)

angle (acute ~, right, obtuse, ideal)

V. Match the words in column A with their meanings in column B.

A	B
advantage <i>n</i>	measurement of any sort
resolution <i>n</i>	dividing line
discriminate <i>v</i>	changing from one condition to another
dimension <i>n</i>	benefit, profit
boundary <i>n</i>	something that is decided
transition <i>n</i>	treat differently, make distinctions
quality <i>n</i>	idea
blur <i>v</i>	suitable, well adapted, good enough
fit <i>adj</i>	become unclear in appearance
concept <i>n</i>	high standard

VI. Fill in the gaps in the sentences below using words from column A of Exercise V in the correct form.

1. The concept enables wide fields of view, sharp between views.
2. Field sequential 3D displays have the that in principle they need no more pixels than a 2D display with equivalent resolution.
3. The of image produced by field sequential 3D is excellent.
4. It gives a sharp ... between views.
5. The between the views of a field sequential display are defined by a single element.
6. Field sequential 3D displays enable wide fields of view, a sharp transition between views, pixels which not at depth.
7. A simple way to make a field sequential 3D display is to show a sequence of views of a solid object on a liquid crystal display.

VII. Arrange the words given in a. and in b. in pairs of synonyms.

- a. Distant, limit, connect, evolve, collect, simple, demand.
- b. Link, develop, gather, mere, require, remote, restrict.

VIII. Arrange the words given in a. and in b. in pairs of antonyms.

- a. Cover, tiny, finite, exclude, fill, obey.
- b. Boundless, include, empty, vast, reveal, resist.

IX. Give the English equivalents for the following using the text.

Трёхмерный дисплей, ферроэлектрик, прозрачный, область обзора, различение, переход, угол, появляться.

X. Give the Russian equivalents for the following.

Light emitting diode, frame rate, incident rays, interface, overlap, partially reflective mirror, bulk, capture, gain acceptance.

PRACTICE

I. Translate the following noun groups into Russian.

a flat panel field sequential 3D display
 a ferroelectric liquid crystal display
 a lenslet array, light source
 a spot source of light
 a mirror stack
 a frame rate
 off-axis lens aberration
 a cathode ray tube
 amorphous silicon active matrix displays
 high brightness LEDs.

II. Correct the wrong statements using the following as phrase-openings: *on the contrary, I don't believe that; to my mind; it is considered that.*

1. Field sequential displays use only simple lenses.
2. Compound lenses can't be used in field sequential displays.
3. A single element doesn't give a sharp transition between lenses.
4. Field sequential 3D displays have the advantage that they need more pixels than a 2D display with equivalent resolution.
5. The quality of image produced by field sequential 3D is rather low.
6. The injected rays can be formed by placing the mirrors in the focal plane of a lens segment.
7. The lens segment and scanning source of light need be thicker than the mirror stack.
8. The whole illumination system is uneven.
9. Gratings alter the angle of incident rays by reflection.
10. In spite of the latest graphics engines and high resolution LED's the displays won't deliver good quality 3D images.

III. Translate the following sentences into English.¹³

1. Схема идеального кембриджского дисплея содержит ЖКД, линзу и ряд источников света.
2. Источники света помещаются сразу за фокальной плоскостью линзы.
3. Зрители видят изображения полос.
4. Область, в которой создается это изображение, называется 'eye box'.
5. Эти полосы освещаются по очереди.
6. Результат действия линзы состоит в том, что каждый из видов объекта можно увидеть только из определенной области пространства перед дисплеем.

IV. Read the text¹⁴ and be ready to answer the following question: What is the principle of multi-view autostereoscopic displays?

Multi-view autostereoscopic displays offer the user three dimensional realism lacking in conventional (2D) displays. Multi-view autostereoscopic displays work by displaying multiple different images to multiple zones in space. Figure 4.4 illustrates the theory behind multi-view displays. Figure 4.4(a) shows a user looking at a scene in the real world. The user sees a different image of the scene with each eye and different images again whenever he or she moves his or her head. The user is able to view a potentially infinite number of different images of the scene. Figure 4.4(b) shows a thought experiment in which the same viewing space is divided into a finite number of *windows*. In each window only one image, or *view*, of the scene is visible. However the user still sees a different image with each eye, and the images still change when the user moves his or her head — albeit with jumps as an eye moves from window to window. Thus both stereo and horizontal movement parallax cues can be provided with a small number of views. The finite number of views required in Figure 4.4(b) allows the replacement of the scene by a display that outputs a different image to each window (Figure 4.4(c)). This is the principle of multi-view autostereoscopic displays.

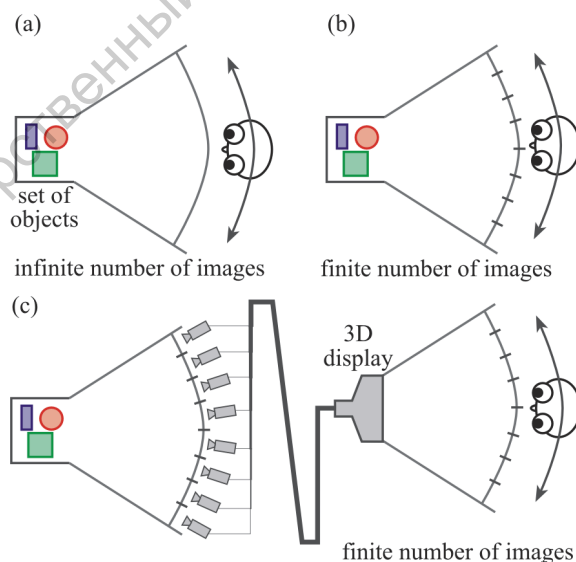


Figure 4.4. (a) When viewing a scene in real life, a user sees a different image with each eye: stereo parallax. When he moves his head he sees different images: movement parallax. There are an

¹³ The text was translated from preprint of the original paper of N.A. Dodgson, J.R. Moore, S.R. Lang, G. Martin, P. Canepa, "A time sequential multi-projector autostereoscopic display" [5].

¹⁴ The text was adopted from preprint of the original paper of N.A. Dodgson et al. "A time sequential multi-projector autostereoscopic display" [5] (Permission for Reprint, courtesy Society for Information Display).

infinite number of different images of the scene that he could see. (b) The number of different images is made finite, each visible in its own window. Each eye still sees a different image: stereo parallax, and different images are seen when the head is moved: movement parallax. (c) An autostereoscopic 3D display provides a different image to each window, producing both stereo and movement parallax with a small number of views [5].

(Permission for Reprint, courtesy Society for Information Display)

Vocabulary Notes:

multi-view display – дисплей, отображающий множество видов (объекта, сцены)

autostereoscopic display – автостереоскопический дисплей

lack – не хватать; недоставать

albeit – хотя и

stereo parallax – бинокулярный параллакс

movement parallax – параллакс движения

V. Read the text and render it in Russian.¹⁵

Time sequential displays use a single display device running at a high frame rate. A secondary optical component is required to direct the images to the appropriate zones in space. Displays based on Travis' concept are of this type. The advantage of time sequential over the other technologies is that all views are displayed on the same image display, so there can be no misalignment between multiple image sources (as in multi-projector devices) nor between pixels and a lenticular array or parallax barrier (as in spatially multiplexed devices). Further, more view directions can be more easily sustained than is currently feasible with a lenticular or parallax barrier display, and a large number of views can be supported less expensively than with multi-projector or holographic devices. The challenges of time sequential autostereoscopic technology lie in producing display devices with sufficiently fast refresh rates, in delivering high enough luminance to be shared amongst the multiple views, and in designing the view direction modulating optics.

Vocabulary Notes:

appropriate – подходящий; соответствующий (to, for)

misalignment – неточное совмещение; несовпадение

multi-projector display – многопроекторный дисплей (мультипроекторный)

lenticular array – линзовый растр; линзовый экран

parallax barrier – параллакс-барьер

spatially multiplexed display – дисплей с пространственным разделением (изображений)

sustain – поддерживать; обеспечивать

feasible – выполнимый; осуществимый

refresh rate – скорость обновления (частота обновления)

view direction modulating optics – оптика, изменяющая направление наблюдения

VI. Read the text and state the main ideas in 3-4 sentences in English.¹⁶

The design of an ideal Cambridge display as invented by Travis (Figure 4.5) consists of a high speed liquid crystal display, a Fresnel lens, and a series of abutting bar shaped light sources. The

¹⁵ The text was adopted from preprint of the original paper of N.A. Dodgson et al. "A time sequential multi-projector autostereoscopic display"[5] (Permission for Reprint, courtesy Society for Information Display).

¹⁶ The text was adopted from preprint of the original paper of N.A. Dodgson et al. "A time sequential multi-projector autostereoscopic display"[5] (Permission for Reprint, courtesy Society for Information Display).

light sources are placed just beyond the focal plane of the Fresnel lens so that an image of the light bars is projected into the user's view space; this image of the light bars is termed the *eye box*. Each light bar is illuminated in turn and, in synchronisation with this, successive laterally adjacent views of an object are displayed on the liquid crystal display. The effect of the lens is that each view is visible in a different window in front of the display. Provided that the views are repeatedly illuminated sufficiently rapidly, the user will perceive a three-dimensional image with both stereo and horizontal movement parallax, so long as both the eyes are within the eye box. While the best position from which to view autostereo images is at the eye box, a good 3D effect is obtained over a large range of distances.

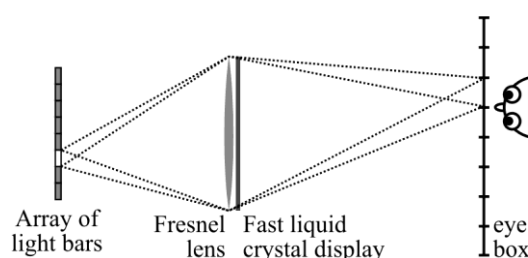


Figure 4.5. An ideal Cambridge display [5].
(Permission for Reprint, courtesy Society for Information Display)

Vocabulary Notes:

Fresnel lens – линза Френеля

abut – примыкать; граничить

bar shaped light source – источник света в форме полосы

laterally – сбоку; вбок

adjacent – смежный; соседний

VII. Render the main text in English.

VIII. Write an annotation on the text.

IX. Topics for discussion.

1. Advantages and disadvantages of the field sequential 3D display concept.

What advantages and disadvantages of the field sequential 3D display concept can you find? Try to consider this issue from viewpoints of manufacturability, usability, cost, image quality.

2. Requirements to mirrors' reflectivity.

Stack of partially reflective mirrors was offered for providing LCD with collimated uniform illumination. Should all mirrors of the stack have equal or different reflectivity in order to have LCD illuminated uniformly? Why? How should mirror's reflectivity vary along the stack in order to have LCD illuminated uniformly? Why?

UNIT 5

SPATIALLY MULTIPLEXED 3D DISPLAY

READING

I. Read the following words paying attention to pronunciation:

Target ['tɑ:ɡrɪt], exit ['eksɪt], alternate *v* ['ɔ:l'tənərt] – alternate *adj* [ɔ:l'tɜ:nɪt], lenticular [len'tɪkjʊlə], variety [və'raɪəti], niche [nɪʃ] / [ni:ʃ], sequential [sɪ'kwɛnʃəl], advent ['ædvent], exaggerate [ɪɡ'zædʒəreɪt].

II. Try to guess the meaning of the words in bold.

capable of *adj* (of persons) having the power, ability or inclination; (of things, situation, etc.) ready for, open to: The situation is capable of improvement./ The display is capable of supplying 3D images to multiple viewers.

steer *v* direct the course of: The positions of the exit pupils are steered to the viewers' eyes by the use of head tracking.

alternate *adj* by turns, first the one and then the others: Tom and Harry do the work on alternate days (e.g. Tom on Monday, Harry on Tuesday, Tom on Wednesday, etc)./ Left and right images are produced on alternate pixel rows of a single UXGA LCD.

aberration *n* turning away from what is expected, normal or right; defect, sudden instance: The steering optics can produce exit pupils over a large area, but without the aberration and coloration effects associated with other methods.

conjunction *n formal* **in conjunction with** together with; a combination of two or more things: This is achieved using arrays of coaxial lenses in conjunction with high-density white LED array sources./ in conjunction with knowledge of the precise topology/ This system is designed to be used in conjunction with a word processing program. There is a team of writers working in conjunction (with each other) on the book. The conjunction of computers and communications is perhaps the most important aspect of information technology.

employ *v* give work to, usually for payment; make use of: How do you employ your spare time?/ He is employed in a bank.

achieve *v* complete, get (sth) done; gain or reach by effect (success/distinction in public life): He will never achieve anything.

adjacent *adj* next, lying near (to) but not necessarily touching: It follows that two adjacent exit pupils could be formed with two adjacent illumination sources.

interpose *v* put forward an objection, etc as an interference; make an interruption: Will they interpose their veto yet again?/ Interposing a transmissive screen between the lens and viewer will cause the screen image to be seen by the viewer.

exaggerate *v* make sth seem larger, better, worse, etc than it really is: You exaggerate the difficulties./ If you always exaggerate, people will no longer believe you. Note that the pitches of the barrier and the LCD are exaggerated for reasons of clarity.

spill *v* (of liquid or powder) (allow to) run over the side of the container: It is necessary to focus the left and right illumination sources on the individual left and right lines of the LCD without light spilling on the adjacent lines.

III. Skim the text quite quickly to get a general understanding and answer the questions given.

Consult the vocabulary after the text.

1. What is the text about?
2. What do you know about the subject?
3. What are 3D television requirements?
4. What does the spatial multiplexing screen require the illumination sources for?

SPATIALLY MULTIPLEXED 3D DISPLAY¹⁷

De Montfort University (DMU) has developed an autostereoscopic display that is targeted specifically at television applications. The display is capable of supplying 3D images to multiple viewers who are not required to wear special glasses, and who are able to move freely over a room-sized area. It operates by producing regions (exit pupils) in the viewing field where either a left or a right image is seen. The positions of the exit pupils are steered to the viewers' eyes by the use of head tracking. The DMU display consists of an LCD whose conventional backlight is replaced by a steerable optical configuration that is capable of producing several pairs of exit pupils. Left and right images are produced on alternate pixel rows of a single UXGA LCD. This spatial image multiplexing is achieved by the use of a lenticular sheet located between the steering optics and the LCD. The steering optics can produce exit pupils over a large area, but without the aberration and coloration effects associated with other methods. This is achieved using arrays of coaxial lenses in conjunction with high-density white LED array sources.

3D displays have been used in a variety of niche applications for many years, and as the quality of the display systems has improved, so too has the range of applications. Broadcast television is probably the largest potential application, however the requirements of a television system are complex and few, if any, existing display systems can meet these requirements. In particular it is desirable to present stereo images to several mobile viewers who will occupy a typical 'living room' sized region. A system that would meet these requirements would be more complex than other systems intended for single, often static, viewers, for example, for computer monitor or arcade game applications.

To satisfy the requirements for 3D television displays, our display operates by generating specific regions in front of the screen (known as exit pupils) where a left or right image is seen at the eye of each viewer. These exit pupils follow the viewer's eyes under the control of a head position tracker, which determines where the viewers are located in front of the screen. The display effectively operates in a similar manner to anaglyph (red/green glasses) or polarized glasses, but without the need for glasses.

Our 3D display requires an exit pupil to be produced for each eye of each viewer. Fig.5.1 shows how this might be achieved with the use of an illumination source and a large lens. The vertical light source produces a real image in the viewing field, resulting in a diamond-shaped exit pupil region. It follows that two adjacent exit pupils could be formed with two adjacent illumination sources. Interposing a transmissive screen between the lens and viewer will cause the screen image to be seen by the viewer.

By adding illumination sources, corresponding exit pupils may be generated. However, if a single image is presented on the screen, the same image is obviously seen in each pupil. To generate a stereo pair of images, possibly the simplest solution would be to employ temporal multiplexing, by presenting left and right images sequentially on the screen and alternating the illumination source position. This is not easily achieved in practice, as currently available LCDs are not sufficiently fast. Another means of producing two images is to use two separate LCDs and combine their images with

¹⁷ The text was adopted for language learning purposes from preprint of the original paper of P. Surman, I. Sexton, R. Bates, W.K. Lee, K.C. Yow "Multi-user 3D display employing coaxial optics" [6].

a semi-silvered mirror. This method was employed by Sharp some years ago. This configuration enables full LCD resolution, but has the disadvantage that the display is necessarily large in relation to the screen size.

With the advent of high-resolution LCDs, it is possible to present two full resolution TV quality images simultaneously on one panel. The DMU display uses this approach and presents left and right images on alternate pixel rows. This scheme is referred to as spatial multiplexing (as opposed to temporal multiplexing where the images are presented sequentially).

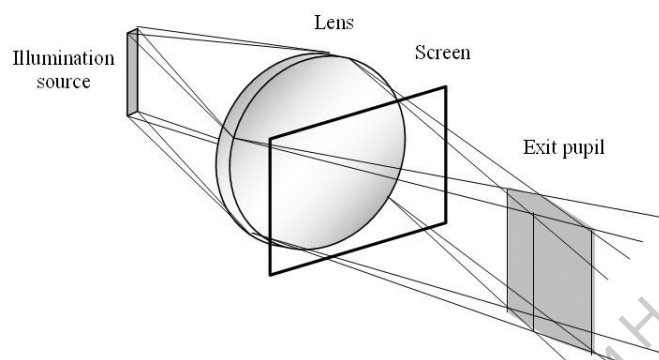


Figure 5.1. Exit pupil generation [6].

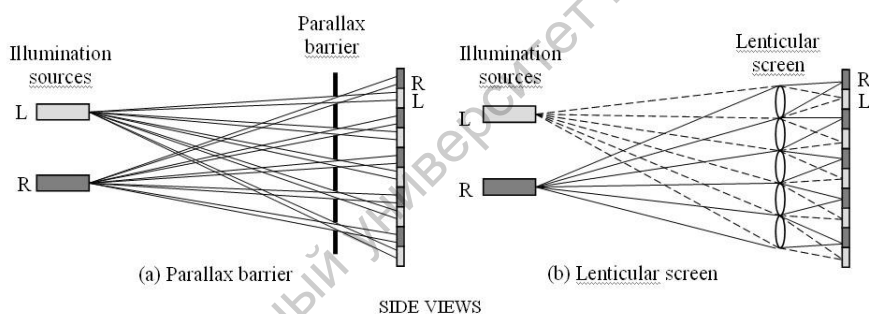


Figure 5.2. Spatial multiplexing [6].

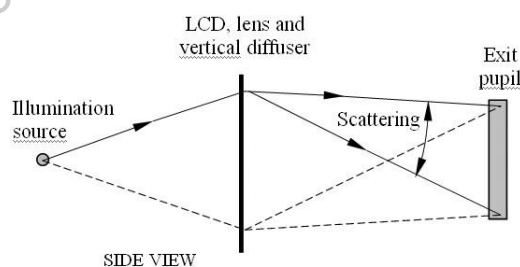


Figure 5.3. Vertical scattering [6].

By using spatial multiplexing, light from individual light sources must be manipulated independently for the left and right images before it reaches the screen. The simplest method of achieving this is with the use of a parallax barrier that consists of a mask with horizontal apertures. The pitch of these apertures is slightly less than double the LCD pixel vertical pitch. Fig.5.2 (a) shows the side view of this arrangement.

Note that the pitches of the barrier and the LCD are exaggerated for reasons of clarity. It can be seen that light from the left illumination source can only fall on the left image pixels, and light from the right source on the right pixels as the light sources are displaced vertically. Although the barrier

is simple to produce, it can theoretically only pass a maximum of 50% of the light, and considerably less if the light sources are the arrays that are used in the DMU display.

A more efficient means of multiplexing uses a lenticular screen with lenses horizontally disposed as shown in Fig.5.2 (b). This enables all of the light to be captured and also has the advantage that the light sources require only a small separation in the vertical direction. This is a particular advantage where the light sources are not simple lamps, but are optical arrays that have considerable height in relation to their spacing.

Even with the use of a lenticular sheet, the spatial multiplexing screen ideally requires the illumination sources to have a restricted height (as close to a point source as possible) to focus the left or right illumination sources on the individual left and right lines of the LCD without light spilling onto adjacent lines. As the exit pupil is a real image of the illumination source, this results in an exit pupil of limited height that can be too small to enable sufficient freedom of vertical head movement. To overcome this, the height of the exit pupil is expanded by using a diffuser placed in front of the LCD that scatters the light in the vertical direction only. Fig.5.3 shows how this is achieved. This diffuser can take the form of a lenticular sheet with horizontal lenses or a holographically produced light shaping diffuser.

Vocabulary Notes:

autostereoscopic display – автостереоскопический дисплей

exit pupils – выходные зрачки (в данном контексте можно перевести как «зоны наблюдения» или «зоны избирательного видения»)

head tracking – слежение за положением головы

steerable optical configuration – управляемая оптическая конфигурация

alternate pixel rows – чередующиеся строки пикселей

UXGA – (Ultra Extended Graphics Array – «ультрасрасширенный массив графики»)

один из стандартов компьютерной графики

spatial image multiplexing – пространственное разделение изображений

lenticular sheet – линзовый растр

steering optics – отклоняющая (управляющая) оптика

coloration effects – эффекты окрашивания

white LED array sources – источники в виде матриц белых светодиодов

broadcast television – вещательное телевидение

head position tracker – устройство, следящее за положением головы

anaglyph (red/green) glasses – анаглифные (красно-зеленые) очки

polarized glasses – поляризационные очки

diamond-shaped exit pupil region – (в данном контексте) зона наблюдения, имеющая форму алмаза

stereo pair of images – стереопара изображений

temporal multiplexing – временное разделение (изображений)

semi-silvered mirror – полупрозрачное зеркало с серебряным покрытием

TV quality images – изображения телевизионного качества

spatial multiplexing – пространственное чередование (в пространстве)

parallax barrier – параллакс-барьер

mask with horizontal apertures – маска с горизонтальными щелями

LCD pixel vertical pitch – период пиксельной структуры ЖКД по вертикали

considerable height in relation to their spacing – высота, значительная по отношению к их интервалу

arrangement – конструкция; конфигурация

Active Vocabulary:

steer – управлять; отклонять
 meet (satisfy) requirements – удовлетворять требованиям
 array – матрица; решетка; периодическая структура
 coaxial – коаксиальный; имеющий общую ось
 mobile viewers – подвижные зрители
 adjacent – смежный; соседний
 to interpose (between) – вставлять; помещать (между чем-л.)
 currently available – доступный в настоящее время
 advent – появление
 as opposed to – в отличие от
 exaggerate – преувеличивать
 result in – приводить к
 scatter – рассеивать
 backlight – подсветка
 pitch – шаг; период
 transmissive – пропускающий (экран)
 light spilling – падение света
 light diffuser – рассеиватель света

IV. Read the text attentively for detail and answer the following questions.

1. What has De Moutfort University developed?
2. How does this display operate?
3. What does the DMU display require?
4. What can you say about spatial multiplexing?

VOCABULARY EXERCISES

I. State the part of speech of the following words pointing out the word-building elements. Give their Russian equivalents.

Depend – dependent – independent – dependently – independently – dependence – independence;
 horizon – horizonless – horizontal – horizontally – horizontality – horizontalize; effect – effecter –
 effectible – effective – effectiveness – effectless; intend – intendment.

II. Make nouns and adjectives from each of the verbs in the table.

Verb	Noun	Adjective
develop		
apply		
produce		
generate		
achieve		

III. Use the correct form of the word in capitals at the end of each sentence to fill the gap.

10. Such wide angles will cause off-axis problems for an array cylindrical lenses. COMPRISE
11. The aperture blocks extreme rays that would be subject to a large degree of aberration. SPHERE
12. Light is contained between the upper and lower surfaces by total internal REFLECT
13. These simple structures the basic building blocks of the steering optics. FORM
14. De Moutfort University has an autostereoscopic display. DEVELOP
15. It operates by regions in the viewing field. PRODUCE
16. 3D displays have been used in a variety of niche APPLY
17. By adding illumination sources, corresponding exit pupils may be GENERATE

IV. Combine the words in bold with those in brackets. Translate the combinations into Russian.

to apply (~ for aid, football tickets, instructions, vacant position)

to employ (~ time in making experiments, time in reading, capital, questionable methods, the right word, workers, temporal multiplexing, this method, special devices)

to improve (~ conditions, handwriting, facilities of mind, working conditions, victory)

to exaggerate (~ problem, difficulty, the gravity of the situation, the pitches of the barrier)

to overcome (~ fear, problem, difficulty, obstacle, danger, bad habits, enemy, disaster)

considerable (~ part, sum of money, number, distance, weight, expense, income, height, amount of effort)

to achieve (purpose, ambition, success, distinction in public life)

V. Match the words in column A with their meanings in column B.

A	B
target <i>n</i>	place from which something comes or is got
apply <i>v</i>	defeat; be too strong for; make weak
source <i>n</i>	make or become larger
overcome <i>v</i>	coming or arrival of an important development
expand <i>v</i>	happening or done at the same time
shape <i>n</i>	make something seem larger, better, worse, etc. than it really is
advent <i>n</i>	something useful, helpful; benefit; profit
simultaneous <i>adj</i>	put with operation; make practice use of
exaggerate <i>v</i>	something to be aimed at; objective, total which it is desired to reach
advantage <i>n</i>	outer form

VI. Fill in the gaps in the sentences below using words from column A of Exercise V in the correct form.

1. An autostereoscopic display is specifically at television applications.
2. The spatial multiplexing screen ideally requires the illumination to have a restricted height.
3. To this, the height of the exit pupil is expanded.
4. This enables all the light to be captured and also has the that the light sources require only a small separation in the vertical direction.
5. If you always ..., people will no longer believe you.
6. With the of high-resolution LCDs it is possible to present two full resolution TV quality images.
7. Without high-resolution LCDs, it was impossible to present these images on one panel.
8. Metals when they are heated.
9. There were clouds of different
10. We intend to economic sanctions.

VII. Arrange the words given in a. and in b. in pairs of synonyms.

- a. Require, employ, merit, produce, apply, cause, conventional, associate.
- b. Use, reason, make use of, manufacture, demand, advantage, usual, connect.

VIII. Arrange the words given in a. and in b. in pairs of antonyms.

- a. Advantage, dependent, move, add, join, complex, with, distant, sufficiently, allow.
- b. Without, adjacent, simple, slightly, restrict, independent, rest, disadvantage, subtract, separate.

IX. Give the English equivalents for the following using the text.

Разрабатывать, применение, носить специальные очки, свободно двигаться по, создать несколько пар, вместе с, качество систем, удовлетворять требованию.

X. Give the Russian equivalents for the following.

Robust, medical imaging and recognition, robotics vision, acquisition, optical remote sensing, due to, inherent, on-axis hologram, space invariant, convolution, free space impulse response function, encoded pattern, depth distribution, optical detection system, superposed light, space varying positive term, intensity term, propagation axis, align.

PRACTICE

I. Translate the following noun groups into Russian.

television applications
 arcade game applications
 head position tracker
 illumination source
 TV quality images
 point source
 light spilling
 vertical head movement
 head-tracked 3D display
 off-axis lens aberration
 lens array
 off-axis problems

II. Translate the following sentences into English.

1. Дисплей, принципы которого здесь описаны, позволяет решить эту сложную проблему.
2. В предлагаемом решении используются доступные на сегодня технологии.
3. Описанный метод налагает минимальные ограничения на количество отображаемой

информации.

4. Каждому зрителю предъявляются два плоских изображения.
5. Другим преимуществом нашего дисплея является то, что его ключевые технологии, LCD и LED, быстро развиваются.
6. Созданный прототип позволил продемонстрировать правильность нашего подхода к построению многопользовательского (multi-viewer) 3D дисплея.
7. В созданном прототипе используется слежение за положением зрителей и пространственное разделение изображений.

III. Read the text¹⁸ and be ready to answer the following question: Why is simple 3D display inappropriate for multi-viewer applications?

Exit pupil generation and spatial multiplexing can now be combined in order to provide a head-tracked 3D display. In principle, if multiple mobile light sources are employed, this approach can be used to supply 3D to several viewers who can move around freely, Fig. 5.4. Here, the spatially multiplexed screen, lenticular sheet, vertical diffuser and a single (Fresnel) lens are combined. DMU have built a head tracked display of this type that serves one viewer, here the light sources only move laterally so that the viewer has fairly restricted movement toward and away from the screen. In addition, MIT have also patented a similar system.

In practice, this simple 3D display is inappropriate for multi-viewer applications for two reasons. Firstly, it is not practicable to have many independent light sources *physically* moving behind the LCD in both x and z-directions as this would create severely challenging mechanical problems. Secondly, this configuration suffers from off-axis lens aberrations.

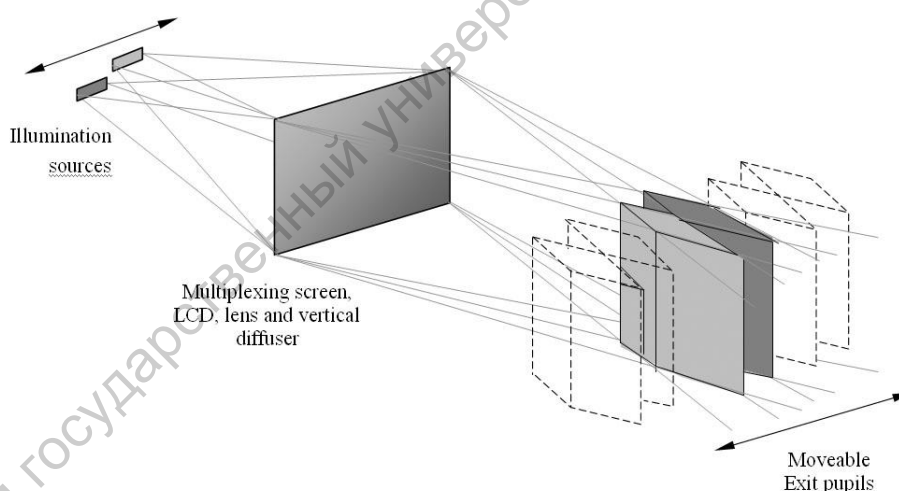


Figure 5.4. Schematic of simple mobile viewer 3D display [6].

Vocabulary Notes:

move laterally – двигаться вбок

MIT (Massachusetts Institute of Technology) – Массачусетский технологический институт

inappropriate – неуместный; несоответствующий

physically moving light sources – физически перемещающиеся источники света

off-axis lens aberrations – вне-осевые линзовые aberrации

¹⁸ The text was adopted for language learning purposes from preprint of the original paper of P. Surman, I. Sexton, R. Bates, W.K. Lee, K.C. Yow "Multi-user 3D display employing coaxial optics" [6].

IV. Read the text and state the main ideas in 2-3 sentences in English.¹⁹

Both of these problems can be addressed by replacing the lens with an array of smaller lenses as in Fig.5.5. From Fig. 5.5(a), this shows a single large lens forming an exit pupil, which is the real image of the single illumination source. A viewer's eye located in the shaded region is illuminated across the complete width of the lens.

In Fig.5.5 (b) it can be seen that the same function can be performed with an array of smaller lenses that each have a separate light source behind the lens. In this case, the exit pupil is formed from a bundle of approximately parallel rays from the lens array, as opposed to continuously converging rays from a single large lens. If the viewer moves laterally, the light sources move laterally in order for the exit pupil to follow the eye. In addition, if the viewer moves toward or away from the screen in the z-direction then the separation between the light sources can be altered to allow for this.

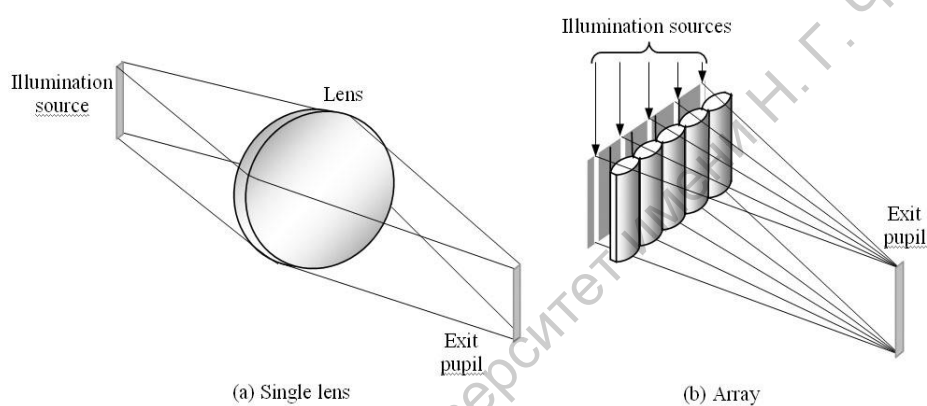


Figure 5.5. Array equivalent of a lens [6].

Vocabulary Notes:

continuously converging rays – постепенно сходящиеся лучи

lens array – линзовый растр

V. Read the text and render it in Russian.²⁰

The lens array shown in Fig. 5.5 (b) could possibly consist of a series of cylindrical lenses with narrow vertical light sources. For a domestic TV application, a display must form exit pupils at reasonably wide viewing angles either side of the axis to be acceptable. Such wide angles will cause off-axis problems for an array comprising cylindrical lenses.

For off-axis aberrations to be eliminated, the illumination and refracting surfaces must be cylindrical, and also have a common axis – hence the term coaxial optics. It follows that if exit pupils are to be formed over the very large area required by television, an *array of coaxial optical elements* may be used.

Fig. 5.6 shows the top view of such an array element. Note that the illumination surface is now curved, not planar as in Fig. 5.5 (b). All points on the illumination surface (on the left of the figures)

³ The text was adopted for language learning purposes from preprint of the original paper of P. Surman, I. Sexton, R. Bates, W.K. Lee, K.C. Yow "Multi-user 3D display employing coaxial optics" [6].

²⁰ The text was adopted for language learning purposes from preprint of the original paper of P. Surman, I. Sexton, R. Bates, W.K. Lee, K.C. Yow "Multi-user 3D display employing coaxial optics" [6].

are equidistant from the centre of the aperture. Hence, an approximately parallel beam of light emerges from the front lens surface, whatever the angle from the axis. The aperture blocks extreme rays that would be subject to a large degree of spherical aberration.

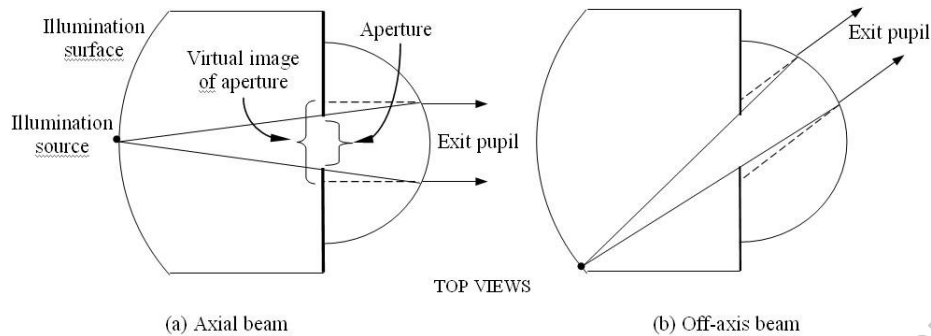


Figure 5.6. Operation of coaxial optical elements [6].

Vocabulary Notes:

series of cylindrical lenses – ряд цилиндрических линз

off-axis problems – проблемы, связанные с отклонением от оси

equidistant – равноудаленный

aperture blocks extreme rays – апертура блокирует крайние лучи

VI. Render the main text in English.

VII. Write an annotation on the text.

VIII. Topics for discussion.

1. 3D television requirements.

What requirements should 3-D television display meet? Which of these requirements are not so important in case of 3-D computer displays? How much does DMU display satisfy requirements for 3-D television display?

2. Temporal multiplexing, spatial multiplexing.

Try to define terms 'temporal multiplexing' and 'spatial multiplexing' using the main text. What is the main difference between these two approaches of stereo pair presenting? Argue your viewpoint using your definitions and the main text.

PART THREE

HOLOGRAPHY

Саратовский государственный университет имени Н. Г. Чернышевского

UNIT 6

HOLOGRAPHY AND 3D OBJECTS RECOGNITION

READING

I. Read the following words paying attention to pronunciation.

Acquisition [ækwɪ'zɪʃn], align [ə'laɪn], application [æplɪ'keɪʃn], axis ['æksɪs], capability [keɪpə'bɪlɪti], coherent [kəʊ'hɪərənt], conjugate ['kɒndʒʊɡeɪt], conventional [kən'venʃənəl], convolution [kɒnvə'lu:ʃn], dimensional [drɪ'menʃnəl], hologram ['hɒləgræm], impulse ['ɪmpʌls], inherent [ɪn'hɪərənt], neglect [nɪg'lekt] – negligible ['neglɪdʒəbl], observation [əbzɜ:'veɪʃn], recognition [rekəg'nɪʃn], record *n* ['rekɔ:d] – record *v* [rɪ'kɔ:d], reference ['refrəns], spatial ['speɪʃl], superpose [sju:pə'pəʊz], technique [tek'ni:k], utilize ['ju:tɪlaɪz], variety [və'raɪəti], visual ['vɪʒʊəl].

II. Try to guess the meaning of the words in bold.

application *n* practical use: the application of this theory to actual economic practice/ A micro computer has a wide range of applications for business./ What are the practical applications of this work?/ The program is designed for general application.

capability *n* the natural ability, skill, or power that makes you able to do something: a child's language capability/ A willingness and a capability to change are necessary to meet the market's needs./ the proven capability of this technology/ beyond the scope of human capability/ She has the capability to become a very fine actress./ The government wants to increase its military capability.

challenging *adj* difficult in an interesting or enjoyable way: Teaching is a challenging and rewarding job./ a challenging problem/ We have changed the course to make it more challenging./ The tasks were not challenging enough for me and I got bored.

compose *v* **be composed of** to be formed from a group of substances or parts: Water is composed of hydrogen and oxygen./ The committee was composed entirely of specialists./ Bones are largely composed of calcium./ The overall composition of the Senate was Democrats 57 and Republicans 43./ the ethnic composition of the region.

define *v* to describe something correctly and thoroughly: the ability to define client's needs/ The powers of the President are clearly defined in the Constitution./ It is important to define these terms accurately./ There may be problems if responsibilities are not adequately defined./ Social values are not easy to define./ We need a good working definition of 'pollution'.

device *n* a piece of equipment intended for a particular purpose, for example, for recording or measuring sth: a useful device for detecting electrical activity/ modern labor-saving devices/ All new cars are now fitted with these safety devices./ The device consists of a large wheel mounted on a metal post./ a tiny device designed to trace telephone calls.

eliminate *v* to completely get rid of sth that is unnecessary or unwanted: Under the agreement, all trade barriers will be eliminated./ Police have eliminated Morris from their enquiries./ The procedure does not completely eliminate the possibility of an accident./ Try to eliminate fatty foods from your diet.

endow *v formal* to give someone sth: give money to pay for creating, or for providing an income for, a college, hospital, etc: The state of Michigan has endowed three institutes to do research for industry. Nature endowed her with a beautiful singing voice. The family pet is endowed with

human intelligence./ the desire to endow pattern recognition systems with robust visual capabilities and a variety of applications.

observation *n* the process of watching something or someone carefully for a period of time: a study based on detailed observation of a group of 20 patients/ a result of scientific observation/ She's in hospital under observation./ The survey was based on direct observation of over 500 schools.

propagate *v formal* to spread an idea, belief, etc to many people: The group started a magazine to propagate its ideas./ Such lies are propagated in the media./ Electromagnetic waves propagate at the speed of light in a vacuum./ In solids, sound waves can propagate in four principle modes that are based on the way the particles oscillate./ The article focuses on experimental and theoretical advances in antennas including design and development, and in the propagation of electromagnetic waves including scattering, diffraction and interaction with continuous media.

recognition *n* the act of knowing someone or sth because you have known or learned about them in the past: Years later, she passed me in the street without even the smallest sign of recognition./ the automatic recognition of handwriting by computer/ He appeared at the Montreux [mɒn'trɜ:] festival in 1978, and at last began to get some international recognition as a pianist./ He was presented with a gold watch in recognition of his service to the company./ The importance of voluntary organizations in the economy still needs to be given recognition.

restrict *v* to limit or control the size, amount, or range of sth: The new law restricts the sale of hand guns./ The government is considering new laws which will further restrict people's access to firearms./ Having small children tends to restrict your freedom./ New heavy industries were concentrated in narrowly restricted areas./ Citizens of the EU can travel without restriction within the EU./ The regulations were seen as a restriction on personal freedom.

review *v* to examine, consider and judge a situation or process carefully: Safety procedures are being urgently reviewed after a chemical leak at the factory./ This film has been favorably reviewed in a number of papers./ The first chapter presents a critical review of the existing nursery education system.

robust *adj* strong and not likely to break; behaving or speaking in a strong and determined way: a six-foot giant who seemed likely to flatten even the most robust of deckchairs/ The US economy is now much more robust.

technique *n* a special skill or way of doing something, especially one that has to be learned: new techniques for producing special effects in movies/ The new technique works better than the one it has replaced./ techniques for the storage of data.

utilize *v formal* to use something effectively: a heating system that utilizes solar energy/ The new computer system is not being fully utilized yet./ Concrete had long been utilized as a bonding and covering material.

variety *n* a lot of a particular type of things that are different from each other: the girls come from a variety of different backgrounds./ The T-shirts are available in a wide variety of colors./ the rich variety of the local bird life/ Dealing with customers adds variety to the job./ the continuously varying intensities of natural light.

whole *adj* all of something; entire: The whole school meets together once a week./ The whole thing just makes me sick./ The project involved the whole of the university.

III. Skim the text quite quickly to get a general understanding and answer the questions given. Consult the vocabulary after the text.

1. What is the article about?
2. What do you know about the subject?
3. Where can 3-D pattern recognition be applied?
4. What are some of the challenges of recognizing a 3-D object?
5. What does the technique discussed in the article use to recognize a 3-D object?

HOLOGRAPHY AND 3D OBJECT RECOGNITION²¹

Three-dimensional (3-D) pattern recognition has been one of the most challenging problems in the pattern recognition area, due to the desires to endow pattern recognition systems with robust visual capabilities and a variety of applications.

Our real spatial world is 3-D, and thus 3-D information about objects can give a pattern recognition system more robust visual capabilities. 3-D pattern recognition finds a variety of applications in the areas of industrial inspections, 3-D microscopy, medical imaging and recognition, robotics vision, 3-D data acquisition and processing, and optical remote sensing. The difficulties of recognizing a 3-D object and learning its location are due mainly to visual systems that are restricted to the sensing and processing of information which can be displayed as 2-D projections.

In this chapter, we discuss a 3-D pattern recognition technique in which, we record the holograms of objects as a form of electric signal and achieving 3-D pattern recognition by digital processing of the holograms. In the technique, we don't need to record a series of 2-D images for representation of a 3-D object because we utilize the holographic information of the object. The depth information of the object can also be extracted directly from the hologram.

The diffracted light from an object contains whole 3-D information of the object as a complex field that is represented by spatial distribution of complex numbers. Complex numbers are composed of their amplitude and phase. However physical devices can only sense the intensity of the complex field. In this section, we review the characteristic of the diffracted light. After that, we present an on-axis hologram that records the phase information of the diffracted light as a form of intensity signal. This makes it possible that the on-axis hologram contains whole 3-D information of the object.

Figure (6.1) shows an optical system in which, coherent light illuminates an object and the diffracted light is observed on the observation plane. Since the free-space is linear and space invariant for the field distribution of light, the diffracted pattern on the observation plane is given by the superposition of the diffracted light from each points of the object. Thus, the diffracted pattern is calculated by convolution between the free space impulse response function and the spatial distribution of the object:

$$\varphi(x, y) = \int o(x, y, z) \otimes h(x, y, z) dz \quad (6.1)$$

where $o(x, y, z)$ is the spatial distribution of the object, λ is the wavelength of the illuminating light and

$$h(x, y, z) = j \frac{1}{\lambda z} \exp \left\{ -j \frac{\pi}{\lambda z} (x^2 + y^2) \right\}$$

is the free space impulse response function. When a point object is located at $(0, 0, z)$ in the fig. (6.1) the diffracted light distribution on the observation plane is the free space impulse response function. The symbol \otimes represents the convolution operation that is defined as

$$g_1(x, y) \otimes g_2(x, y) = \iint g_1(x', y') \times g_2(x - x', y - y') dx' dy'$$

²¹ The text was adopted for language learning purposes from preprint of the original paper of T. Kim "Optical three-dimensional image recognition using holographic information" [7].

The diffracted light, $\varphi(x, y)$ from the object is called object wave. In Eq. (6.1), we can see that the diffracted light on the observation plane is the encoded pattern, in which each points of the object is encoded by the free space impulse response function. Further more, the phase of the free space impulse response function contains the depth location of each points of the object. Thus, the diffracted pattern on the observation plane is a spatial distribution of complex numbers in general, i.e.

$$\varphi(x, y) = |\varphi(x, y)| \exp(j\angle\varphi(x, y))$$

and its phase $\angle\varphi(x, y)$ contains the information of the object's depth distribution. However optical detection system like a film or a CCD responds only to the intensity of light. Thus, we lose the phase information of the object wave $\angle\varphi(x, y)$ when we detect the spatial distribution of light using a conventional optical detection system. This makes it impossible to record the depth distribution of the object by direct detection of the object wave.

In order to detect the phase information of the object wave, we superpose a plane wave with the object wave. The plane wave that is superposed with the object wave is called a reference wave. Figure (6.2) shows the optical system that superposes the object wave with the reference wave. The field distribution of the superposed light on the observation plane is given by:

$$\Psi(x, y) = 1 + \varphi(x, y) \quad (6.2)$$

where 1 represents the plane wave on the observation plane.

When we place a two-dimensional light detection system like a film or a CCD on the observation plane, we can record the intensity distribution of the superposed light. The intensity distribution of the superposed light on the observation plane is given by:

$$\begin{aligned} H_o^{DC}(x, y) &= |\Psi(x, y)|^2 = |1 + \varphi(x, y)|^2 \\ &= 1 + |\varphi(x, y)|^2 + \varphi^*(x, y) + \varphi(x, y) \\ &= 1 + |\varphi(x, y)|^2 + 2\text{Re}\{\varphi(x, y)\} \\ &= 1 + |\varphi(x, y)|^2 + 2|\varphi(x, y)|\cos(\angle\varphi(x, y)) \end{aligned} \quad (6.3)$$

where $\varphi^*(x, y)$ represents the complex conjugate of $\varphi(x, y)$. Note that the phase information of the diffracted light $\angle\varphi(x, y)$ is recorded as an intensity pattern. Further more, we can see that the intensity pattern is composed of three terms. The first term is the space varying positive term $(1 + |\varphi(x, y)|^2)$, the second term is the complex conjugate of the object wave $\varphi^*(x, y)$ and the third term is the object wave itself $\varphi(x, y)$. The object wave contains the information of the whole 3-D distribution of the object. Here we can see that if we record the intensity pattern of the superposed light, the recorded pattern contains whole 3-D information of the object. Thus, the recorded pattern is called a hologram (a whole record).

Since the propagation axes of the reference wave and the object wave is aligned, this kind of holographic recording is called an "on-axis hologram".

In a hologram, the space between fringes is determined by depth information of an object. Thus, the information of the object's depth distribution is encoded as a form of the fringe pattern in the hologram. This makes it possible that one matches whole 3-D aspects of objects just by 2-D matching between the holograms of the objects.

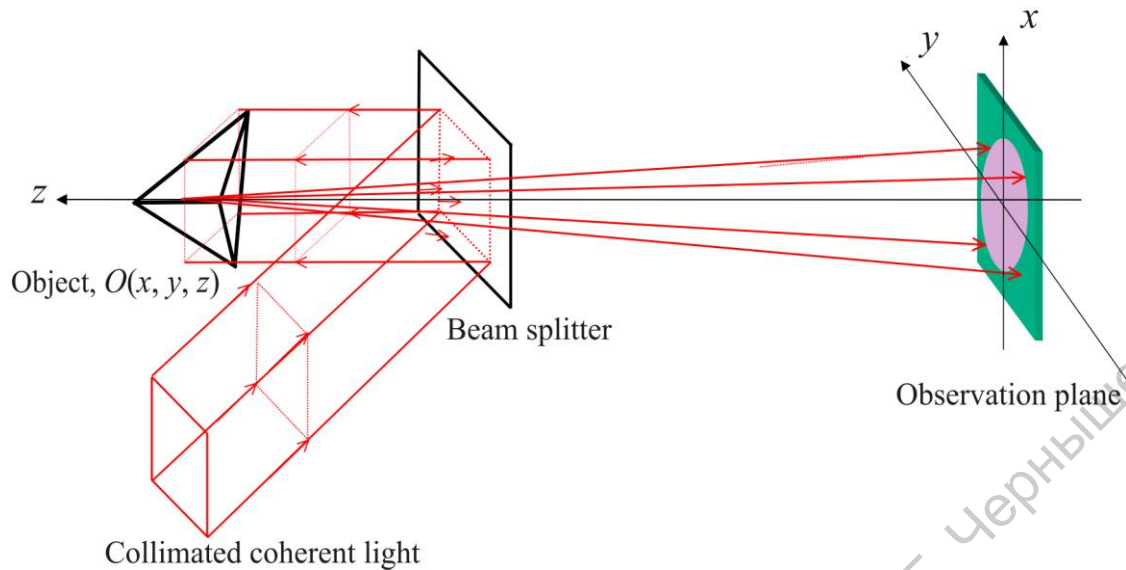


Figure 6.1. Illuminating an object with coherent light [7].

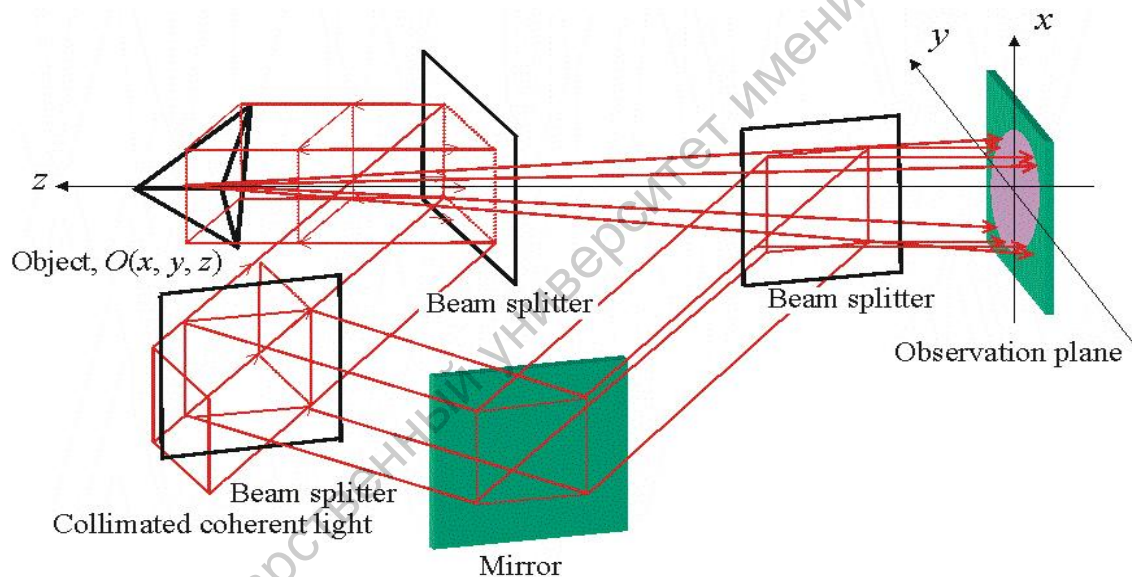


Figure 6.2. On-axis hologram of an object [7].

Vocabulary Notes:

3-D data acquisition and processing – сбор и обработка трехмерных массивов данных

CCD (Charge Coupled Device) – прибор с зарядовой связью (ПЗС)

challenging – трудный

field distribution of light – распределение освещения

free space impulse response function – функция импульсного отклика свободного пространства (импульсный отклик свободного пространства)

intensity term – слагаемое, связанное с интенсивностью

imaging – визуализация

optical detection system – (в данном случае) система регистрации оптического излучения

optical remote sensing – оптическое дистанционное зондирование

phase information of the object wave – информация, содержащаяся в фазе предметной волны

space varying positive term – положительное слагаемое, зависящее от пространственных координат

Active Vocabulary:

recognize – узнавать; распознавать
 pattern – структура
 negligible small – пренебрежимо малый
 align – совмещать
 i.e. (id est) – то есть
 compared to – по сравнению с
 display – показывать
 distribution – распределение
 endow – снабжать; обеспечивать
 extract – извлекать; получать
 representation – воспроизведение
 respond – отвечать; реагировать
 review – делать обзор; рассматривать
 robust – крепкий; устойчивый (к сбоям)
 series – ряд; серия
 spatial – пространственный
 technique – метод; способ
 utilize – использовать
 variety – разнообразие
 process information – обрабатывать информацию
 complex conjugate – комплексно сопряженное
 convolution – свертка
 diffracted light – дифрагированный свет
 diffracted pattern – дифракционная картина
 object wave – предметная волна
 reference wave – опорная волна
 on-axis hologram – осевая голограмма
 superpose – осуществлять суперпозицию; совмещать; накладывать
 wavelength – длина волны
 interference fringes – интерференционные полосы

IV. Read the text attentively for detail and answer the following questions.

1. Why should pattern recognition be three-dimensional?
2. What kind of object wave information should we detect to have the whole 3-D information of the object?
3. Why do we usually lose phase information of the object wave using conventional optical detection system?
4. Why do we need an additional wave called 'reference wave' to detect the phase information of the object wave?
5. What type of wave was used in the main text as a reference wave?
6. Why is the hologram described called 'on-axis hologram'?

VOCABULARY EXERCISES

I. State the part of speech of the following words pointing out the word-building elements. Give their Russian equivalents.

Capability – capable; dimension – dimensional; to acquire – acquisition; to apply – application – applicable – applied; to challenge – challenging; to compose – composition; to detect – detection – detector – detectable; to eliminate – elimination; to extract – extraction; to inhere – inherence – inherent – inherently; to locate – location; to observe – observation – observer; to propagate – propagation; to represent – representation – representative; to superpose – superposition; to utilize – utilization – utilizable.

II. Make nouns and adjectives from each of the verbs in the table.

Verb	Noun	Adjective
apply		
define		
detect		
distribute		
observe		
recognize		
represent		
restrict		
utilize		
vary		
inhere		

III. Use the correct form of the word in capitals at the end of each sentence to fill the gap.

1. Computerized voice systems respond to people's voices. RECOGNIZE
2. With the new machines we finally have the to do the job properly. CAPABLE
3. The company, which has been exploring means of expansion, has decided to open 10 more restaurants. VARIETY
4. This part of the law is only to companies employing more than five people. APPLY
5. He devotes his time to the of knowledge. ACQUIRE
6. Luminous is a measure of the light-emitting ability of a light source, either generally or in a particular direction. INTENSE
7. Priority must be given to sensible of the world's resources. UTILIZE
8. Scientists study the of the soil. COMPOSE
9. The conference was attended by 200 delegates and also by from another 30 countries. OBSERVE
10. There's a smell of gas - did you turn the oven off? DEFINE
11. In the stage the reference wave illuminates the hologram. RECONSTRUCT
12. We found the answer by a process of ELIMINATE
13. The article focuses on experimental and theoretical advances in antennas including design and development, and in the of electromagnetic waves including scattering, diffraction and interaction with continuous media. PROPAGATE
14. Nuclear power is dangerous and wasteful. INHERE

IV. Combine the words in bold with those in brackets. Translate the combinations into Russian.

recognition (immediate ~, automatic, instant, early; character, face, handwriting, speech, text (computing), computer)

capability (enormous ~, limited, potential, human, intellectual, mental, technical, technological, manufacturing, research, computing, design, graphics, multimedia, processing, sound, video, military, nuclear)

applicable (be ~, prove, seem, become, make sth)

application (practical ~, general, wide, agricultural, industrial, possible, technical)

technique (recognition ~, effective, powerful, useful, basic, simple, conventional, established, standard, traditional, advanced, modern, sophisticated, ingenious, alternative, experimental; communication ~, evaluation, examination)

to record (~ hologram, distribution, names, events, conversation, sound, CDs)

device (~ physical, clever, ingenious, labor-saving, useful, complex, sophisticated, simple, hi-tech, hand-held, automatic, electrical, electronic, mechanical, measuring)

to define (~ accurately, carefully, correctly, exactly, clearly, fully; ~ needs, duties, problems, targets, size)

pattern (intensity ~, geometric, existing, familiar, set, traditional, behavior)

distribution (depth ~, light; spatial ~, fair, equal, uniform, optimal, general, wide, local, global, geographical, population, social)

observation (careful ~, close, detailed, direct, systematic, casual, scientific, clinical)

spatial (~ world, pattern, architecture, distribution, dispersion, movement)

robust (~ visual capabilities, people, voice, performance, energy, technique, economic growth, piece of equipment)

remote (~ town, area, parts, cameras, control, family connections, ancestor, chance, possibility)

extract (~ nectar, DNA, water, oil, information, benefit, confession, data, promise, tooth)

display (~ information on screens, train times, work, data, results, paintings, the latest fashions, interest, emotion, enthusiasm, skills, talent)

V. Match the words in column A with their meanings in column B.

A	B
align v	show information; show signs of sth
neglect v	examine, consider and judge a situation or process carefully
utilize v <i>formal</i>	a special skill or way of doing something, especially one that has to be learned
display v	in the form of a straight line; going from one thing to another in a single series of stages
conventional <i>adj</i>	use sth effectively
detect v	carefully remove a substance from another substance which contains it, using a machine, chemical process etc
distribute v	watch carefully the way sth happens or someone does sth
technique n	used or available for a long time and considered the usual type

extract <i>v</i>	relating to space and the position, size, shape of things in it
observe <i>v</i>	spread, scatter or supply sth over an area
review <i>v</i>	notice sth that is partly hidden or not clear, or discover esp. using a special method
linear <i>adj</i>	not give enough attention to sb/sth
spatial <i>adj</i>	put two or more things into a straight line

VI. Fill in the gaps in the sentences below using words from column A of Exercise V in the correct form.

1. The role of scientists is to and describe the world, not to try to control it. 2. Objects in the scene are recorded by a digital camera without wave interference. 3. The oil which is from olives is used for cooking. 4. In this chapter we recently proposed method of holographic computer-aided imaging. 5. Some sounds cannot be by the human ear. 6. This is only true in deep space when the gravitational force can be 7. Overhead the beautiful stars flickered and themselves into patterns. 8. Worms commonly network services to propagate to other host systems. 9. Each panel sound evenly in all directions. 10. A surprising to concentrate, manipulate and separate a wide class of swimming bacteria has been identified by scientists. 11. In general, scan data processing within 2MAPPS (Production Processing System) is a process with the output of each step being the input for each subsequent step. 12. This article will show you how to tabular data in a non-conventional manner. 13. As pioneers in image technology, the company creates custom applications that break the boundaries of conventional 2D imaging to bring new dimensionality and interactivity to the fields of medicine, engineering, advertising, and entertainment.

VII. Arrange the words given in a. and in b. in pairs of synonyms.

- Challenging, conventional, capability, robust, distribution, pattern, application, inherent, extract, device, technique, acquire, detect, observe, recognize, review, respond, eliminate, neglect, negligible, remote.
- Use, ability, ignore, typical of, method, appliance, obtain, watch, strong, answer, complicated, examine, remove, common, draw out, model, insignificant, spread, identify, find, distant.

VIII. Arrange the words given in a. and in b. in pairs of antonyms.

- Eliminate, neglect, negligible, remote, challenging, restricted, display, acquire, capability, whole.
- Close, unlimited, accept, partial, significant, easy, incompetence, regard, lose, conceal.

IX. Give the English equivalents for the following using the text.

Распознавание трехмерных образов, сложная проблема, наделять, пространственный, обработка данных, дистанционный, ограниченный, использовать, извлекать, пространственное распределение, состоять из, интенсивность комплексного поля, плоскость наблюдения, линейный, отвечать на, плоская волна, объектная волна, опорная волна,

комплексно сопряженное, по сравнению с, пренебрежимо малый, устранять, не принимать во внимание.

X. Give the Russian equivalents for the following.

Robust, medical imaging and recognition, robotics vision, acquisition, optical remote sensing, due to, inherent, on-axis hologram, space invariant, convolution, free space impulse response function, encoded pattern, depth distribution, optical detection system, superposed light, space varying positive term, intensity term, propagation axis, align.

PRACTICE

I. Translate the following sentences into Russian defining if forms ending in -ed are verb forms or participles.

1. Holographic technology supplies high-quality images and accurate depth cues **viewed** by human eyes without any special observation devices.
2. The reconstructed wave front from a holographic stereogram is **composed** of a set of discrete patches.
3. Because of the discontinuity between those patches, the imitation of the **observed** reality cannot be complete.
4. The objects to be constructed by the CGH can be **represented** in the computer by mathematical or graphical descriptions.
5. Complex numbers are **composed** of their amplitude and phase.
6. In the early days of the CGH, Waters **designed** a CGH **based** on the assumption that any object is **constructed** from many independent light scatterers.
7. The superposition of all these complex amplitudes yields the **desired** complex amplitude distribution on the hologram plane.
8. In this chapter we review recently **proposed** method of holographic **computer-aided** imaging.
9. The main feature of this hologram is that its transparency values are identical to a Fourier hologram **recorded** by an interference between two laser beams.
10. This hologram is not **related** to the well-known multiplex or stereoscopic hologram.
11. The true wave front diffracted from the object can be **reconstructed** from the proposed hologram.
12. The same algorithm can be **employed** on a set of angular perspectives of realistic objects **captured** by a digital camera from some realistic scene.
13. The depth information of the object can also be **extracted** from the hologram.
14. The **diffracted** light is **observed** on the observation plane.
15. The plane wave **superposed** with the object wave is **called** a reference wave.

II. Read the text and reproduce it in Russian in short.²²

Figure (6.3) shows the optical system for reconstruction of the object in 3-D space. In the reconstruction stage, the reference wave illuminates the hologram. Then, the reference light is

²² The text was adopted for language learning purposes from preprint of the original paper of T. Kim "Optical three-dimensional image recognition using holographic information" [7].

spatially modulated by the hologram. This is calculated by multiplication between the hologram and the reference wave; i.e. $H_o^{DC}(x, y) \times 1$. After that, the modulated light propagates through the 3-D space. The propagating wave reconstructs the object's transverse image at each matched depth locations with some noise. That is calculated by the convolution between the modulated reference wave and free space impulse response:

$$\begin{aligned} R(x, y) &= (H_o^{DC}(x, y) \times 1) \otimes h(x, y, z_R) \\ &= (1 + |\varphi(x, y)|^2) \otimes h(x, y, z_R) + \varphi^*(x, y) \otimes h(x, y, z_R) + \varphi(x, y) \otimes h(x, y, z_R) \end{aligned} \quad (6.4)$$

where $h(x, y, z_R)$ is the free space impulse response function at (x, y, z_R) in the 3-D space.

Note that the reconstructed image has three terms. First term is the reconstruction of space varying positive term. Second term is the reconstruction of the complex conjugate of the object wave. Third term is the reconstruction of the object wave. The second term contributes the reconstruction of the object in the 3-D space.

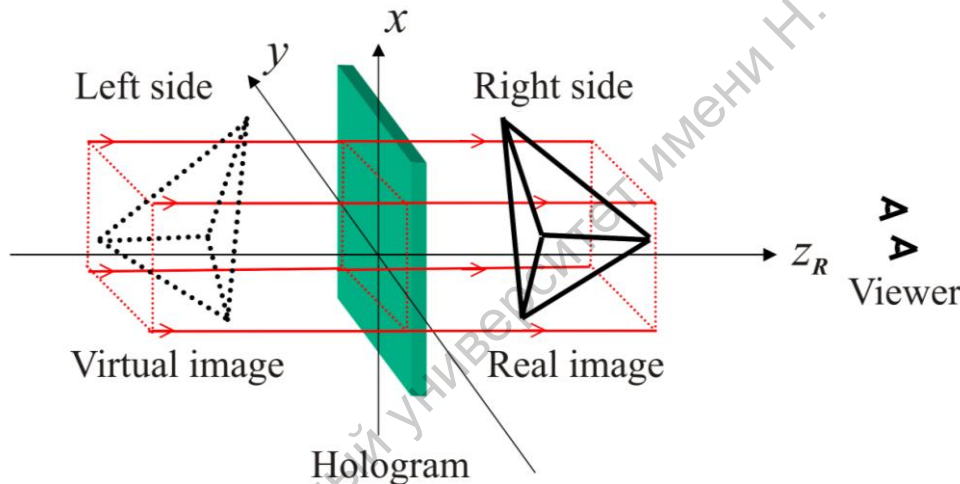


Figure 6.3. Reconstruction of the hologram [7].

Vocabulary Notes:

transverse image – изображение поперечного сечения

at each matched depth locations – во всех соответствующих положениях по глубине

real image – действительное изображение

virtual image – мнимое изображение

III. Translate the following text into English.²³

Голография имеет огромный потенциал для применения в области распознавания трехмерных образов. Голограмма содержит полную запись информации о трехмерной структуре объекта в виде двумерной картины, и существует ряд техник, позволяющих извлечь эту информацию в форме электрического сигнала. Это открывает новые возможности для распознавания трехмерных образов. Использование голографической

²³ The text was translated from preprint of the original paper of T. Kim "Optical three-dimensional image recognition using holographic information" [7].

информации об объекте для распознавания и слежения в трехмерном пространстве имеет ряд преимуществ. Во-первых, нам не нужно записывать серию двумерных изображений, чтобы представить трехмерный вид объекта. Во-вторых, информация о глубине может быть получена путем анализа голограммы.

Vocabulary Notes:

3-D pattern recognition – распознавание трехмерных образов

3-D aspect of an object – трехмерный (внешний) вид объекта

IV. Read the text and render it in English.²⁴

Recently, the electro-optical techniques that record the whole diffracted light from an object as a form of electric signal have been proposed. This recording of the whole diffracted light as spatial distribution of complex numbers is known as a complex hologram. The first of this kind is the optical scanning holography.

The optical scanning holography has been proposed by Poon and Korpel and subsequently formulated by Poon. In the optical scanning holography, the spatial distribution of the whole diffracted light is recorded as a form of electric signal. The followings represent other techniques for electronic recording of a complex hologram. Recording on-axis holograms with four different phase shifts as using a CCD instead of a film permits synthesizing a complex hologram. Using triangular interferometer, polarization optics and CCD allows the recording of a complex hologram with an incoherent light. Heterodyne detection and recording two on-axis holograms using CCD permits the calculation of a complex hologram. Most recently a digital technique that calculates the complex hologram of a realistic object without the wave interference was proposed.

V. Reproduce the main text.

VI. Write an annotation on the text.

VII. Topics for discussion.

1. Complete registration of the light wave.

Conventional optical detection systems like film or CCD respond only to the intensity of light. Thus phase information of detected wave is lost. How is this obstacle overcome in holography? Does holography use non-conventional or conventional optical detection systems? Supply your viewpoint with arguments.

²⁴ The text was adopted for language learning purposes from preprint of the original paper of T. Kim "Optical three-dimensional image recognition using holographic information" [7].

UNIT 7

COMPUTER-GENERATED HOLOGRAMS

READING

I. Read the following words paying attention to pronunciation.

Accurate ['ækjʊrət], amplitude ['æmplɪtju:d], angular ['æŋgjʊlə], array [ə'reɪ], assumption [ə'sʌmpʃn], authentic [ɔ:'θentɪk], coherence [kəʊ'hɪərəns], cue [kju:], design [dɪ'zaɪn], discontinuity [dɪskontɪnju:ɪti], enable [ɪ'neɪbl], interference [ɪntə'fɪərəns], naked ['neɪkɪd], relatively ['relətɪvli], requirement [rɪ'kwaɪəmənt], retrievable [rɪ'tri:vəbl], review [rɪ'vju:], slight [slaɪt], source [sɔ:s], synthesize ['sɪnθaɪsaɪz], transparency [træn'spærənsi], transverse [trænz'veɜ:s], value ['vælju:], volumetric [vɒlju'metrɪk], yield [ji:ld].

II. Try to guess the meaning of the words in bold type.

accurate *adj* an accurate measurement, calculation, record etc has been done in a careful and exact way and is completely correct: His predictions proved accurate./ The figures he gave were not strictly accurate./ It's impossible to predict the weather accurately./ Would it be more accurate to say that the plan failed?

assumption *n* sth that you think is true although you have no proof: make an assumption/ mistaken assumption/ I set the table to eight people, on the assumption that Jo would come./ Your argument is based on a completely false assumption./ People tend to make assumptions about you based on your appearance.

authentic *adj* real, not false or copied; genuine; done or made in the traditional or original way: authentic Chinese food/ The letter is certainly authentic./ Korg seem to have done the impossible and produced a totally digital processor with some absolutely authentic guitar sounds./ A single hologram is capable of creating the most authentic illusion of observing volumetric objects by the naked eye.

beam *n* a shining line of light from the sun or a lamp etc: a laser beam/ the beam of the car headlights/ the beam of a powerful flashlight/ Maggie stumbled across the field with only a narrow beam of light from her flashlight to help her./ We could see the beams of searchlights scanning in the sky.

capture *v* to catch someone in order to make them a prisoner; to express what someone really likes in a way that people can clearly recognize: Japanese firms have now captured over 50% of the market./ The film succeeds in capturing the mood of the 1960s./ The whole incident was captured by a young American photographer.

demand *v* to ask for sth very firmly, especially sth that someone does not want to give you: There are just too many things demanding my attention at once./ This experiment demands skill and energy./ This letter demands an immediate answer.

feature *n* a part of sth that you notice because it seems important, interesting or typical: common features/ geographical feature/ distinguishing features/ Window design is also a characteristic feature of Gothic architecture./ An important feature of Van Gogh's paintings is their bright colors./ Each room has its own distinctive features.

ordinary *adj* average, common, or usual, not different or special: It was just an ordinary Saturday morning./ the needs of ordinary citizens/ an ordinary workday/ Can you get connected to the

Internet through an ordinary telephone line?/ Gillman is known for her photographs of ordinary household items.

partial *adj* not complete: They could provide only a partial solution to the problem./ He can make only a partial payment./ The exhibition was only a partial success./ From where I was standing, I had a partial view of the house.

patch *n* a part of an area that is different or looks different from the parts that surround it: a small dog, white with brown patches/ patch of dirt/ patch of light/ patch of sky/ Patches of blue sky peeked through the clouds./ She had sewn colorful patches on her jeans.

discrete *adj* separate: The reconstructed wave front from a holographic stereogram is composed of a set of discrete patches. The change happens in a series of discrete steps./ The situation is different for native speakers of the language who automatically perceive the speech as being chopped up into discrete units.

propose *v* to suggest sth as a plan or a course of action: Hansen has proposed that I become his business partner./ The measures have been proposed as a way of improving standards./ Einstein proposed his theory of general relativity in 1915.

replace *v* to start doing sth instead of another person, or being used instead of another thing: These PCs replace the old system network./ I'll replace the vase I broke as soon as possible./ Suddenly John's relaxed mood was replaced by a feeling of panic.

retrieve *v* to find something and bring it back: The wreckage of the crashed plane was retrieved from the ocean./ retrievable/ The depth information is retrievable from continuous parallax and from focusing on different transverse planes through the volume./ The new version of the software automatically retrieves digital information.

slight *adj* not serious or not important; small in size, amount, or degree: a slight increase in temperature/ There's been a slight change of the plan./ I didn't have the slightest idea who that man was./ A very slight movement can destroy the interference fringes, which contain both intensity and phase information./ I haven't given the slightest thought to my holiday plans.

supply *v* to provide people with something that they need or want, especially regularly over a long period of time: An informer supplied the police with the names of those involved in the crime./ Any room where gas is used must be adequately supplied with air./ goods supplied for private use/ a contract to supply something

III. Skim the text quite quickly to get a general understanding and answer the questions given. Consult the vocabulary after the text.

1. What does the article centre around?
2. Why is holography considered to be a more attractive method of displaying 3-D images than others?
3. What methods of holographic imaging are mentioned in the article?
4. How are the objects constructed by CGHs represented?
5. What does the choice of an algorithm for synthesizing CGHs for 3-D imaging depend on?

COMPUTER-GENERATED HOLOGRAMS²⁵

Holography seems to be a more attractive method of displaying 3-D images than others because a single hologram is capable of creating the most authentic illusion of observing volumetric objects by the naked eye. Holographic technology supplies high-quality images and accurate depth cues viewed by human eyes without any special observation devices.

²⁵ The text was adopted for language learning purposes from preprint of the original paper of J. Rosen, D. Abookasis, "Holographic three-dimensional computer-aided imaging" [8].

Since the invention of the hologram more than 50 years ago, holographic recording of real objects has been performed by wave interference. In general, interference between optical waves demands relatively intense light with a high degree of coherence between the involved beams. The optical system must be very stable, since a very slight movement can destroy the interference fringes, which contain both intensity and phase information. These requirements have prevented hologram recorders from becoming as widely used for outdoor photography as conventional cameras.

A possible solution to these limitations is obtained by the techniques of holographic stereograms (also known as multiplex holograms). However, optical interference is also involved in recording of holographic stereograms. Besides, unlike ordinary holograms, holographic stereograms do not reconstruct the true wave front that is diffracted from an object when this object is coherently illuminated. The reconstructed wave front from a holographic stereogram is composed of a set of discrete patches; each patch contains a different perspective projection of the object. Because of the discontinuity between those patches, the imitation of the observed reality cannot be complete.

A partial solution for these limitations might be using computer-generated holograms (CGHs). The objects to be constructed by the CGH can be represented in the computer by mathematical or graphical descriptions, or by their spatial samples. The physical interference between light waves is replaced by mathematical computation. However, synthesizing CGHs of 3-D images is usually a heavy computational task. This is because one needs to superpose the mathematical contributions of many waves originating from many points on the objects, when not all of them are located at the same distance from the hologram plane.

Many algorithms for synthesizing CGHs for 3-D imaging have been proposed in the past three decades. The choice among the various algorithms depends on different factors such as computation time, the hologram applications, and image characteristics. In the early days of the CGH, Waters designed a CGH based on the assumption that any object is constructed from many independent light scatterers, each of which is considered as a point source of a parabolic wave front. The superposition of all these complex amplitudes yields the desired complex amplitude distribution on the hologram plane. The depth information is retrievable from continuous parallax and from focusing on different transverse planes through the volume (accommodation effect). The difficulty of this technique comes from the long computation time necessary to superpose waves coming from large number of object points.

In this chapter, we review recently proposed method of holographic computer-aided imaging. Generally in this method, a hologram is computed from a set of angular projections of the observed 3-D object, recorded by a conventional digital camera. The recorded data are numerically processed to yield a two-dimensional complex function, which is then encoded as a computer-generated hologram. When this hologram is illuminated by a plane wave, a 3-D real image of the object is reconstructed. The main feature of this hologram is that its transparency values are identical to a Fourier hologram recorded by an interference between two laser beams. It is important to note that this hologram is not related to the well-known multiplex or stereoscopic holograms. The main advantage of this technique is that, although objects in the scene are recorded by a conventional digital camera without wave interference, the process yields a hologram of the observed scene with a 3-D nature.

Following the presentation of the basic hologram, we describe different configurations of scanning the scene. The two main examples are, on one hand, a hologram computed from a set of different viewpoints along a horizontal arc around the observed object²⁴. On the other hand, using two-dimensional (2-D) array of observation points enables us to capture the scene from horizontal as well as vertical points of view, and thus such a technique yields a different type of hologram.

Vocabulary Notes:

holographic three-dimensional computer-aided imaging – создание трехмерных голографических изображений с помощью компьютера

accurate depth cues – четкие признаки глубины

holographic stereograms (multiplex holograms) – голографические стереограммы (составные голограммы)

outdoor photography – фотография вне помещения

a set of discrete patches – набор дискретный фрагментов

a different perspective projection – отличающаяся центральная проекция

computer-generated hologram (CGH) – голограмма, созданная на компьютере (синтезированная голограмма)

focusing on different transverse planes through the volume – фокусировка на различных поперечных плоскостях на протяжении объема

two-dimensional complex function – двумерная комплексная функция

Fourier hologram – голограмма Фурье

two-dimensional (2-D) array of observation point – двумерный массив точек наблюдения

Active Vocabulary:

authentic – подлинный; достоверный

volumetric – объемный

capability – способность

conventional – обычный

obtain – получать

ordinary – обычный

discontinuity – неоднородность; прерывистость

yield – приводить; выдавать; производить

partial – частичный

retrievable – восстанавливаемый

enable – давать возможность

requirement – требование

diffract (from) – дифрагировать (на)

transparency – прозрачность

wave front – волновой фронт

wave interference – волновая интерференция

interference fringes – интерференционные полосы

hologram plane – плоскость голограммы

by the naked eye – невооруженным глазом

IV. Read the text attentively for detail and answer the following questions.

1. What physical phenomenon is holography based on?
2. Why haven't hologram recorders become as widely used for outdoor photography as conventional cameras?
3. Why is imitation of the observed reality given by multiplex hologram incomplete?
4. What is the main problem connected with synthesizing of CGHs?
5. What advantages and disadvantages of holography as a method of displaying 3-D images can you single out from the main text?
6. What does proposed method of holographic computer-aided imaging consist in?

VOCABULARY EXERCISES

I. State the part of speech of the following words pointing out the word building elements. Give their Russian equivalents.

Intense – intensity; cohere – coherence – coherent – coherently; continue – continuity – discontinuity – continuous; compute – computer – computation – computational; volume – volumetric; hologram – holography – holographic; attract – attraction – attractiveness – attractive – attractively; illusion – illusive; deepen – depth – deep – deeply; invent – invention – inventor – inventive; relate – relation – relative – relativity – relatively; move – movement; require – requirement; numerate – numeral – numeration; numerical – numerous – numerically.

II. Make nouns and adjectives from each of the verbs from the table.

Verb	Noun	Adjective
enable		
originate		
differ		
create		
deepen		
retrieve		
depend		
continue		
compose		
replace		

III. Use the correct form of the word in capitals at the end of each sentence to fill the gap.

9. There's often a lack of between one government and the next. CONTINUE
10. Water normally moves more slowly at shallower DEEP
11. The new central heating has made an enormous to the house. DIFFER
12. Our new boss tackles problems in a completely way. ORIGIN
13. The shop has a very limited of ties. CHOOSE
14. Money from her aunt Jan to buy the house. ABLE
15. We need to reduce our on oil as a source of energy. DEPEND
16. structural alterations have been carried out. NUMERAL
17. A good imaging system makes of relevant documents fast, easy and efficient. RETRIEVE
18. The amount of energy which is transported past a given area of the medium per unit of time is known as the of the sound wave. INTENSE
19. The color of a star depends on its chemical and its mass. COMPOSE
20. These have prevented hologram recorders from becoming as widely used for outdoor photography as conventional cameras. REQUIRE
21. A possible to these limitations is obtained by the techniques of holographic stereograms. SOLVE
22. This low pressure made a vacuum above the liquid. PART

IV. Combine the words in bold with those in brackets. Translate the combinations into Russian.

intense (be ~, become, remain; extremely, incredibly, quite; ~ heat, cold, sunlight, pain, pressure, concentration, personality, nature)

single (~ hologram, tree, day, sheet of paper, people, parent, word, ticket)

authentic (~ painting, document, book, statue, uniform, sounds, atmosphere)

demand (~ resignation, apology, attention, remedy, explanation, control, time)

requirement (main ~, fundamental, reasonable, basic, minimum, additional, further, special, individual, annual, daily, constitutional, formal, legislative; safety ~, visa, energy; fulfil ~, meet, satisfy, impose)

conventional (be ~, seem; ~ camera, methods, view, phone lines, tastes, approach, light bulb)

discrete (~ patches, groups, stages, units, detectors, functions)

partial (~ solution, success, recovery, compensation, refund, victory)

description (mathematical ~, graphical, complete, comprehensive, detailed, full, accurate, vague, objective; give ~, provide)

computation (mathematical ~, scientific, simple, statistical; ~ of the monthly statistics; the speed of ~, a series of; an error in ~)

distribution (equal ~, unfair, uniform, optimal, overall, local, spatial; ~ on the plane, of aid supplies; population ~)

contribution (important ~, significant, enormous, modest, valuable, outstanding, voluntary; make ~)

source (excellent ~, reliable, valuable, principal, external, independent, additional, alternative, natural; point ~, energy, food, water, light, data, information; be ~, constitute, prove, provide, use)

yield (~ crop, solution, results, benefits, profit, information, distribution)

encode (~ message, information, gene, broadcasts, CDs; ~ electronically)

beam (bright ~, intense, powerful, narrow, thin, electron, laser, searchlight, torch; direct ~, send)

capture (~ perfectly, brilliantly, neatly; attempt to ~, try to, manage to, fail to; ~ scene, imagination, attention, data)

obtain (be able/unable to ~, attempt to, fail to, be easy to, be possible to, need to, be required to; ~ dishonestly, illegally; ~ goods, information, details, permission, visa, approval, evidence, funding, license)

V. Match the words in column A with their meanings in column B.

A	B
design <i>v</i>	the quality of glass, plastic etc that makes it possible for you to see through it
yield <i>v</i>	a view of a place as you see it, or as it appears in a picture
transverse <i>adj</i>	a curved shape
compute <i>v</i>	catch person or animal; get control of a place; express how sb/sth is
encode <i>v</i>	a way of solving a problem or dealing with a difficult situation
capture <i>v</i>	calculate (an answer or amount) by using a machine
enable <i>v</i>	sth that makes one person or thing more likely to succeed than others
arc <i>n</i>	placed across sth/ in a position or direction that is at an angle of 90° to sth else
advantage <i>n</i>	give sb the ability or opportunity to do sth
originate <i>v</i>	find something and bring it back
solution <i>n</i>	put secret information onto code (a system of words, numbers, or symbols that hides its real meaning)
retrieve <i>v</i>	start to develop in a particular place or from a particular situation

transparency <i>n</i>	decide how sth will look, work, etc., especially by drawing plans or making models
scene <i>n</i>	produce sth useful such as information or evidence

VI. Fill in the gaps in the sentences below using words from column A of Exercise V in the correct form.

1. The home team always have an over their opponents. 2. After a process of recording the under incoherent illumination and digital computing, we get a 2-D complex function. 3. The method is specially for use in small groups. 4. The wreckage of the crashed plane was from the ocean. 5. These variable factors include the depth of the water, its temperature and, and its velocity, among others. 6. Some music CDs are now with information about the performers and their music, but you need a special player to use them. 7. A bar joints the two posts. 8. This will users to conduct live video conversations. 9. The research has useful information. 10. Both sides are trying to find a peaceful 11. The data is by an optical scanner. 12. Buddhism in India and came to China in the first century A. D. 13. the ratio of the object's height to its weight. 14. The mountains formed an around the north of the city.

VII. Arrange the words given in a. and in b. in pairs of synonyms.

- Authentic, demand, device, perform, stable, destroy, obtain, technique, solution, ordinary, originate, imitation, propose, design, yield, review, feature, capture, retrieve, view.
- Carry out, acquire, way out, usual, restore, offer, see, genuine, copy, produce, require, examine, come from, fixed, develop, method, characteristic, mechanism, catch, ruin.

VIII. Arrange the words given in a. and in b. in pairs of antonyms.

- Attractive, accurate, intense, single, conventional, authentic, discontinuity, partial, transparency, outdoor, enable.
- False, whole, continuity, ugly, indoor, opaqueness, slight, rough, prevent, numerous, rare.

IX. Give the English equivalents for the following using the text.

Достоверная иллюзия, видеть невооруженным глазом, точное ощущение глубины, выполнять, требование, обычные камеры, получать, состоять из, набор дискретных фрагментов, неоднородность, частичное решение, объемные образцы, области применения голограммы, предположение, независимые рассеиватели света, точечный источник, производить, восстанавливаемый, непрерывный параллакс, поперечные плоскости, набор угловых ракурсов, коэффициенты прозрачности, с одной стороны, с другой стороны.

X. Give the Russian equivalents for the following.

Demand, relatively, slight movement, interference fringes, outdoor photography, true wave front, perspective projection, discontinuity, partial solution, computer-generated hologram, computational task, originate, parabolic wave front, yield, retrievable, computer-aided imaging, encode, note, related to, capture.

PRACTICE

I. Translate the following sentences into Russian defining if forms ending in -ing are gerunds or participles.

1. Current approaches to **displaying** three-dimensional images can be classified into several main types.
2. A single hologram is capable of **creating** the most authentic illusion of observing volumetric objects by the naked eye.
3. Since the invention of the hologram more than 50 years ago, holographic **recording** of real
4. objects has been performed by wave interference.
5. These requirements have prevented hologram recorders from **becoming** as widely used for
6. outdoor photography as conventional cameras.
7. This is because one needs to superpose the mathematical contribution of many waves **originating** from many points on the objects, when not all of them are located at the same distance from the hologram plane.
8. Many algorithms for **synthesizing** CGHs for 3-D imaging have been proposed in the past three decades.
9. The depth information is retrievable from continuous parallax and from **focusing** on different transverse planes through the volume.
10. The difficulty of this technique comes from the long computation time necessary to superpose waves **coming** from large number of object points.
11. The CGH is computed in a relatively short time without **sacrificing** image quality.
12. Since the **resulting** hologram is similar to a Fourier hologram, the reconstruction stage will be carried out by a Fourier lens, as described in the **following** sections.
13. The experimental construction was successfully demonstrated, thus **indicating** the potential of the technique for 3-D display.
14. The **propagating** wave reconstructs the object's transverse image at each matched depth locations with some noise.
15. **Using** triangular interferometer, polarization optics and CCD allows the recording of a complex hologram with an incoherent light.

II. Translate the following text into English.²⁶

Необходимо подчеркнуть, что здесь мы не создаем составную синтезированную голограмму. Источником общего заблуждения, состоящего в том, что наш алгоритм относят к составной голограмме, является схожесть природы входных данных. В обоих методах вычислительный процесс начинается с похожих входных данных по многим ракурсам объекта. Однако, на этом сходство между двумя голограммами заканчивается.

Хотя входными данными в нашем методе является набор точек наблюдения объекта под разными углами, наш алгоритм отличается от составной голограммы. В нашем методе каждая точка голограммы вносит вклад во все восстанавливаемое объемное изображение, и каждая точка восстанавливаемого изображения формируется светом, дифрагирующим на всей голограмме.

²⁶ The text was translated from preprint of the original paper of J. Rosen, D. Abookasis, "Holographic three-dimensional computer-aided imaging" [8].

Данная ситуация определенно непохожа на составную голограмму, в которой для получения эффекта трехмерности объекта разные «субголограммы» создают разные двумерные изображения для разных зрительных ракурсов. В нашем алгоритме входные данные по всем ракурсам объединяются вместе в конечную голограмму, никакая часть которой не может быть отдельно отнесена к тому или иному ракурсу наблюдаемого объекта.

Vocabulary Notes:

emphasize – подчеркивать

synthesize a multiplex computer-generated hologram – создавать составную синтезированную голограмму

origin – источник

common confusion – общее заблуждение

relate to – относить к

similarity – схожесть

of multiple perspectives of the object – по многим ракурсам объекта

the set of the object's angular viewpoints – набор точек наблюдения объекта под разными углами

definitely dissimilar – определенно непохожа

create the effect – создавать эффект

generate 2-D images – создавать двумерные изображения

view perspectives – зрительные ракурсы

all of the input perspectives – входные данные по всем ракурсам

be fused together – объединяться вместе

III. Read the text and reproduce it in English in short.²⁷

With the first type of hologram, we propose a process of recording a CGH of a real-world 3-D object under conditions of incoherent white illumination.

After a process of recording the scene under incoherent illumination and digital computing, we get a 2-D complex function. This function is equal to the complex amplitude of coherent light diffracted from the same object and propagates through a particular optical system described below. Thus apparently we succeed in recording the complex amplitude of some wave front without beam interference. We record several digital pictures of the object from different points of view. The pictures are recorded into a digital computer, which computes a CGH from the input data.

Illuminating this hologram by a plane wave reconstructs the original objects and creates the volume effect in the observer's eyes. The hologram that we would like to produce is of the type of a Fourier hologram. This means that the image is reconstructed in the vicinity of the back focal plane of a spherical lens when the hologram is displayed on the front focal plane.

Vocabulary Notes:

under conditions of incoherent white illumination – в условиях некогерентного освещения белым светом

coherent light diffracted from the same object – когерентный свет дифрагировавший на том же самом объекте

particular optical system – специфическая оптическая система

²⁷ The text was adopted for language learning purposes from preprint of the original paper of J. Rosen, D. Abookasis, "Holographic three-dimensional computer-aided imaging" [8].

original objects – исходные объекты
 volume effect – эффект объемности
 in the vicinity – поблизости
 front (back) focal plane – передняя (задняя) фокальная плоскость

IV. Read the text and render it in Russian.²⁸

A new process of computing holograms of computer designed 3-D objects has been proposed and demonstrated. By fusion of multiple projections of the object, a 2-D function has been obtained that contains 3-D information of the object. The resulting CGH is equivalent to an optical Fourier hologram of a realistic 3-D scene. The experimental construction was successfully demonstrated, thus indicating the potential of the technique for 3-D displays.

It should be mentioned that although the method is seemingly limited to Fourier holograms, once the complex wave front on the Fourier plane is computed, any other type of hologram, such as Fresnel or image holograms, can also be computed. This can be done simply by computing the propagation of the wave front from the Fourier plane to any other desired plane by means of Fresnel or near-field operators.

Possible applications of the suggested CGH are in areas where the 3-D representation is required. Areas such as computer-aided design, computer graphics, virtual reality, 3-D work stations, tomography, and holographic cameras might benefit from the proposed method. Since our hologram is classified as a Fourier hologram, it can also be applied to the areas of object recognition and target tracking in 3-D space.

Vocabulary Notes:

fusion of multiple projections of the object – объединение многих проекций объекта
 manifest – ясно показывать; доказывать
 legitimate – оправданный; обоснованный
 the method is seemingly limited to Fourier holograms – метод, по-видимому, применим только к голограммам Фурье
 near-field operators – операторы ближнего поля
 object recognition and target tracking in 3-D space – распознавание объекта и отслеживание цели в трехмерном пространстве

V. Reproduce the main text.

VI. Write an annotation on the text.

VII. Topics for discussion.

1. Does holography seem to be a more attractive method of displaying 3-D images than others? Supply your viewpoint with arguments showing and comparing advantages and disadvantages of different methods (for example: holography and stereoscopy).

²⁸ The text was adopted for language learning purposes from preprint of the original paper of J. Rosen, D. Abookasis, "Holographic three-dimensional computer-aided imaging" [8].

2. Hologram recorders based on interference haven't become widely used devices for holograms obtained in outdoor photography. How much could method of holographic computer-aided imaging proposed in the main text help to obtain holograms in outdoor photography? You can use information from the main text to argue your viewpoint.

UNIT 8

3D TELEVISION USING OPTICAL SCANNING HOLOGRAPHY

READING

I. Read the following words paying attention to pronunciation.

Transmission [trænz'mɪʃn], frequency ['fri:kwənsi], subsequently ['sʌbsɪkwəntli], circuit ['sɜ:kɪt], emerge [ɪ'mɜ:dʒ], carrier ['kæriə], tremendous [trɪ'mendəs], alleviate [ə'li:vɪeɪt], surface ['sɜ:fɪs], spherical ['sferɪkəl], finite ['faɪnaɪt], synchronization [sɪŋkrənaɪ'zeɪʃn], similarly ['sɪmɪləli], area ['eəriə], associate [ə'səʊʃɪeɪt], acquire [ə'kwəɪə], formidable ['fɔ:mɪdəbl], nevertheless [nevəðə'les].

II. Try to guess the meaning of the words in bold type.

shift *v* change or move from one position or direction to another: The wind shifted from east to north./ The audience shifted uneasily in their seats./ Help me to shift the sofa away from the fire.

raster *n* the pattern of scanning lines on the screen of the cathode-ray tube in a television receiver or other device that provides a visual display: The raster is slightly smaller than the physical dimensions of the display screen./ The raster varies for different resolutions./ Raster is the rectangular area of a display screen actually being used to display images.

denote *v* indicate or represent: What does the term 'organic' denote?/ A very high temperature often denotes a serious illness./ In the table T denotes time and W weight.

alleviate *v* to make something less painful or difficult: to alleviate suffering/ A number of measures were taken to alleviate the problem./ The doctor has prescribed some drugs to alleviate the pain.

refresh *v* give new strength to something, restore or revive: refresh oneself with a cool shower/ She felt refreshed after her sleep./ He had to refresh his memory by looking at his notes./ Click here to refresh this document./ The page refreshes automatically.

rate *n* speed of movement: at a great/dreadful/steady rate/ The rate of flow can be calculated by measuring the resistance of the wire./ His pulse-rate dropped suddenly. At the rate you work, you'll never finish.

target *n* a result you try to achieve: set a target/ target date/ The university will reach its target of 5,000 students next September./ A target audience is the particular audience that a product, programme, etc is aimed at.

lower *v* reduce something in number, amount, value, or strength: The voting age was lowered from 21 to 18. Less fat in your diet lowers the risk of heart disease. Joe lowered his voice, as if they might be overheard.

formidable *adj* difficult to deal with or overcome: Meeting the energy demands of a big city is a formidable task./ They had to overcome formidable obstacles.

nevertheless *adv* despite a fact or idea that you have just mentioned: There was no news, nevertheless we went on hoping./ I disagreed with everything she said, but she's a very good speaker nevertheless./ It's a difficult race. Nevertheless, about 1,000 runners participate every year.

novel *adj* new and strange; of a kind not known before: a novel idea/ a novel solution to a problem/ Keeping a sheep in the garden is a novel way of keeping the grass short!/ We need to find a novel approach to our advertising.

remark *n* something you say or write which expresses an opinion, a thought, etc about sth or sb: His remarks on the employment question led to a heated discussion./ The children made rude remarks about the old man./ Critics remarked that the play was not original.

split *v* to divide, or to make something divide into two or more parts: split the atom/ The results split neatly into two groups./ Let's split into groups and work separately./ Many American families are split by large geographical distances.

temporal *adj* connected with or limited by time; belonging or relating to time, often in being relatively short: temporal frequency of the optical beam/ a universe which has spatial and temporal dimensions/ The temporal sequence of the play is confusing for the audience./ The user can manipulate time and change the temporal order of the information being viewed. So they can find new patterns and visions.

pick up *v* obtain or acquire casually, by chance, etc; receive (a signal, programme, etc): An antenna picks up the transmitted signal./ I don't think this thing can pick up foreign stations./ These bombs have a guidance system which can pick up signals from targets on the ground./ Can you pick up (receive broadcasts from) Moscow on your radio?

emerge *v* appear by coming out of sth or out from behind sth: He emerged from the sea cold but exhilarated./ After a few weeks, the caterpillar emerges from its cocoon./ The moon emerged from behind the clouds.

path *n* a line along which somebody or something moves: The charged particles move in spiral paths./ I hope our paths cross./ They followed the path until they came to a gate.

spot *n* a particular place or area; a small round area that has a different color or feels different from the surface it is on: one of the region's best-known tourist spots./ The king himself had stood on this very spot./ His jacket was covered with spots of mud./ The flower is yellow with red spots.

process *v* put information into a computer in order to organize it: Data is processed as it is received./ How fast does the new micro process the data./ My new laptop can process information much more quickly than my old computer.

circuit *n* the complete path that an electric current flows around: an electrical circuit/ There must be a break in the circuit./ A defect was found in the water-cooling electrical circuit.

III. Skim the text quite quickly to get a general understanding and answer the questions given. Consult the vocabulary after the text.

1. What technique is proposed in the article for achieving holographic recording?
2. What device is proposed for holographic reconstruction?
3. What device was used for obtaining spherical wave temporal frequency shift in the optical heterodyne scanning system?

3D TELEVISION USING OPTICAL SCANNING HOLOGRAPHY²⁹

The first television transmission of a hologram was demonstrated in 1966. The interference between the Fresnel diffraction pattern of an object transparency and an off-axis plane wave formed a spatial carrier-frequency hologram to be recorded by a TV camera. The holographic information was then transmitted over closed-circuit TV, displayed on a 2-D monitor, and photographed to form a hologram, which was displayed subsequently by a coherent optical system. Since a hologram has a tremendous amount of information, information reduction techniques have been investigated in order to alleviate the problems associated with reduced image resolution and restricted field of view upon holographic reconstruction. In addition, if holographic information is to be refreshed at a TV

²⁹ The text was adopted for language learning purposes from preprint of the original paper of T.-C. Poon, "Three-dimensional television using optical scanning holography" [9].

rate, information reduction techniques can lower data transmission rate through the channel linking the holographic acquiring end and the holographic reconstruction/display end. Indeed live 3-D TV using hologram formation and transmission is a formidable problem. Nevertheless, much progress has been made and novel devices have been invented.

In this paper, we discuss the use of optical scanning holography (OSH) to achieve holographic recording upon optical scanning the object. For holographic reconstruction, we will concentrate on coherent spatial light modulator reconstruction and make some remarks.

Figure 8.1 shows a typical optical heterodyne scanning system used to record the complex hologram of a 3-D target in real time with only a single two-dimensional scan and such a real-time holographic recording technique is called optical scanning holography (OSH).

In fig. 8.1, the laser beam is split into two optical paths by beam splitter BS1. The temporal frequency of the upper path beam is then up-shifted by an acousto-optic frequency shifter (AOFS), operating at frequency Ω , that is, the temporal frequency of the optical beam emerging from the AOFS is now at $\omega_0 + \Omega$, where ω_0 is the temporal frequency of the laser. This upper path beam is subsequently collimated by beam expander BE1.

Now, lens L provides a focused beam on the surface of BS2, which then generates a temporal frequency shifted spherical wave of finite extent towards a remotely located 3-D object or target characterized by an intensity reflectance $I_0(x, y; z)$, where z is a distance or depth parameter defined as the distance between the focused spot on BS2 and the target. Regarding the lower path beam, it is collimated by beam expander BE2. This generates a plane wave of finite extent with temporal frequency of the laser ω_0 at beam splitter BS2.

The upper and lower path beams are combined by beam splitter BS2. The interference of the temporal frequency shifted spherical wave and the plane wave, both of limited extent, creates a temporally modulated Fresnel zone pattern of the form

$$\sin\left[\left(\pi / \lambda z\right)\left(x^2 + y^2\right) + \Omega t\right]$$

where z is the distance measured from beam splitter BS2 to the target and λ is the wavelength of the He-Ne laser. This time-dependent Fresnel zone pattern is projected onto the target and scanned in a 2-D raster covering the area of the target object. The photomultiplier collects all the light and its heterodyne current output is given by

$$i_{\Omega}(x, y) \propto \int \sin\left[\left(\pi / \lambda z\right)\left(x^2 + y^2\right) + \Omega t\right] \otimes I_0(x, y; z) dz$$

where $I_0(x, y; z)$ is the intensity distribution of the object located at z away from the x-y scanner, \otimes denotes two-dimensional correlation involving transverse x, y coordinates. Note that $x=x(t)$ and $y=y(t)$ are both function of time, and the integration of z is over the depth of the target object. It is important to note that the heterodyne current $i_{\Omega}(x, y)$ has a carrier frequency Ω , which can now be radiated through a transmitting antenna. At this point, the holographic acquiring end is complete.

At the receiving stage, an antenna picks up the transmitted signal and the signal is to be electronically processed as shown in the figure and finally we have two processed currents i_r and i_i as outputs. For example, when $i_{\Omega}(x, y)$ is multiplied by $\cos(\Omega t)$ and then lowpass-filtered, we can extract the phase of $i_{\Omega}(x, y)$ to give

$$i_r = \int \sin\left[\left(\pi / \lambda z\right)\left(x^2 + y^2\right)\right] \otimes I_0(x, y; z) dz$$

When the current is displayed in synchronization with the signals used to drive the x-y scanner, we have a 2-D record and the record is called the sine-hologram, $H_{sin}(x, y)$:

$$H_{\sin}(x, y) = \int \sin\left[\left(\pi / \lambda z\right)\left(x^2 + y^2\right)\right] \otimes I_0(x, y; z) dz$$

Similarly, for the processed output current i_i , we have the cosine-hologram:

$$H_{\cos}(x, y) = \int \cos\left[\left(\pi / \lambda z\right)\left(x^2 + y^2\right)\right] \otimes I_0(x, y; z) dz$$

The holograms can be combined to become a complex hologram:

$$H_j(x, y) = H_{\cos} - jH_{\sin} = \int \exp\left[-j\left(\pi / \lambda z\right)\left(x^2 + y^2\right)\right] \otimes I_0(x, y; z) dz$$

This hologram can be inputted to a phase spatial light modulator (SLM) for optical holographic reconstruction.

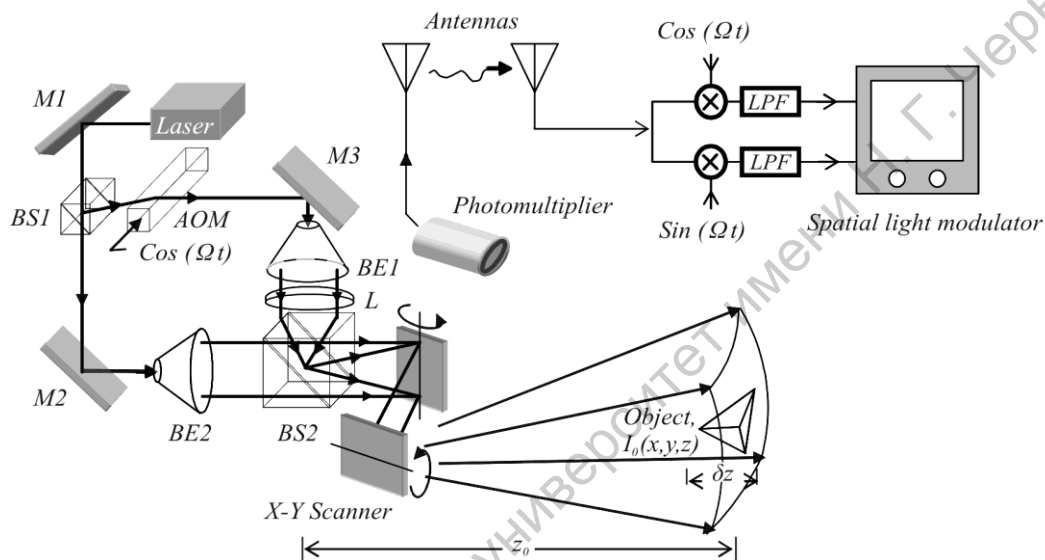


Figure 8.1. 3-D Television System Using Optical Scanning Holography [9]

(M's, mirrors; AOM, acousto-optic modulator; BS1, 2, beam splitter; BE1, 2, beam expanders; L, focusing lens; electronic multiplexer; LPF, low pass filter).

Vocabulary Notes:

Fresnel diffraction pattern – дифракционная картина Френеля

spatial carrier-frequency hologram – голограмма на несущей пространственной частоте

closed-circuit TV – кабельное телевидение

optical-scanning holography – оптическая сканирующая голография

acousto-optic frequency shifter – акустооптический преобразователь частоты

temporal-frequency shifted wave – волна со сдвинутой временной частотой

wave of finite extent – волна с ограниченной апертурой

Fresnel zone pattern – структура типа зоны Френеля

scan in a 2-D raster – сканировать по двумерному растру

heterodyne system – гетеродинная система

complex hologram – амплитудно-фазовая голограмма

two-dimensional scan – двумерное сканирование

temporal frequency – временная частота

up-shift frequency – повышать частоту

intensity reflectance – отражательная способность

temporally modulated – модулируемый во времени

integration over the depth – интегрирование по глубине

holographic acquiring – получение голограммы
 receiving stage – стадия приема
 be lowpass-filtered – подвергаться низкочастотной фильтрации

Active Vocabulary:

transmit – передавать
 subsequently – впоследствии; позже; потом
 tremendous – огромный
 reduction – снижение; уменьшение; сокращение
 investigate – изучать; исследовать
 alleviate – облегчать; смягчать
 restrict – ограничивать
 acquire – получать; приобретать
 split – разделять; расщеплять
 collimate – коллимировать; сводить в параллельный пучок
 remotely – удаленно
 photomultiplier – фотоумножитель
 output – выходной сигнал
 denote – обозначать
 pick up – принимать; ловить (сигнал, передачу)
 extract – извлекать; получать
 sine – синус
 cosine – косинус
 off-axis – внеосевой
 beam splitter – светоделитель
 beam expander – расширитель пучка
 spatial light modulator – пространственный модулятор света
 carrier frequency – несущая частота

IV. Read the text attentively for detail and answer the following questions.

1. Why is it necessary to refresh holographic information at a TV rate at the holographic reconstruction end?
2. How was the plane wave obtained from the laser beam in the optical heterodyne scanning system?
3. How was the spherical wave obtained from the laser beam in the optical heterodyne scanning system.
4. Interference between what waves resulted in the scanning Fresnel zone pattern formation?
5. What happens at the receiving stage of the described 3-D television system?

VOCABULARY EXERCISES

I. State the part of speech of the following words pointing out the word building elements. Give their Russian equivalents.

Transmit – transmission – transmitter – transmissible; demonstrate – demonstration – demonstrative – demonstratively; reduce – reduction; investigate – investigation – investigator – investigative – investigatory; add – addition – additional – additionally; measure – measurement – measurable –

measureless – measurably; low – lower; radiate – radiation – radiator – radioactive – radioactivity; similar – similarity – similarly; coordinate – coordination – coordinator; expand – expander – expansion – expandable – expansive; sphere – spherical; electronics – electronic – electronically; split – splitter; shift – shifter – shiftless – shiftlessly – shiftlessness – shiftily – shiftiness.

II. Make nouns and adjectives from each of the verbs from the table.

Verb	Noun	Adjective
transmit		
multiply		
achieve		
synchronize		
expand		
demonstrate		
limit		
add		
operate		
measure		
resolve		
radiate		

III. Use the correct form of the word in capitals at the end of each sentence to fill the gap.

1. This information is also important for data transmission consideration. REDUCE
2. Changes in sea temperature will increase the of hurricanes. FREQUENT
3. The Earth is not perfectly SPHERE
4. Accurate is very important in science. MEASURE
5. Emphasis was placed on the school as a of moral values. TRANSMIT
6. Before you set your targets, make sure that they are ACHIEVE
7. The company has expanded its product range. SUBSEQUENT
8. The required number of pixels as about 1.1 billion in the SLM (spatial light modulator). RESOLUTION
9. The telephone is fully again. OPERATE
10. The possibilities were almost LIMIT
11. , we request a deposit of \$ 200 in advance. ADD
12. The book is an of a series of lectures given last year. EXPAND
13. The children were dressed. SIMILARITY
14. Television as we have it now is the product of many , both amateur and professional. INVENT

IV. Combine the words in bold with those in brackets. Translate the combinations into Russian.

transmission (direct ~, one-way, data, information, voice, fax, light, money, cable, radio, satellite, simultaneous; ~ equipment, line, technology, mechanism, network, system, route)

operate (~ effectively, reliably, continuously, at full power, manually, remotely, electronically; designed to ~, easy to)

investigate (~ carefully, closely, fully, thoroughly, properly; ~ complaints, claims, techniques)

alleviate (~ considerably, greatly, partly, somewhat, a problem, a situation, fears)
reconstruction (fundamental ~, total, image, holographic; ~ period, work, programme, scheme)
rate (constant ~, steady, slow, fast, increase, reduce, lower)
link (~closely, directly, inseparably, somehow, computers, people, cities, ends)
live (~ 3-D TV, concert, show; appear ~, play, be transmitted, record)
formidable (~ problem, task, obstacle)
remark (brief ~, casual, careless, tactless, insulting, cynical, controversial, rude; make ~, utter, address, ignore)
measure (~ distance, room, data, length, benefits; ~ accurately, carefully)
target (achievable ~, realistic, ambitious, clear, main, initial, long-term, set, achieve, exceed; ~ audience, date, object)
pick up (~ signal, programme, station; ~ casually)
process (~ electronically, signal, information, data)
path (trace ~, block, choose)
emerge (~ slowly, suddenly, eventually, gradually; ~ from)
generate (~ quickly, automatically, spontaneously, randomly, electricity; ~ idea, wave)
extent (full ~, greatest, maximum, geographical; reach ~, examine, explore, assess, calculate, measure, define, to a lesser/limited/small/considerable/certain, some)

V. Match the words in column A with their meanings in column B.

tremendous <i>adj</i>	the size or area of sth
investigate <i>v</i>	get sth, for example by buying it or being given it
reduction <i>n</i>	afterwards; later; after sth else has happened
restrict <i>v</i>	describe clearly and exactly what it is
acquire <i>v</i>	keep sth within strict limits
remotely <i>adv</i>	find out and examine in order to obtain the truth
combine <i>n</i>	existing only in limited numbers or amounts or continuing only for a limited time or distance
subsequently <i>adv</i>	the process or result of making sth smaller or less in amount, size, importance etc
finite <i>adj</i>	to come together to form a single sing or group
extent <i>n</i>	very great in amount or level, or extremely good
define <i>v</i>	far away

VI. Fill in the gaps in the sentences below using words from column A of Exercise V in the correct form.

1. The world's resources must be used wisely. 2. Travel is a dream of mine, but a busy working life has my opportunities. 3. The upper and lower path beams are by beam splitter BS2. 4. z is a distance or depth parameter as the distance between the focused spot on BS2 and the target. 5. There has been some in unemployment. 6. The church is situated high in the mountains. 7. The original interview notes were lost. 8. She has been a help to me over the last few months. 9. The River Nile is over 6,500 kilometers in 10. Police are possible links between the murders. 11. He the firm in 1978.

VII. Arrange the words given in a. and in b. in pairs of synonyms.

- a. Alleviate, refresh, rate, target, lower, formidable, novel, remark, nevertheless, split, path, subsequently, expand, remote, extent, define, record, pattern, operate, denote.
- b. Register, perform, ease, jog, comment, degree, model, speed, reduce, distant, objective, however, determine, indicate, separate, extend, way, original, tough, later.

VIII. Arrange the words given in a. and in b. in pairs of antonyms.

- a. Formidable, novel, split, expand, remote, reduce, forwards, upper, emerge, acquire, record, collect, multiply, combine, plane, limit.
- b. Spherical, lower, vanish, increase, simple, lose, erase, broaden, disperse, divide, common, contract, backwards, join, close, separate.

IX. Give the English equivalents for the following using the text.

Прозрачность, несущая частота, временная частота, кабельное телевидение, позднее, огромное количество, уменьшение, облегчать, обновлять, получать, трудноразрешимая проблема, плоская волна, обозначать, извлекать.

X. Give the Russian equivalents for the following.

Diffraction pattern, novel device, spatial light modulator, beam splitter, beam expander, up-shift frequency, intensity reflectance, integration over the depth, holographic acquiring, receiving stage.

PRACTICE

I. Make the active sentences passive and translate them into Russian.

1. They are discussing the use of optical scanning holography.
2. We will make some remarks concerning coherent spatial light modulator reconstruction.
3. One matches whole 3-D aspects of objects just by 2-D matching between the holograms of the objects.
4. We recorded the on-axis hologram of a reference object using a CCD instead of a film.
5. The photomultiplier has collected all the light.
6. We can convolve digitally the hologram with the free-space impulse response.
7. The figure shows the optical system for reconstruction of the object in 3-D space.
8. The antenna picked up the transmitted signal.
9. We can also use vertical and horizontal polarization for the two views.
10. They have placed linear polarisers at the output to purify the linear polarization in the desired directions.
11. This may produce a considerably different set of price/performance ratio figures that you might have originally considered.

II. Translate the following text into English.³⁰

³⁰ The text was translated from preprint of the original paper of T.-C. Poon, "Three-dimensional television using optical scanning holography" [9].

Возьмем в качестве объекта точку, находящуюся на оптической оси системы на удалении z_0 , как показано на рисунке 8.1. Для восстановления голограммы такого объекта, имеющей полный параллакс и размеры 20 на 20 мм с углом обзора 60 градусов, необходимо, чтобы пространственный модулятор света имел примерно 1,1 миллиарда отображаемых пикселей. Это находится за пределами возможностей современных модуляторов, работающих в реальном времени.

Однако, поскольку мы привыкли смотреть на мир двумя глазами, находящимися примерно на горизонтальном уровне, обычно оказывается достаточно только горизонтального параллакса. В случае устранения вертикального параллакса, для воспроизведения 256 вертикальных линий потребуется всего около 8,5 миллионов пикселей, и возможность создания голографического телевидения становится реальной.

Это уменьшение количества информации также важно для передачи данных. Как было посчитано ранее, для воспроизведения одного кадра с голограммой размером 20 на 20 мм, имеющей угол обзора 60 градусов, требуется модулятор света, имеющий примерно 1,1 миллиарда пикселей. Для обновления такого кадра при разрешении 8 бит с частотой 30 кадров в секунду скорость последовательной передачи данных должна быть равна 0,26 терабит в секунду, если мы хотим воспроизвести полный параллакс. При устранении вертикального параллакса требуемая скорость передачи данных становится равной двум миллиардам бит в секунду, что вполне осуществимо в продвинутых современных оптических коммуникационных системах.

Vocabulary Notes:

on-axis point object – точечный объект, расположенный на оси

full parallax hologram – голограмма с полным параллаксом

resolvable – разрешимый; отображаемый

beyond capabilities – за пределами возможностей

on a horizontal level – на горизонтальном уровне

information reduction – уменьшение количества информации

frame – кадр

update – обновлять

serial data rate – скорость последовательной передачи данных

advanced – продвинутый

III. Read the text and reproduce it in English in short.³¹

Optical Scanning holography (OSH) is a form of electronic holography. The idea of OSH was first implicated in Poon and Korpel's paper when the authors were investigating the implementations of bipolar functions in their optical heterodyning image processor in the context of incoherent image processing.

Since then, applications using OSH have been extensively explored and investigated. These applications include 3-D holographic microscopy, optical recognition of 3-D objects, 3-D optical remote sensing, 3-D holographic TV and display, and most recently 3-D optical scanning cryptography.

Briefly, OSH is a technique in which holographic information of a 3-D object or target can be extracted using only a single 2-D optical heterodyne scanning. The scanning optical beam used to record the holographic information of the 3-D object is a temporally modulated Fresnel zone pattern

³¹ The text was adopted for language learning purposes from preprint of the original paper of T.-C. Poon, "Three-dimensional television using optical scanning holography" [10].

that is created by the interference of a plane wave and a spherical wave of different temporal frequencies.

Vocabulary Notes:

3-D optical remote sensing – трехмерное оптическое дистанционное зондирование

3-D optical scanning cryptography – криптография с трехмерным оптическим сканированием

IV. Read the text and render it in Russian.³²

As far as the transmission of holographic information is concerned, current technologies can handle a small 20 mm by 20 mm hologram (with viewing angle of 60 degrees) transmission at video rate. As for the issue of SLMs, one of the bottlenecks we discussed is its limited spatial resolution.

Using some of the best quality SLMs commercially available (100 lp/mm), the achievable viewing angle is about 7 degrees. In the movie Star Wars, Luke Skywalker's adventure begins when a beam of light comes out of the robot R2-D2 which projects a small 3-D holographic image of Princess Leia. This is tangible with current technologies. However, the 'Holy Grail' for holographic display research is the realization of live 3-D and life-size interactive displays such as 'The Doctor' in the science fiction series Star Trek Voyager, who is a holographically projected computer program devised by 'Starfleet' as the Emergency Medical Hologram.

To put things into perspective, it took over half a century from the first adopted video standard (40 lines and 640 pixels horizontally) to nowadays high-end computer terminals (1024 lines and 1280 pixels horizontally). How long does it take to find the 'Holy Grail'?

Vocabulary Notes:

handle – выдерживать

viewing angle – угол обзора

bottleneck – *перен.* узкий проход; узкое место

spatial resolution – пространственное разрешение

tangible – осязаемый; реальный

devise – разрабатывать; изобретать

V. Reproduce the main text.

VI. Write an annotation on the text.

VII. Topics for discussion.

1. Light losses in the optical scanning system.

Look at Figure 8.1 with a typical optical heterodyne system used to record the complex hologram of a 3-D target. In which blocks of the system could we expect noticeable light losses? Why? Is there

³² The text was adopted for language learning purposes from preprint of the original paper of T.-C. Poon, "Three-dimensional television using optical scanning holography" [9].

any principle difference between contributions of beam splitter BS1 and beam splitter BS2 to the light losses in the optical system? Supply your viewpoint with arguments.

Саратовский государственный университет имени Н. Г. Чернышевского

PART FOUR

VOLUMETRIC DISPLAYS

Саратовский государственный университет имени Н. Г. Чернышевского

UNIT 9

SOLID-STATE VOLUMETRIC DISPLAY

READING

I. Read the following words paying attention to pronunciation.

Alias ['eɪliəs], scheme [ski:m], schematic [ski:'mætrɪk], subtle [sʌtl], proprietary [prə'praɪətəri], exhibit [ɪg'zɪbɪt], leverage ['li:vərɪdʒ], convergence [kən'vɜ:dʒəns].

II. Try to guess the meaning of the words in bold.

sequence *n* succession; connected line of events, ideas, etc; the sequence of events, the order in which they occur: The high-speed video projector projects a sequence of slices of the 3D image into the multi-planar optical element where each slice is halted at the proper depth./ The tasks had to be performed in a particular sequence./ These pages are out of sequence./ A computer can store and repeat sequences of instructions.

smooth *adj* having a surface like that of glass; free from roughness; *v* make smooth: smooth away/over obstacles, difficulties, get rid of them/ Multi-planar algorithms smooth the appearance of the resultant stack of image slices.

shutter *n* movable cover for a window to keep out light; device that opens to admit light through the lens of a camera: The shutter exhibits 88% transmission in the clear state, 2% transmission in the scattering state.

degrade *v* reduce in rank or status: Multi-planar anti-aliasing is very effective to an on-axis viewer and degrades gradually as viewing angle increases.

subtle *adj* difficult to describe, define, or explain; clever, cunning: A difference between two ideas so small that it is hard to understand./ Multi-planar anti-aliasing effectively leverages the subtle character of visual perception.

enormous *adj* very great: an enormous sum of money/ In order to address the enormous demand for 3-D displays, we have developed and are commercializing a system called the Depth Cube 3D Display System.

III. Skim the text quite quickly to get a general understanding and answer the questions given. Consult the vocabulary after the text.

1. What is the text about?
2. What kind of projection is used in the Depth Cube 3D display?
3. What does the development of the Depth Cube system represent?

SOLID-STATE VOLUMETRIC DISPLAY³³

³³ The text was adopted from the original paper of A.Sullivan, "A solid-state multi-planar volumetric display" [11] (Permission for Reprint, courtesy Society for Information Display).

The DepthCube 3D display is a solid-state multi-planar volumetric display system in which a DLP based high speed projector projects slices of the 3D scene onto a stack of LC scattering shutters acting as an electronically controlled projection volume. Highly continuous appearing 3D images are obtained through multi-planar antialiasing.

A high performance three dimensional display system has been the goal of many experimental quests over at least the last 40 years. And the level of effort has only increased recently due to the exponential increase in the computational performance of modern computers and the wide range of 3D applications that run on them.

In order to address the enormous demand for three dimensional displays, we have developed and are commercializing a system called the DepthCube 3D Display System. A schematic diagram of a DepthCube 3D Display System is shown in figure 9.1. The DepthCube Display System is a solid state, rear projection, volumetric display that consists of two main components: a highspeed video projector, and a multi-planar optical element (MOE) composed of a air-spaced stack of liquid crystal scattering shutters. The high-speed video projector projects a sequence of slices of the 3D image into the multi-planar optical element where each slice is halted at the proper depth. Proprietary multi-planar anti-aliasing algorithms smooth the appearance of the resultant stack of image slices to produce a continuous appearing truly three dimensional image.

The multiplanar optical element (MOE) is a stack of 20 air-spaced liquid crystal scattering shutters. The MOE acts as an electronically variable solid-state projection volume and, in conjunction with the high speed video projector, creates the 3D image. Figure 9.2 shows the transmission as a function of time of one of the scattering shutters. The shutter exhibits 88% transmission in the clear state, 2% transmission in the scattering state, and switches from clear to scattering in 0.39 msec and from scattering to clear in 0.08 msec. The application of an appropriate anti-reflection coating can increase the clear state transmission to over 96% giving an overall MOE transmission of 44%.

If image slices are transferred to the DepthCube's framebuffer without special processing the resultant image will look like a stack of 2D slices rather a single continuous 3D image. To eliminate the appearance of depth discontinuities we have developed the technique of *multiplanar anti-aliasing*. Antialiasing is achieved by using the fractional portion of the depth value transferred to the framebuffer to compute the proportion of the given RGB brightness to assign to the adjacent planes of the display. For example, if a given pixel is transferred to the DepthCube with a z value of 5.25, 75% of the given RGB brightness will be written to the memory location associated with that pixel in plane 5 and 25% will be written to the same pixel in plane 6. This process is similar to conventional anti-aliasing used to smooth the "jaggies" in lines in 2D images.

The effectiveness of the multiplanar anti-aliasing in reducing the level of perceived discontinuity of the resultant 3D image is difficult to overstate. For images having large continuous shapes the image looks completely smooth out to large off-axis viewing angles ($\sim 45^\circ$). For fine lines like those associated with wire frame images multiplanar anti-aliasing is very effective to an on-axis viewer and degrades gradually as viewing angle increases. Multiplanar anti-aliasing effectively leverages the subtle character of visual perception to synthesize perceived depth planes between the physical planes of the display. This gives a 32-fold increase in the perceived number of planes with the result that the commercial DepthCube system has 465.7 Million perceived voxels.

By its very nature the 3D images in the DepthCube Display System have all of the depth cues found in viewing real objects thereby giving rise to the phrase "true 3D display". Unlike stereoscopic and autostereoscopic displays, the DepthCube maintains the normal relationship between eye focusing and convergence to produce a very comfortable and natural 3D viewing experience. The DepthCube Display System also provides both horizontal and vertical parallax. The 3D images can be viewed from any distance over a wide field of view ($\sim 90^\circ$) by a large number of viewers, each with the appropriate perspective. Unlike other volumetric displays the DepthCube has no rapidly

spinning parts, and the rectilinear Cartesian geometry of the DepthCube allows the entire display volume to be used without image distortion or obstruction.

Images in the DepthCube Display System can be either solid textured surfaces, translucent textured surface with background surfaces visible at the appropriate depth, wireframe images, or complete volumetric datasets in which a significant number of display voxels are activated. In all cases the images are truly three-dimensional and provide an automatic and intuitive understanding of the data.

The development of the DepthCube Display System represents a significant breakthrough in three-dimensional visualization as well as an important advance in display technology. The DepthCube Display System technology is capable of producing high resolution, three-dimensional images from existing software that provide natural eye focusing and convergence, as well as both horizontal and vertical parallax. The 3D images are full color, have a large number of simultaneously addressable voxels, and are visible over a wide field of view.

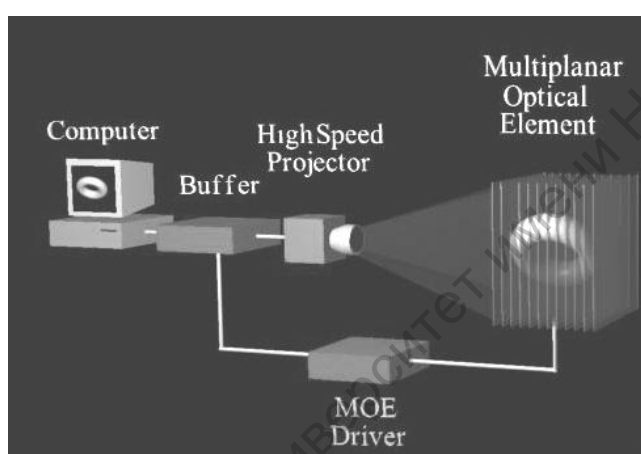


Figure 9.1. Schematic diagram of the DepthCube 3D Display System [11].
(Permission for Reprint, courtesy Society for Information Display)

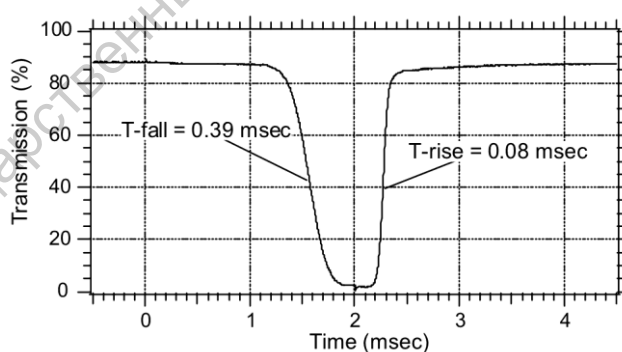


Figure 9.2. Transmission vs. time of PSCT shutter [11].
(Permission for Reprint, courtesy Society for Information Display)

Vocabulary Notes:

DLP projector (Digital Light Processing) – проектор с цифровой обработкой света

multi-planar – мультипланарный

solid-state – твердотельный; монолитный

anti-aliasing – сглаживание, устранение контурных неровностей

air-spaced – с воздушными прослойками

electronically variable – с электронной настройкой

clear state – пропускающее состояние; прозрачное состояние
 scattering state – рассеивающее состояние
 RGB (Red, Green, Blue) – красный, зеленый, синий – три цвета, используемые в телевидении для передачи всех остальных цветов
 proportion of given RGB brightness – доля данной яркости в каналах R, G, B
 jaggies – неровности (при изображении линий на дисплее)
 wireframe images – каркасные изображения
 leverage – (в данном случае) использовать
 solid textured surface – сплошная текстурированная поверхность
 translucent textured surface – полупрозрачная текстурированная поверхность
 voxel – volumetric pixel – воксел; объемный пиксель
 subtle – тонкий; хитроумный

Active Vocabulary:

volumetric – объемный
 slice – тонкий слой
 stack – набор
 shutter – obturator
 exponential increase – экспоненциальный рост
 proprietary – патентованный
 smooth – сглаживать; выравнивать
 in conjunction with – вместе с
 fractional portion – дробная часть
 assign – назначать; присваивать
 overstate – преувеличивать
 spin – крутиться
 obstruction – помеха; препятствие
 rear projection – проекция на просвет
 anti-reflection coating – антиотражательное покрытие; антибликовое покрытие
 transmission – пропускание (света)
 framebuffer – кадровый буфер
 Cartesian geometry – картезианская (декартова) геометрия

IV. Read the text attentively for detail and answer the following questions.

1. What kind of projection is used in the Depth Cube 3D display?
2. Why is multi-planar anti-aliasing needed in Depth Cube 3d display system?
3. What transmission values would be ideal for LC scattering shutter in the clear state and in the scattering state?
4. What switching time would be ideal for LC scattering shutter?
5. What advantages does the Depth Cube 3D display have over stereoscopic and autostereoscopic displays?
6. How is it possible to increase the clear state shutter transmission?

VOCABULARY EXERCISES

I. State the part of speech of the following words pointing out the word-building elements. Give their Russian equivalents.

Plane – planar; project – projectile – projector – projection – projective; exhibit – exhibiter – exhibition – exhibitional – exhibitiv; transmit – transmission – transmittance – transmitter; nature – natural – naturalism – naturalist – naturalistic – naturality – naturalization – naturalize; visual – visuality – visualization – visualize – visualizer.

II. Make nouns and adjectives from each of the verbs in the table.

Verb	Noun	Adjective
relate		
compute		
add		
process		
vary		
specify		

III. Use the correct form of the word in capitals at the end of each sentence to fill the gap.

- The strength of plane transfer mode is that the Depth Cube can at nearly real-time rates. UPDATE
- Using block transfer mode, the value for every voxel in the display to the frame buffer. TRANSFER
- The memory manager two 8-bit operations for each pixel. PERFORM
- Anti-aliasing, if any, by the computer. MUST, PERFORM
- The MOE acts as an variable solid-state projection volume and creates the 3D image. ELECTRONICS
- The performance specifications of the current Depth Cube commercial system in table 1. SHOW
- The author wishes to acknowledge the generous support of the in Vizta 3D, Inc. INVEST
- The high-speed video projector is based upon the DLP technology of Texas Instruments. REVOLUTION
- The result is an spaced, 3D array of voxels. EVEN
- Unfortunately, these images the correct eye focusing and convergence cues. NOT, CONTAIN
- The first commercial Depth Cube product some years ago. LAUNCH

IV. Combine the words in bold with those in brackets. Translate the combinations into Russian.

subtle (~ perfume, texture, policy, mind, senses, observer, remark, irony, charm, power, device, fingers, art, enemy)

processing (special ~, chemical, data, heat; ~ equipment, industries)

create (~ drama, theory, system of philosophy, army, illusions, mood, feeling)

allow (~ sb to do sth, sb spending money; ~ argument)

analyse (~ carefully, profoundly, chemically, scientifically, logically)

campaign (electoral ~, propaganda; against sth)

develop (~ business, memory, mind, melody; ~ rapidly, normally; ~ case, plans, attack)

V. Match the words in column A with their meanings in column B.

A	B
smooth <i>adj</i>	substance like water or oil that flows freely
enormous <i>adj</i>	manufacture, make, create
effective <i>adj</i>	near to the beginning of a period of time
liquid <i>n</i>	changeable
variable <i>adj</i>	free from roughness
early <i>adj</i>	making a striking expression
produce <i>v</i>	happening or done at the same time
simultaneous <i>n</i>	very great

VI. Fill in the gaps in the sentences below using words from column A of Exercise V in the correct form.

1. The author thanks Vizta 3D, Inc. for funding the phase of the development of the Depth Cube technology.
2. The Depth Cube Display System technology is capable of high resolution, 3-D images.
3. The 3D images are full color, have a large number of addressable voxels, and are visible over a wide field of view.
4. Multi-planar algorithms the appearance of image slices.
5. The children were suffering from the of the hot weather.
6. The town has changed
7. They have reasons not to go there.

VII. Arrange the words given in a. and in b. in pairs of synonyms.

- a. Scatter, speed, aim, recently, stop.
- b. Goal, lately, disperse, halt, velocity.

VIII. Arrange the words given in a. and in b. in pairs of antonyms.

- a. Solid, gather, high, increase, slow.
- b. Scatter, reduce, liquid, rapid, slow.

IX. Give the English equivalents for the following using the text.

Объемный, твердотельный, мультипланарный, прозрачное состояние, рассеивающее состояние, ухудшаться, 10-кратное увеличение, экспоненциальный рост, огромный, трехмерный дисплей, сглаживать, непрерывный.

X. Give the Russian equivalents for the following.

Overall transmission, depth discontinuities, rectilinear, textured surface, field of view, scattering state, anti-reflection coating, solid state, a high speed projecto, anti-aliasing.

PRACTICE

I. Translate the following noun groups into Russian.

depth Cube 3D Display System
electronically controlled projection volume
wireframe images
on-axis viewer
background surface
high speed projector
solid state physics
liquid crystal
scattering shutters
image slices
anti-reflection coating.

II. Correct the wrong statements using the following as phrase openings: *on the contrary, I don't believe that, to my mind, it is considered that.*

1. The development of the Depth Cube Display System doesn't represent an important advance in display technology.
2. The 3D images are colorless.
3. The Depth Cube has rapidly spinning parts.
4. The rectilinear Cartesian geometry of the Depth Cube allows the entire display volume to be used only with image distortion.
5. The Depth Cube Display System provides only vertical parallax.
6. In the Depth Cube Display System the images are two-dimensional.
7. The MOE is a stack of 10 air-spaced liquid crystal scattering shutters.

III. Read the text and render it in Russian.³⁴

3D information is acquired by the human visual system in two forms: psychological depth cues and physical depth cues. Psychological depth cues, such as forced perspective, shading, shadows, occlusion are the only depth cues found in viewing a 3D scene on a 2D display; they can even be created by hand on a piece of paper. On the other hand physical depth cues, such as ocular accommodation (changes in eye focusing), convergence (both eyes point toward a point in space), disparity (a slightly different perspective image in each eye), and real motion parallax (image look-around), are 3D cues that cannot be created on conventional 2D monitors.

The leading technologies for creating low cost, low performance 3D perception exploit stereopsis in a stereoscopic or autostereoscopic display. These displays use special eyewear or optical elements on top of LCDs to create slightly different perspective views in each eye. Unfortunately, these images do not contain the correct eye focusing and convergence cues. In the case of many autostereoscopic LCD technologies, there may also severe viewing position restrictions; if you are not in the precisely correct location you see a highly confusing image.

Vocabulary Notes:

³⁴ The text was adopted from "DepthCube Technology White Paper" of LightSpace Technologies, Inc. [12] (Courtesy of LightSpace Technologies, Inc.).

to acquire – получать
 forced perspective – неестественная перспектива
 occlusion – преграда; преграждение
 ocular accommodation – глазная аккомодация
 disparity – диспаратность
 look-around capability – возможность видеть объект в любом ракурсе
 on top of LCD – поверх ЖКД
 perspective view – перспективное изображение

IV. Read the text and say what it is about.³⁵

The first commercial DepthCube product, the DepthCube Z1024 3D Display, was launched at the SuperComputer2002 tradeshow in 4Q'02 and significant production began in 3Q'03. A photograph of the DepthCube Z1024 is shown in figure 3. The Z1024 produces 15-bit color images with a 3D resolution of 15.3 million voxels (1024 x 748 x 20). The front diagonal dimension is equivalent to a conventional 20 inch computer monitor and the Z1024 has an appearance similar to a conventional 21 inch CRT monitor.

Using multi-planar anti-aliasing increases the perceived voxel count by a factor of 32 resulting in a extraordinary perceived voxel count of over 465 million voxels, by far the world's highest perceived resolution. The volume refresh rate of the display is 50 volume images per second (100 interlaced volumes per second) and the image update rate is better than 15 images per second resulting in near real-time interactivity.



Figure 9.3. Photograph of a commercial DepthCube 3D Display [11].
 (Permission for Reprint, courtesy Society for Information Display)

Vocabulary Notes:

tradeshow – промышленная выставка
 appearance – внешний вид
 perceived voxel count – итоговое число воспринимаемых вокселей

³⁵ The text was adopted from "DepthCube Technology White Paper" of LightSpace Technologies, Inc. [12] (Courtesy of LightSpace Technologies, Inc.).

volume refresh rate – частота обновления изображения в объемной среде дисплея
 interlaced – чересстрочный
 image update rate – частота обновления изображения

V. Translate the following text into English.³⁶

Трехмерный дисплей DepthCube создает полноцветные объемные изображения высокого качества, обеспечивающие зрителя всеми физическими и психическими факторами пространственного зрения, которые имеют место при наблюдении реального объекта. Этот дисплей устраняет зрительное утомление и ограничение положения зрителя, присущие стереоскопическим дисплейным технологиям.

Трехмерный дисплей DepthCube представляет собой объемный компьютерный монитор с проекцией на просвет, в котором обычная проекционная поверхность заменяется объемной проекционной средой, называемой мультипланарным оптическим элементом. Эта проекционная среда состоит из набора оптических элементов с электронным управлением, что делает возможным создание объемных изображений, реально заполняющих пространство. Результатом является изображение с реальной глубиной и возможностью наблюдения в любом ракурсе.

Высокоскоростной видеопроектор на основе революционной технологии цифровой обработки света от компании Texas Instruments способен создавать 1500 качественных кадров в секунду. Он проецирует последовательность полноцветных тонких слоев трехмерного изображения на мультипланарный оптический элемент, где каждый слой отображается на соответствующей глубине. Результатом является эквидистантный трехмерный массив вокселей, причем каждому вокселу можно присвоить произвольное 15-битное значение яркости и цвета.

Vocabulary Notes:

full color – полноцветный

3D vision cues – факторы пространственного зрения

eliminate – устранять

eye fatigue – зрительное утомление

look-around capability – возможность наблюдения в любом ракурсе

be halted at the corresponding depth – отображаться на соответствующей глубине

evenly spaced – эквидистантный; равноотстоящий

each voxel capable of being set to – каждому вокселу можно присвоить

arbitrary – произвольный

VI. Divide the main text into parts and make the one-sentence summary of each part.

VII. Render the main text in English.

VIII. Topics for discussion.

1. True 3D display concept.

³⁶ The text was translated from "DepthCube Technology White Paper" of LightSpace Technologies, Inc. [12] (Courtesy of LightSpace Technologies, Inc.).

How could you define the term ‘true 3D display’? Is it the display which produces images indistinguishable from those viewed when looking at real objects? What kind of 3D display technologies (stereoscopic, holographic, volumetric) seems today to be closer to true 3D display concept? Supply your viewpoint with arguments.

2. Video projector performance.

Why is it so important that projector used in DepthCube 3D display had very high frame refresh rate? Should its refresh rate be higher than refresh rate needed for conventional flat images projection? Why?

UNIT 10

SWEPT-SCREEN VOLUMETRIC DISPLAY

READING

I. Read the following words paying attention to pronunciation.

Reciprocate [rɪ'sɪprəkeɪt], multiplanar [mʌltɪ'pleɪnə], vapor ['veɪpə], sequence ['siːkwəns], aggregate ['ægrɪɡɪt] – aggregate ['ægrɪgeɪt], helix ['hiːlɪks], imagery ['ɪmɪdʒəri], various ['veəriəs], utilize ['juːtɪlaɪz], series ['sɪəriːz], constitute ['kɒnstɪtuːt], visualization [vɪʒuəlaɪ'zeɪʃən], therefore ['ðeəfɔː], legacy ['legəsi], persistence [pə'sɪstəns], core ['kɔː], ensure [ɪn'ʃʊə], accurate ['ækjʊrət], stationary ['steɪʃənəri], extensively [ɪk'stensɪvli], hover ['hʌvə], continuum [kən'tɪnjuəm], translucent [træns'luːsənt], obviously ['ɒbvɪəsli].

II. Try to guess the meaning of the words in bold type.

vapor (AmE) = vapour (BrE) *n* a mass of very small drops of liquid in the air, for example steam: water vapor/ Poisonous vapors burst out of the factory during the accident./ Warmer air is able to hold more water vapor than cold air.

rotate *v* to turn or make sth turn about an axis like a wheel: Stay well away from the helicopter when its blades start to rotate./ The satellite slowly rotates as it circles the earth./ The earth rotates 360 degrees every 24 hours.

slice *n* thin wide flat piece cut off an item of food: cut the bread into thick slices/ lemon slices/ 'Some films are slices of life; mine are slices of cake' (Alfred Hitchcock)/ These displays of human body slices represent a rare look into the amazing and complex structure of the human body (Museum of Science and Industry).

constitute *v* make up or form; be the components of: Nuclear weapons constitute a very real threat to world peace./ Female workers constitute the majority of the labor force./ Twelve months constitute a year.

stack up *phr v informal* arrange things so that they stand one on top of another; put things so that they are standing together: A sequence of CT scans are mentally stacked-up to constitute a patient's (3-D) anatomy./ Melanie stacked up the plates and carried them to the sink./ He stacked up a few rows of stones./ Idea of the game is to stack bricks up in such a way that bricks of the same type form columns, rows, or diagonals of three or more items.

aggregate *n* the total of several things or numbers: Snowflakes are loose aggregates of ice crystals./ Arsenal won only two of the three games, but got through to the final on aggregate (adding together all their goals)./ Multiplanar displays present an aggregate of surfaces over time which the eye integrates into a volume-filling image.

helix *n* a shape like a spiral or a line curved around a cylinder or cone: Some biological molecules have the form of a helix./ A corkscrew is the shape of a helix./ Swept-screen multiplanar displays use a spinning projection screen, typically a plane or a helix.

rare *adj* seldom done, found, or occurring; uncommon, unusual: This is one of the rarest plants in the collection./ He has a rare talent for managing people./ a rare disease/ a rare occurrence/ a rare sight.

dopant *n* an impurity added usually in minute amounts to a pure substance to alter its properties: The ability to analyze single dopant atoms could help engineers squeeze further power out of

conventional computer systems. The amount of dopant is usually measured in atomic percent./ It is found that photoluminescence properties are sensitive to the crystal structure which is controlled by surface coating and dopant concentration.

entire *adj* whole, complete: I have wasted an entire day on this./ We are in entire agreement with you./ The railroad enables distribution across the entire North American Continent.

similar *adj* resembling sb or sth but not the same; alike: We have similar tastes in music./ Gold is similar in color to brass./ The two houses are similar in size.

compatible *adj* suited; that can exist together: The platform is based on an open standard and is therefore compatible with a range of legacy applications./ compatible blood groups/ Are measures to protect the environment compatible with economic growth?/ This computer program isn't compatible with this operating system./ This printer is compatible with most microcomputers.

properly *adv* in a way that is correct and/or appropriate: Make sure the letter is properly addressed. He was never properly trained, so you can't really blame him if he can't do the job./ Do it properly or don't do it at all.

range *n* group or series of similar things; selection or variety: have a wide/narrow range of interests, etc/ The new model comes in an exciting range of colors./ The hotel offers a wide range of facilities./ There is a broad range of opinions on this issue.

arrange *v* put sth in a particular order: Here is the list arranged chronologically./ The books are arranged alphabetically by author./ Everything has to be supervised and arranged in advance.

core *n* a central and often foundational part; centre of such fruits as the apple or pear, containing the seeds: the earth's core/ Although the acting and scripts are excellent, the real core of the film is its ecological message./ These 2,500 words form the core of the language./ Human persistence of vision is capable of integrating a series of 2-D slices – arranged like slices of an apple around its core – into a volume-filling 3-D image.

hover *v* stay in the air in one place: There was a helicopter hovering overhead./ A hawk hovered over the hill./ A 3-D image will be perceived to hover in the addressable region swept by the projection screen.

relay *v* receive and pass on: TV pictures of the war were relayed around the world by satellite./ Rose immediately relayed news of the accident to her boss. A group of three mirrors relay the imagery to the rotating screen.

III. Skim the text quite quickly to get a general understanding and answer the questions given. Consult the vocabulary after the text.

1. What does the text discuss?
2. What does the 3-D display system represent?
3. What ways to create volumetric imagery exist?
4. What kind of multiplanar displays are there?
5. What is a slice?

SWEPT-SCREEN VOLUMETRIC DISPLAY³⁷

There are several ways to create volumetric imagery. Some researchers have created vector-scanned 3-D images within various vapors or glasses, and often refer to these architectures as *solid-state* displays. Other volumetric displays, called *multiplanar displays*, utilize a rotating or translating projection surface which receives a series of 2-D cross-sections, or "slices," of a 3-D image. The series of slices constitutes a full 3-D image, just as a sequence of CT scans are mentally

³⁷ The text was adopted for language learning purposes from preprint of the original paper of G.E.Favalora, J.Napoli, D.M.Hall, R.K.Dorval, M.G.Giovinco, M.J.Richmond, W.S.Chun, "100 Million-voxel volumetric display" [13].

stacked-up to constitute a patient's (3-D) anatomy. *Multiplanar displays* present an aggregate of surfaces over time which the eye integrates into a volume-filling image.

There are several types of multiplanar displays. *Swept-screen* multiplanar displays use a spinning projection screen, typically a plane (as in this example) or a helix. *Reciprocating-screen* multiplanar displays have a projection surface that translates back-and-forth. Note that the screen need not be physical. It can be an electronically-switched optically-diffuse surface or a macroscopic "surface" comprised of rare-earth dopants in a metastable state.

Note that the definition of "slice" bears discussion. If the projection screen is swept around its center, it sweeps an entire volume in just 180° of rotation. Therefore the volume refresh rate (in Hz) is twice the screen's rotation rate (in rps). Here, a slice is defined a 2-D cross-sectional surface of the 3-D dataset; for our 198-slice display, there are approximately 1.1 slices per degree. Also note that the 198 slices that comprise 0°-180° ("front-scan") are different than the 198 slices from 180°-360° ("back-scan"), even though care is taken to make them as visually similar as possible.

The design of the 100-million voxel volumetric display presented here has been described in detail elsewhere; this is a system-level summary and report of results achieved. The authors have developed a *visualization platform* that is a combination of hardware and software:

- Hardware: 768 x 768 x 198 volumetric 3-D display.
- Software: Development of a 3-D "operating system" or, more properly, visualization platform. At the time of writing, the platform is based on an open standard (OpenGL) and is therefore compatible with a range of legacy applications.

The theory of operation is that human persistence of vision is capable of integrating a series of 2-D slices – arranged like slices of an apple around its core – into a volume-filling 3-D image. As illustrated in Fig. 10.1, a high-speed 2-D projection engine images a time series of approximately 5,000 frames per second onto a diffuse projection screen which rotates at 730 rpm. A group of three mirrors relay the imagery to the rotating screen in a manner that ensures accurate focus regardless of the screen's angle. That is, a sequence of 2-D images is projected onto a rotating screen by a stationary projector via several relay mirrors.

Each 2-D slice is a cross-section of a 3-D dataset, as explained earlier. As has been reported extensively in the past 40 years, if the sequence of slices is projected rapidly, a 3-D image will be perceived to hover in the addressable region swept by the projection screen. Unlike panoramagrams (frequently called "autostereoscopic displays"), the image can be seen at any of a continuum of locations around the display without the restriction of discrete viewzones and the dark patterns they create. The reason is that the projector illuminates the screen with *cross-sections* of a dataset, not *snapshots normal to the screen*. However, because the screen is essentially a Lambertian diffuser, each voxel appears to emit omnidirectionally. Therefore, images are perceived to be translucent, and hidden-surface removal is not possible without knowledge of the viewer's position. Obviously, no headwear is required to view the 3-D imagery, and all focus (accommodation) and parallax cues are correct.

The system software allows the display to be integrated easily into existing applications and workflows. In particular, the software platform incorporates Mesa, the open-source graphics library similar to OpenGL. Simply put, this implies that (1) developers have a familiar programming interface, and (2) the display functions in real-time. For example, the user can rotate a DNA molecule at-will, or pilot a helicopter over synthetic animated terrain with a standard joystick.

The volumetric display's projector is based on the Texas Instruments Digital Mirror Device technology, which utilizes a MEMS-based reflective array to create single-bit-depth frames at approximately 5 kHz. The system uses a 3-SLM projection engine, which uses a color-mixing prism to combine R, G, and B image components with 1-bit depth each. Please refer to Fig. 10.2, which illustrates a simplified optical system.

A standard high-pressure mercury arc lamp illuminates a 3-SLM projector via an integrator rod and condensor lenses. The image of the SLMs is projected onto a custom projection screen that (1) approximates a Lambertian diffuser, and (2) has approximately 50/50 reflectance and transmission properties. The image is projected through the center of an openframe DC motor that rotates the final fold mirrors and the screen. Unfolding the optical path reveals that the SLMs throw an image at a 45° angle onto the screen. Therefore, additional optics (proprietary; not shown) is required for good focus across the screen. Real-time algorithms are used to counteract the effects of (1) keystoneing, and (2) rotation of the SLM image in the plane of the projection screen.

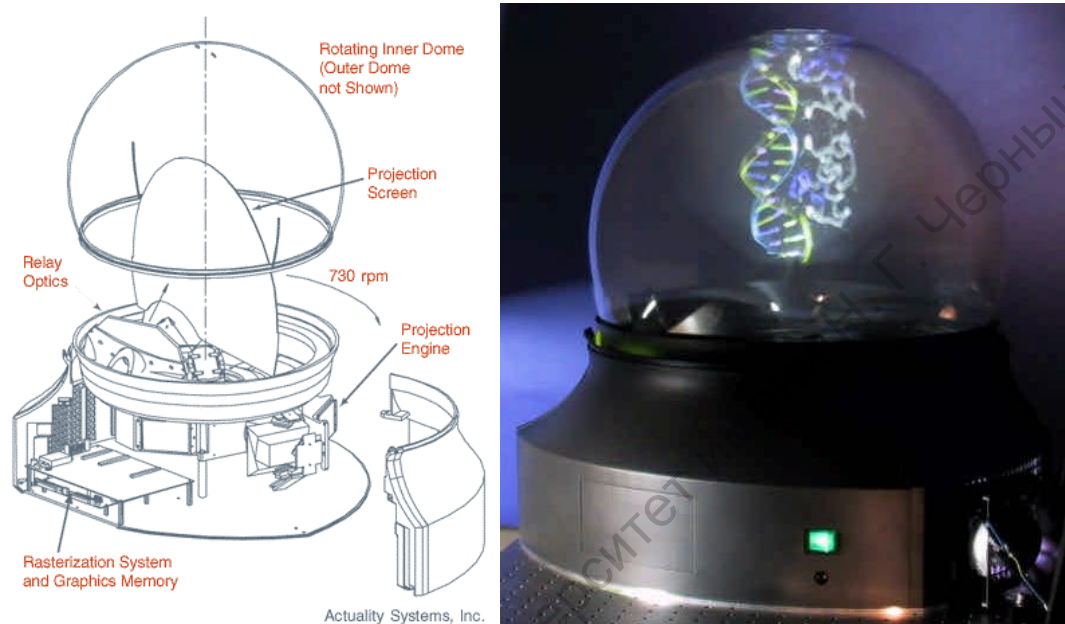


Figure 10.1. Schematic illustration of the volumetric 3-D display and a photograph of the display in operation [13]. (A fast projection engine illuminates a rotating projection surface via several relay mirrors which rotate with the screen. The projector and control electronics and fixed. The imagery is of a DNA helix and nearby protein from a popular molecular visualization package).

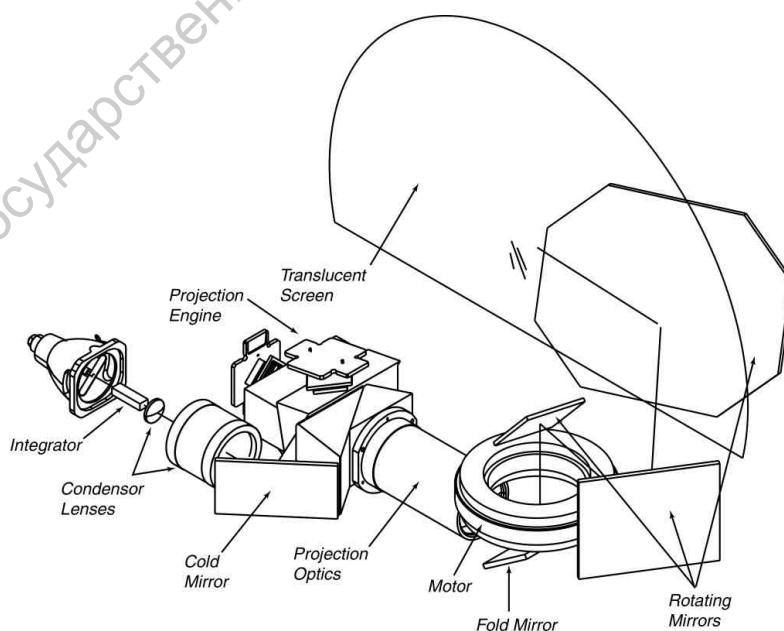


Figure 10.2. Simplified (schematic) layout of optical assembly [13]. (Some components are not shown).

Vocabulary Notes:

vector-scanned images – изображения, получаемые путем векторного сканирования
 solid-state – твердотельный; монокристаллический
 multiplanar – мультипланарный
 CT (Computer Tomography) – компьютерная томография
 swept-screen display – дисплей с вращающимся экраном
 dopant – легирующая смесь
 rps (revolutions per second) – оборотов в секунду
 rpm (revolutions per minute) – оборотов в минуту
 fps (frames per second) – кадров в секунду
 panoramogram – панорамограмма
 viewzone – зона наблюдения
 Lambertian diffuser – ламбертовский рассеиватель
 DNA (deoxyribonucleic acid) – дезоксирибонуклеиновая кислота
 MEMS (microelectromechanical systems) – микроэлектромеханические системы
 DMD (digital mirror device) – цифровое зеркальное устройство
 parallax cues – признаки глубины, связанные с эффектом параллакса
 single-bit-depth frame – кадр с глубиной цвета 1 бит
 SLM (spatial light modulator) – пространственный модулятор света
 mercury-arc lamp – ртутная дуговая лампа
 integrator rod – стержневой интегратор
 open-frame – бескорпусный
 DC motor (direct current) – электродвигатель постоянного тока
 fold mirrors – направляющие зеркала
 keystoneing – трапецевидное искажение

Active Vocabulary:

imagery – визуальная информация; совокупность изображений; образы
 aggregate – совокупность
 reciprocate – совершать возвратно-поступательные движения
 relay – передавать; транслировать
 regardless of – независимо от
 hover – парить; неподвижно висеть в воздухе
 addressable – адресуемый
 translucent – полупрозрачный
 fold – сгибать; сворачивать; заворачивать
 counteract – противодействовать; нейтрализовать
 omnidirectional – действующий по всем направлениям
 persistence – инерционность
 helix – спираль; винт
 snapshot – моментальный снимок
 diffuse – рассеивать (свет)
 relay mirrors – зеркала-ретрансляторы; зеркала переноса (изображения)

IV. Read the text attentively for detail and answer the following questions.

1. Is volumetric display presented here swept-screen or reciprocating-screen display?
2. Why is the volume refresh rate (in Hz) in the presented display twice the screen's rotation rate (in rps)?

3. Is the projector stationary or rotating in unison with the screen?
4. What advantage does presented display have over autostereoscopic displays?
5. Does the projector illuminate the screen with cross-sections of a dataset or with snapshots normal to the screen?
6. Why images produced by presented display are translucent?

VOCABULARY EXERCISES

I. State the part of speech of the following words pointing out the word building elements. Give their Russian equivalents.

Entire – entirety – entirely; similar – similarity – similarly; vaporize – vapor – vaporization – vaporous – vaporously; utilize – utilization – utilizable; reciprocate – reciprocation – reciprocal; rotate – rotation – rotator – rotational; constitute – constitution – constitutional; sequence – sequential – sequentially; typify – type – typical – typically; physics – physician – physicist – physical; define – definition – definite – definitely; approximate – approximation – approximately; summarize – sum – summary; arrange – arrangement; regard – regardless; extend – extension – extent – extensive; address – addressee – addressable; continue – continuity – continuum – continuous – continuously; rare – rarity – rarely.

II. Make nouns and adjectives from each of the verbs from the table.

Verb	Noun	Adjective
create		
vary		
visualize		
approximate		
refer		
constitute		
present		
define		
persist		
explain		
locate		
remove		
utilize		

III. Use the correct form of the word in capitals at the end of each sentence to fill the gap.

1. It had the dusty smell of an apartment whose windows were opened. RARE
2. Visits by presidential candidates are a here. RARE
3. The film should be shown in its or not at all. ENTIRE
4. Towns are only a few miles apart can have different dialects. ENTIRE
5. They are both doctors but that is where the ends. SIMILAR
6. Typically the imagery can be seen from a wide of angles. VARY
7. There are several ways to create imagery. VOLUME
8. I am writing to you with to your letter of 15 March. REFER

9. Their debts mounted with alarming RAPID
10. Make yourself for the interview. PRESENT
11. We could see the of clouds on the river. REFLECT
12. This part of the form is not to foreign students. APPLY
13. They have ignored our advice. PERSISTENCE
14. In , this was a disappointing performance. SUMMARIZE
15. Shevek is a brilliant working on a Theory of Simultaneity. PHYSICS
16. This seemed to me to show Wikipedia's growing role as an knowledge base.
ADDRESS

IV. Combine the words in bold with those in brackets. Translate the combinations into Russian.

property (chemical ~, magnetic, mechanical, physical, antiseptic, observable, individual, general; reflectance ~, transmission)

reveal (~ ignorance, truth, secret, facts, cause, plans, hidden skills, emotion)

utilize (~ extensively, fully, effectively, successfully; ~ resources, solar energy, criteria, material, tools, power)

simplify (~ considerably, slightly; ~ system, laws, procedure, preparation, demands, tasks, version)

sequence (complete ~, whole, complex, correct, alphabetical, chronological, logical, random; ~ of slices, of events)

translucent (~ image, wings, skin, materials, paper, glass)

removal (complete ~, temporary, effective, immediate, easy, surgical; stain ~, hair; demand ~, allow, facilitate, prevent)

ensure (must ~, aim to, try to, take steps to, be designed to, help (to), be important to; attempt to ~, efforts to ~, measures to ~; ~ accurate focus, safety, defense, efficiency, success, survival, good results)

arrange (~ easily, hastily, secretly, specially, alphabetically; ~ meeting, visit, trip, work, furniture, people)

compatible (~ star signs, people, aims, plans, functions, responsibilities; seem ~; highly ~, entirely, fully, directly, logically, technologically)

create (~ imagery, fashion, problems, impression, universe, music, graphs, atmosphere, style)

surface (~ projection, level, layer, temperature; even ~, flat, smooth, rough, curved, firm, soft, slippery, glassy, polished, reflective, inner, water, rock, earth's; rise to ~, bring sth to, scratch, touch; above the ~, along the, below the)

discussion (detailed ~, lengthy, brief, further, public, formal, informal, group, frank, open, heated, lively; have ~, hold, enter into, be involved in, join in, participate in, initiate, stimulate)

rate (rotation ~, volume refresh, transmission; constant ~, regular, steady, slow, phenomenal, high; increase ~, reduce, slow down, stabilize, maintain)

care (extreme ~, good, extra, special, due, proper, reasonable; exercise ~, take)

within (~ vapors, month, 20 meters, sight, reach, New Zealand, law, reason, the last few days)

summary (accurate ~, clear, excellent, detailed, full, brief, financial, statistical; make ~, prepare, write, give, provide)

development (gradual ~, rapid, commercial, economic, industrial, evolutionary, historical, regional, human, educational, psychological, physical, software; aid ~, allow, assist, encourage, enhance, facilitate, stimulate, monitor, trace; ~ plan, programme, project, scheme, work, process)

restriction (severe ~, major, further, artificial, proposed, legal, age, parking, price, speed, time, visa, travel; impose ~, introduce, accept, be subject to)

V. Match the words in column A with their meanings in column B.

A	B
restriction <i>n</i>	without being affected or influenced by sth
within <i>prep</i>	different from
solid <i>adj</i>	make it certain that sth will happen
reciprocate <i>v</i>	inside the range or limits of sth
regardless of <i>adv</i>	move quickly and with a lot of force
unlike <i>prep</i>	correctly, or in a way that is considered right
mental <i>adj</i>	flow of operations
sweep <i>v</i>	suggest that sth is true, without saying this directly
care <i>n</i>	hard or firm, with a fixed shape, and not a liquid or gas
properly <i>adv</i>	make known sth that was previously secret or unknown
ensure <i>v</i>	a rule or law that limits or controls what people can do
workflow <i>n</i>	effort and attention
reveal <i>v</i>	move backwards and forwards in a straight line
imply <i>v</i>	relating to the mind and thinking, or happening only in the mind

VI. Fill in the gaps in the sentences below using words from column A of Exercise V in the correct form.

1. The high level of radiation in the rocks that they are volcanic in origin. 2. All the necessary steps had been taken their safety. 3. He questioned whether the experiments were conducted 4. His letters a different side of his personality. 5. Recent business studies have shown an increasing need for some kind of management software to enable more efficient management. 6. Salt in the diet can help lower blood pressure. 7. The steam engine came into its own (became very useful) during the nineteenth century, when it found greatest use in mills, locomotives and pumping systems. 8. I can see that a lot of has gone into your work. 9. The ability to maintain physical and mental powers has allowed some individuals to pursue their chosen careers their age. 10. Because the glow fades almost immediately, the electron beam must continue the screen to maintain an image. 11. relativity theory, quantum theory is beginning to have a really significant impact on technology. 12. When they make new observations and discuss with colleagues, they are developing. 13. During winter the lake became a block of ice. 14. The machine is not being operated safety guidelines.

VII. Arrange the words given in a. and in b. in pairs of synonyms.

- Helix, utilize, ensure, rapidly, location, various, range, essentially, hover, obviously, imply, property, counteract, therefore, within, slice, constitute, aggregate, properly.
- Basically, indicate, form, total, guarantee, spiral, place, sphere, apparently, adequately, reduce, inside, use, fast, thus, layer, different, hang, quality.

VIII. Arrange the words given in a. and in b. in pairs of antonyms.

- Approximate, surface, familiar, simplify, reveal, diffuse, entire, care, stationary, obvious, illuminate.
- Unconcern, complicate, darken, unknown, accurate, mobile, partial, conceal, interior, concentrate, obscure.

IX. Give the English equivalents for the following using the text.

Изображения, получаемые путем векторного сканирования, монолитный, использовать, поперечное сечение, тонкий слой, располагаться один над другим, составлять, совокупность, дисплей с вращающимся экраном, вращающийся проекционный экран, совершать возвратно-поступательные движения, перемещаться, рассеивающая свет поверхность, состоять из, редкоземельный, легирующая примесь, метастабильное состояние, требовать обсуждения, правильно, совместимый, инертность зрительного восприятия, передавать, гарантировать, независимо от, ретрансляционные зеркала, неподвижно висеть в воздухе, в отличие от, ограничение, моментальный снимок, ламбертовский рассеиватель, по всем направлениям, полупрозрачный, удаление, подразумевать, отражательная матрица, упрощенный, бескорпусный, двигатель постоянного тока, направляющий зеркала, противодействовать, трапецевидное искажение.

X. Give the Russian equivalents for the following.

Sequence, entire volume, volume refresh rate, system-level summary, range, legacy applications, arrange, core, projection engine, frame, extensively, hover, addressable region, continuum, discrete viewzones, dark patterns, hidden-surface removal, parallax cues, workflow, imply, synthetic animated terrain, single-bit-depth frames, mercury arc lamp, integrator rod, custom projection screen, reflectance and transmission properties, open-frame DC motor, unfold, reveal, proprietary, counteract, keystoneing.

PRACTICE

I. Translate the sentences into Russian defining the function of infinitives.

Infinitive can have different functions in sentences. It can be used as subject, predicate, object, attribute and adverbial modifier. Study the examples and pay special attention to the ways of translation:

To do (subject) work an object must have energy.

The group used a CRT **to create (adverbial modifier)** simple 2-D images which were imaged onto a rotating screen.

A 3-D image **will be perceived to hover (part of predicate)** in the addressable region swept by the projection screen.

The system software **allows the display to be integrated (complex object)** easily into existing applications and workflows.

The visual system's ability **to process (attribute)** binocular information is well-documented.

1. Volumetric displays create imagery that appears **to float** in a volume.
2. There are several ways **to create** volumetric imagery.
3. Care is taken **to make** the slices as visually similar as possible.
4. The volume refresh rate does not necessarily match the video hardware's ability **to fill** graphics RAM with new imagery.
5. Because the screen is essentially a Lambertian diffuser, each voxel appears **to emit** omnidirectionally.
6. Images are perceived **to be** translucent.

7. No headwear is required **to view** the 3-D imagery.
8. The system described here is able **to support** higher resolution imagery than is generated by the current projector system.
9. In order **to detect** the phase information of the object wave, we superpose a plane wave with the object wave.
10. **To alleviate** the problem, the use of on-axis holography has become more important and relevant for holographic 3-D display.
11. Four such arrays are then projected around the entire inner surface of the display, allowing the user **to easily interact** with the objects by touching the surface of the enclosure directly above them.
12. Even by altering the mappings between the hand and cursor **to reduce** the necessary movements, it can still be a tedious task **to perform** repeatedly.
13. **To scale** a model, both index fingers are placed on and dragged along the surface of the display.
14. The volumetric display will indeed enable users **to better view** a 3-D scene.
15. The objects **to be constructed** by the computer-generated hologram can be represented in the computer by mathematical or graphical descriptions.
16. **To synthesize** CGHs of 3-D images is a heavy computational task.

II. Translate the following text into English.³⁸

Поперечный размер изображений, создаваемых объемными дисплеями, колеблется от менее чем одного дюйма до, приблизительно, трех футов. Некоторые исследователи предпочитают описывать пространственную протяженность изображения исходя из его объема. Например, представленный здесь дисплей имеет объем приблизительно в 113 кубических дюймов.

Разрешение объемного дисплея обычно определяется разрешением и кадровой частотой его проекционного устройства. Мультипланарный объемный дисплей мог бы использовать одно проекционное устройство с разрешением 1024×768. Такое устройство могло бы иметь кадровую частоту от 5 КГц до 10 КГц (согласно уровню передовых технологий, существующих на момент написания).

В некотором смысле производитель объемного дисплея ограничен следующим соотношением: (частота обновления изображения во всем объеме) × (количество слоев, приходящихся на одно изображение) = (кадровая частота проектора). В нашем случае проектор, имеющий кадровую частоту 5 КГц, используется для создания 198-слойного изображения с частотой обновления 24 Гц.

Vocabulary Notes:

range – колебаться

inch – дюйм

foot (pl. feet) – фут

spatial extent – пространственная протяженность

in terms of its volume – исходя из его объема

be governed (by) – определяться

frame rate – кадровая частота

be bound (to) – ограничиваться

relationship – соотношение

³⁸ The text was translated from preprint of the original paper of G.E.Favalora, J.Napoli, D.M.Hall, R.K.Dorval, M.G.Giovinco, M.J.Richmond, W.S.Chun, "100 Million-voxel volumetric display" [13].

volume refresh rate – частота обновления изображения во всем объеме
 slices per image – количество слоев, приходящихся на одно изображение

III. Read the text and reproduce it in English in short.³⁹

Volumetric displays are the set of three-dimensional display technologies that produce volume-filling imagery. (This term is not to be confused with ‘volume rendering’, a computer graphics technique of a similar name that is commonly used in medical imaging and petroleum visualization). Barry Blundell and Adam Schwarz offer the following definition: ‘a volumetric display device permits the generation, absorption, or scattering of visible radiation from a set of localized and specified regions within a physical volume’.

Simply put, volumetric displays create imagery that appears to float in a volume. Typically the imagery can be seen from a wide variety of angles. Furthermore, goggles are generally not required to perceive the 3-D imagery.

Several publications provide surveys of existing volumetric display architectures. The authors point out the work of M. Halle, K. Langhans *et al*, and Blundell and Schwarz as particularly instructive. The majority of volumetric displays exploit persistence of vision by projecting 0-, 1-, or 2-D components of a scene rapidly enough that the retina fuses them into a 3-D perception.

Vocabulary Notes:

volume rendering – объемная визуализация – метод формирования изображения, при котором представляется внутреннее строение трехмерного объекта

medical imaging – медицинская визуализация

petroleum visualization – визуализация в нефтяной промышленности

IV. Read the text and render it in Russian.⁴⁰

The authors chose a three-dimensional display method that provides high-resolution imagery in a mechanically-simple manner at reasonable cost. The solution was inspired by a system reported in 1960 by ITT Laboratories. The group used a CRT to create simple 2-D images which were imaged onto a rotating screen. A similar design is taught by Max Hirsch in a patent application filed in 1958 – a fast CRT is imaged onto a rotating screen with a slightly different arrangement of relay mirrors. One clever aspect of these designs is the placement of several relay mirrors which rotate in unison with the screen, thereby keeping the optical path length (and therefore the focus) the same regardless of the screen’s angle.

More recently, Batchko teaches a system using scanning a laser beam relayed by a similar architecture. Tsao *et al* report a volumetric display that interposes image-derotation optics between the image generator and projection screen, since the image of the screen would otherwise rotate in the plane of the projection screen as the screen rotates.

In the author’s case, the CRT is replaced with a high-frame-rate MEMS-based projector; a specialized off-axis projection system is employed; and data is generated by a suite of graphics-processing hardware and software. Software, instead of de-rotation optics, stabilizes the projector image in the plane of the rotating screen.

³⁹ The text was adopted for language learning purposes from preprint of the original paper of G.E.Favalora, J.Napoli, D.M.Hall, R.K.Dorval, M.G.Giovinco, M.J.Richmond, W.S.Chun, “100 Million-voxel volumetric display” [13].

⁴⁰ The text was adopted for language learning purposes from preprint of the original paper of G.E.Favalora, J.Napoli, D.M.Hall, R.K.Dorval, M.G.Giovinco, M.J.Richmond, W.S.Chun, “100 Million-voxel volumetric display” [13].

Vocabulary Notes:

CRT (cathode ray tube) – ЭЛТ (электронно-лучевая трубка)

patent application – заявка на патент

file – подавать какой-л. документ

off-axis projection system – система внеосевой проекции

hardware and software – программное и аппаратное обеспечение

V. Reproduce the main text.

VI. Write an annotation on the text.

VII. Topics for discussion.

1. Physical phenomena in volumetric displays.

Barry Blundell and Adam Schwarz define the term ‘volumetric display’ as a device which permits ‘the generation, absorption, or scattering of visible radiation from a set of localized and specified regions within a physical volume’. Which of these three phenomena is used in presented volumetric display (also known as Perspecta Spatial 3-D Display) for 3-D image creating? More precisely, does the Perspecta 3D Display use generation, absorption, or scattering of light from a set of specified regions within a physical volume in order to create 3-D image? Supply your viewpoint with arguments.

2. Swept-screen vs. solid-state volumetric displays.

The DepthCube 3-D Display described in Unit 9 of the textbook is a solid-state volumetric display and the Perspecta Spatial 3-D Display described here is swept-screen. What advantages may swept-screen approach to volumetric displays creation have over solid-state approach? What advantages may solid-state approach have over swept-screen one? Try to compare these two approaches from viewpoints of manufacturability, reliability, complexity, cost and usability using the information obtained from reading texts about the DepthCube 3-D Display and the Perspecta Spatial 3-D Display.

UNIT 11

INTERACTION WITH VOLUMETRIC DISPLAYS

READING

I. Read the following words paying attention to pronunciation.

Inherent [ɪn'hɪərənt], leverage ['li:vərɪdʒ], physiological [fɪzɪə'lɒdʒɪkəl], perception [pə'sepʃn], although [ɔ:l'dəʊ], commercially [kə'mɜ:ʃəli], unique [ju:'ni:k], feature ['fi:tʃə], desirable [dɪ'zɑɪərəbəl], enclosure [ɪn'kləʊʒə], uniformly ['ju:nɪfɔ:mli], identify [aɪ'dentɪfaɪ], label ['leɪbəl], conjunction [kən'dʒʌŋkʃən], precise [prɪ'saɪs], posture ['pɒstʃə], gesture ['dʒestʃə], facilitate [fə'sɪlɪteɪt], infer [ɪn'fɜ:], entire [ɪn'taɪə], initiate [ɪ'nɪʃieɪt].

II. Try to guess the meaning of the words in bold type.

imagery *n* images in general or collectively: Their dreams involved complex stories with visual imagery./ Advertisers use all kinds of imagery to play on our emotions./ Satellite imagery (photographs of the earth taken from space) indicated that dust from the Sahara is spreading westwards.

view *v* to look at or watch sth; to look at information on a computer screen: To view the next page press 'tab'./ view imagery on volumetric displays/ view physical objects in the real world./ The mountain is best viewed from the north side. If we view the problem from a different angle, a solution may become more obvious.

akin *adj formal* **akin to sth** very similar to sth: Something akin to panic overwhelmed him. Pity and love are closely akin. Viewing imagery on volumetric displays is akin to viewing physical objects in the real world.

inherent *adj formal* a quality that is inherent in sth is a natural part of it and cannot be separated from it: I'm afraid the problems you mention are inherent in the system./ Every business has its own inherent risks./ There are dangers inherent in almost every sport./ She seems completely unaware of the contradictions inherent in her professed point of view.

perception *n* an awareness of things through the physical senses, esp. sight: Psychologists have been studying perception in rats in an attempt to discover more about human mental processes connected with sight./ These photographs will affect people's perceptions of war./ our perception of reality/ visual perception/ One theory is that caffeine somehow counteracts the perception of pain.

promising *adj* showing signs of being successful or good in the future: a promising career in law/ a promising young actor/ a promising start/ The weather doesn't look very promising./ They won the award for the most promising new band of the year./ The results of the first experiments are very promising.

leverage *v technical* spread or use (resources, money, skills, buildings etc that an organization has available), ideas etc again in several different ways or in different parts of a company, system etc: Reusable software is leveraged across many applications./ In order to fully leverage the unique features of these displays, it would be desirable if one could directly interact with and manipulate the 3-D data being displayed./ New IBM software tools allow developers to leverage open standards to build security into applications./ Here's our startup business advice on a few things small companies, or even solo entrepreneurs, can do to leverage the web for their internet startup business.

challenge *n* difficult, demanding or stimulating task: The company is ready to meet challenges of the next few years./ Martins now faces the biggest challenge of his career./ This application area itself presents many interesting challenges.

enclosure *n* an area surrounded by a wall or fence and used for a particular purpose: enclosure surrounding the displayed 3-D volumetric image/ The swimming pool was enclosed by a high fence. Expressions are enclosed in brackets./ a fear of enclosed spaces/ An enclosed community or way of life does not have much communication with the outside world.

uniform *adj* the same everywhere; unvarying: Critics were uniformly enthusiastic about the production. The rows of houses were uniform in appearance./ of uniform color/ The water must be of uniform temperature for the process to take place.

dome *n* rounded roof with a circular base: the dome of St Paul's Cathedral/ The zoo's main feature is a jungle setting under a glass dome./ The domed ceiling (shaped like a dome) of the library was its most famous feature./ The display can be viewed from any direction around the hemisphere dome.

track *v* follow the direction smb/ sth takes: The progress of each student is tracked by computer./ The study tracked the careers of 1, 226 doctors who trained at the University of Michigan Medical School./ The military use radar to track targets through clouds or at night./ A Vicon motion tracking system is used to track the positions of markers on the user's fingers.

tip *n* the end of sth, especially sth pointed: Use the tip of the brush to paint fine lines./ lights on the wing tips of airplanes/ the tips of one's fingers/ the tip of one's nose/ walking on the tips of her toes/ His name's on the tip of my tongue.

facilitate *v formal* make possible or easier: facilitate the execution of a task/ Modern inventions facilitate housework./ The new trade agreement should facilitate more rapid economic growth./ We implemented two techniques to facilitate command input using fingers.

carry out *v* do and complete a task: carry out an inquiry/ an investigation/ a survey/ The building work was carried out by a local contractor./ Turn off the water supply before carrying out repairs.

III. Skim the text quite quickly to get a general understanding and answer the questions given. Consult the vocabulary after the text.

1. What does the text focus on?
2. How does the user interact with the virtual data?
3. 3-D display of what type was used in the research described in the text (stereoscopic, holographic, swept screen, solid-state?)

INTERACTION WITH VOLUMETRIC DISPLAYS⁴¹

Viewing imagery on volumetric displays, which generate true volumetric 3D images by actually illuminating points in 3D space, is akin to viewing physical objects in the real world. Viewers can use their inherent physiological mechanisms for depth perception to gain a richer, more accurate understanding of the virtual 3D scene. These displays typically have a 360° field of view, and the user does not have to wear hardware such as shutter glasses or head-trackers. As such, they are a promising alternative to traditional display systems for viewing in 3D.

Although these displays are now commercially available, current applications tend to use them as a non-interactive output-only display device, much like one would use a printer. In order to fully leverage the unique features of these displays, however, it would be desirable if one could directly interact with and manipulate the 3D data being displayed.

⁴¹ The text was adopted for language learning purposes from preprint of the original paper of T.Grossman, D.Wigdor, R.Balakrishnan, "Multi-finger gestural interaction with 3D volumetric displays" [14].

In this paper, we investigate interaction techniques for volumetric display interfaces, through the development of an interactive 3D geometric model building application. While this application area itself presents many interesting challenges, our focus is on the interaction techniques that are likely generalizable to interactive applications for other domains. We explore a very direct style of interaction where the user interacts with the virtual data using direct finger manipulations on and around the enclosure surrounding the displayed 3D volumetric image. In our implementation, the enclosure is a hemisphere (Figure 10.1). If the enclosure was instead a cuboid or cylinder, some of the mappings we use may need modification, but the overall ideas would remain applicable.

We use a 3D volumetric display from Actuality Systems (Figure 10.1). It generates a 3D volumetric image by sweeping a semi-transparent 2D image plane around the up axis. A total of 198 2D slices (images) of 768x768 pixels each are uniformly displayed around the center axis, resulting in a total of 116 million voxels. The display has a refresh rate of 24Hz, and was driven by a 2 GHz Pentium4 computer on which our application software ran. The display can be viewed from any direction around the hemispheric dome, without requiring the user to wear any hardware.

A Vicon motion tracking system is used to track the positions of markers placed on the user's fingers. The Vicon system uses several high-resolution cameras to track the 3D location of multiple passive reflective markers in real time. In addition to tracking the location of the markers in 3D space, the system can uniquely identify and label each marker according to its position on a user's fingers. The 3D coordinates of these labeled markers can then be streamed in real-time to other applications. Our prototype uses four cameras for tracking. In our current work, we track markers on the index fingers of both hands, and the thumb of the user's dominant hand.

We use the labeled marker data, in conjunction with knowledge of the precise topology and 3D spatial location of the display's enclosure in the tracking volume, to simulate an enhanced touch sensitive display. Our system categorizes the precise positional information of the tips of the two index fingers and thumb into one of three discrete states. We also detect static postures and dynamic gestures of the fingers by examining the relative distance between the markers.

Given that we intend to perform all interaction on and around the display itself, and wanted to avoid using additional input devices like keyboards, we implemented two techniques to facilitate command input using the fingers: *surface menus* and a set of *postures and gestures*.

Similar to interfaces for 2D touch screens, we display frequently used commands as buttons on the surface of the display. We call this *surface menus*. We provide two surface menus, one for each hand.

While surface menus provide a nice mechanism for command input, there are instances when it could be inconvenient to have to touch the surface menu buttons to invoke a command. For example, if the user is manipulating a virtual object, it may be easier to enter commands using other finger movements. We also wanted to experiment with more than one command input mechanism, to enable later determination of optimal solutions. Accordingly, we developed a set of hand postures and gestures which can be carried out on or off the surface of the display. We infer the set of postures based on the shape of the fingers, while the set of gestures is determined based on the dynamic characteristics of the fingers' movement over time.

For interacting in three dimensions, we need to support a variety of basic operations such as file visualization and browsing, selection, translation, scaling, and rotation.

In order to allow for basic file operations of load, save, organize, copy, and delete we developed a simple file/object management mechanism called *SurfaceBrowser*. The SurfaceBrowser displays various objects by organizing them into cells of a 2D array. Four such arrays, or *pages*, are then projected around the entire inner surface of the display, allowing the user to easily interact with the objects by touching the surface of the enclosure directly above them. The pages either contain

models or *scenes*. Models are primary shapes used in building more complex scenes. The contents of each cell rotate slowly to aid in their visualization.

A flat arrow cursor is displayed below the dominant hand's index finger, which is used to perform basic operations with objects in the SurfaceBrowser. A quick tap on any object opens it. When this occurs, the selected model or scene smoothly animates from its 2D form on the surface of the display, to its 3D shape at the center of the display.

Once a model has been opened, we allow for rotation, translation, and scaling.

Rotation is initiated by touching the display with the dominant hand's index finger. The finger is then dragged across the surface of the display, and this movement is transformed into rotation of the model, as if there were a stick connecting the finger to the model's center. This provides two degrees of freedom of rotation. A third rotational degree of freedom is achieved by twisting the hand, while the index finger is still down. This rotates the model about the vector defined from the finger to the model.

Translation is imitated by assuming a pinch posture with the dominant hand. While pinched, moving the hand in any direction moves the model the same distance in that direction. The metaphor here is that of picking up an object with a pinch grip and moving it.

Unlike translation and rotation which are performed with a single finger, scaling is a bimanual technique. To scale a model, both index fingers are placed on and dragged along the surface of the display. Sliding the fingers further apart on the surface increases the scale, while sliding them together decreases it. The object is scaled uniformly along all dimensions.

The rotate and translate transformations discussed allow users to simultaneously control three degrees of freedom.

The interaction techniques we developed make maximal use of the three dimensional nature of the display and input system. While the direct finger tracking allows users to perform high degree of freedom operations with multiple fingers, the display technology allows users to accurately visualize the virtual 3D manipulations with excellent depth perception. Taken together, this allows for interesting interactions not possible in traditional input and display combinations.

Vocabulary Notes:

leverage – (в данном случае) использовать

enclosure – (в данном случае) корпус (дисплея)

mapping – отображение

motion tracking system – система отслеживания движений

marker – маркер

topology – топология (в данном случае – конфигурация купола, огораживающего дисплей)

touch sensitive display – сенсорный дисплей

browsing – просмотр и редактирование

bimanual – бимануальный; двуручный

tap – слабый удар

Active Vocabulary:

akin (to) – быть сродни чему-либо; быть похожим на

inherent – присущий; врожденный

gain – получать; приобретать

investigate – изучать; исследовать

generalize – обобщать; распространять

explore – исследовать; рассматривать

implementation – исполнение; реализация
 hemisphere – полушарие
 cuboid – кубоид; прямоугольный параллелепипед
 uniformly – равномерно
 dome – купол
 uniquely – однозначно
 in conjunction with – вместе с
 sensitive – чувствительный; сенсорный
 categorize – распределять по категориям
 precise – точный
 posture – положение; поза
 examine – исследовать; изучать
 facilitate – облегчать; помогать
 invoke – вызывать; осуществлять
 infer – означать; подразумевать
 inner – внутренний
 initiate – начинать
 twist – вращать; поворачивать
 scaling – масштабирование

IV. Read the text attentively for detail and answer the following questions.

1. According to the text, what is the problem with current applications for interaction with 3D volumetric displays?
2. What devices were used in order to obtain the precise positional information about the user's fingers?
3. What spatial characteristic was examined for detecting postures and gestures of the user's fingers?
4. Why were such techniques as surface menus and gestures tracking chosen for interaction?
5. Which three spatial transformations were allowed once a model had been opened?

VOCABULARY EXERCISES

I. State the part of speech of the following words pointing out the word building elements. Give their Russian equivalents.

Imagine – image – imagery – imaginary – imagination – imaginable; perceive – perception – perceptiveness – perceptive – perceptible – perceptively; enclose – enclosure; convenient – inconvenient; uniform – uniformity – uniformly; enhance – enhancement; precise – precision – precisely; implement – implementation; manage – management – manager – manageable; unique – uniqueness – uniquely; entire – entirety – entirely; direct – direction – directional – directly; perform – performance – performer; dimension – dimensional; assume – assumption; mark – marker, available – availability; tend – tendency.

II. Make nouns and adjectives from each of the verbs from the table.

Verb	Noun	Adjective
manage		

perceive		
imagine		
direct		
promise		
interact		
present		
reflect		
dominate		
relate		
intend		
desire		
optimize		
infer		
initiate		
free		

III. Use the correct form of the word in capitals at the end of each sentence to fill the gap.

1. It is that you should have some familiarity with computers. DESIRE
2. The Equator is just an line. IMAGE
3. Pressure must be distributed over the whole surface. UNIFORM
4. Parents' views influence their children's of the world. PERCEIVE
5. We bought this house for ; it's near the shops and the railway station. CONVENIENT
6. Most photos, no matter how carefully composed, need some to achieve their full potential. ENHANCE
7. The full of the system will take some time. IMPLEMENT
8. E-commerce is a recent phenomenon. RELATE
9. Towns only a few miles apart can have different dialect. ENTIRE
10. It was impossible to make about people's reaction. ASSUME
11. The report said that the of the museum staff was outstanding. PERFORM
12. She decorated the room to make it a little more PRESENT
13. Rotation is by touching the display with the dominant hand's index finger. INITIAL
14. The issue of climate change was the theme of the conference. DOMINATE

IV. Combine the words in bold with those in brackets. Translate the combinations into Russian.

perception (depth ~, clear, visual, human; have ~, gain, affect)

promising (~ alternative, results, actor, start; be ~, look, seem, sound; extremely ~, highly, hardly)

application (current ~, practical, general, wide, agricultural, industrial, database, multimedia, software; run ~, develop; ~ area)

device (display ~, clever, ingenious, labor-saving, sophisticated, hi-tech, automatic, electrical, electronic, mechanical, measuring)

challenge (interesting ~, big, considerable, real, tough, main, new, political, technical; pose ~, present, face, meet, respond to)

implementation (effective ~, complete, detailed, strict, smooth, practical, early, immediate, gradual; achieve ~, ensure, monitor, consider, discuss; ~ plan, problem)

overall (~ ideas, impression, cost, effect, picture, performance, effectiveness, analysis, development, increase, configuration)

dome (hemispheric ~, spherical, monolithic, luminous)

track (~ positions, e-mails, messages, documents, work performance, changes)

label (~ correctly, properly, wrongly, carefully, neatly, automatically; ~ images, products, CDs, containers)

current (~ work, month, events, expenses)

facilitate (~ execution, growth, input, learning; ~ greatly; be designed to ~, help (to),)

determine (~ solution, needs, display size, value, rules, development; exactly ~; try to ~, help to, be easy to, be possible to, be difficult, be necessary to, be able to)

entire (~ staff, afternoon, surface, world, collection, system, generation, population, database, life)

scene (beautiful ~, idyllic, peaceful, touching, extraordinary, familiar; watch ~, witness)

flat (~ arrow cursor, surface, plain, roof; fall ~, look, become, make sth; very ~, absolutely, completely, quite, almost)

dominant (seem ~, become, remain; extremely ~, overwhelmingly, totally, increasingly, relatively, economically, politically, socially; ~ class, hand, ideas, genes, strategy, design, domain, force)

perform (~ effectively, efficiently, properly, successfully, well, automatically, manually; be able/unable to ~, be expected to; ~ task, operation, duties, experiment)

V. Match the words in column A with their meanings in column B.

A	B
surround <i>v</i>	stay in a particular place or position and not leave it
implement <i>v</i>	exact and accurate
overall <i>adj</i>	the way you position your body when sitting or standing
remain <i>v</i>	help someone or sth by making their situation or what they are doing easier
dominant <i>adj</i>	piece of paper or another material that is attached to sth and gives information about it
precise <i>adj</i>	operate a computer program
enhance <i>v</i>	an area of activity, interest, or knowledge, esp one that a particular person, organization etc deals with
posture <i>n</i>	considering and including everything
examine <i>v</i>	work or do sth, carry out
aid <i>v</i>	more important, powerful, or successful than the other people or things of the same type
domain <i>n</i>	the things that are inside a box, bag, room
label <i>n</i>	be all around smb or sth on every side
contents <i>n</i>	look at sth carefully in order to find out more or see what it is like
invoke <i>n</i>	improve sth or make it more attractive or more valuable
perform <i>v</i>	put into operation

VI. Fill in the gaps in the sentences below using words from column A of Exercise V in the correct form.

1. The date and place of his birth are unknown. 2. As a result, the United Nations continued to a peacekeeping role. 3. He picks up each item and it carefully. 4. It can be inconvenient to have to touch the surface menu buttons to a command. 5. Poor posture can lead to muscular problems. 6. Calcium in bone development. 7. Gwen has always been by people who adore

her. 8. I need to find a way of my income. 9. The lock had been broken and the drawer emptied of its 10. We don't want all the details now, just the picture. 11. The on the bottle says not to take more than six tablets a day. 12. Some of the mappings we use may need modification, but the overall ideas would applicable. 13. Red is usually the color in his paintings. 14. The changes to the national health will be next year. 15. This is a subject that has now moved into the political

VII. Arrange the words given in a. and in b. in pairs of synonyms.

- a. Akin, view, generate, gain, current, leverage, unique, manipulate, investigate, domain, implementation, track, prototype, enhance, detect, perform, facilitate, instance, invoke, enable, tip, initiate, occur.
- b. Handle, see, characteristic, similar, end, ease, happen, original, use, execution, find, explore, produce, follow, intensify, obtain, field, start, allow, example, enforce, work, special, present.

VIII. Arrange the words given in a. and in b. in pairs of antonyms.

- a. Akin, real, additional, single, increase, enhance, remain, current, dominant, precise, static, avoid, frequently, inner, initiate.
- b. Rarely, decrease, secondary, basic, different, terminate, multiple, depart, loose, imaginary, outer, minimize, face, obsolete, dynamic.

IX. Give the English equivalents for the following using the text.

Совокупность изображений, быть похожим на, свойственный, получать, точный, многообещающий, текущий, эффективно использовать, уникальные черты, желательно, задачи, область, окружать, исследовать, общий, оставаться, вращать, равномерно, купол, система отслеживания, большой палец, указательный палец, кончики пальцев, вместе с, изучать, выполнять, облегчать, сенсорный дисплей, пример, неудобный, весь, содержимое, плоский, вращение, перемещение, масштабирование, в отличие от, перетаскивать, уменьшать.

X. Give the Russian equivalents for the following.

Depth perception, shutter glasses, head trackers, promising alternative, non-interactive output-only display device, interaction techniques, enclosure, sweep, refresh rate, result in, high-resolution cameras, label markers, enhanced, touch sensitive display, static postures, dynamic gestures, discrete states, invoke a command, enable determination of optimal solutions, cell, inner surface, perform operations, smoothly, define, assume, pinch posture, twist the hand, slide the fingers.

PRACTICE

I. Translate the sentences into Russian defining the function of gerunds.

Gerund can have different functions in sentences. It can be used as subject, predicate, object, attribute and adverbial modifier. Study the examples and pay special attention to the ways of translation:

Viewing imagery (subject) on volumetric displays, which generate true volumetric 3D images by actually **illuminating (adverbial modifier)** points in 3D space, is akin to **viewing (object)** physical objects in real world.

Наблюдение изображений на объемных дисплеях, которые создают настоящие объемные образы, освещая точки в трехмерном пространстве, похоже на наблюдение физических предметов в реальном мире.

A Vicon motion **tracking (attribute)** system is used to track the positions of markers placed on the user's fingers.

Система отслеживания «Викон» используется для того, чтобы следить за положением маркеров на пальцах пользователя.

The conference hall was packed but people kept on **coming (predicate)**.

Конференц-зал был переполнен, но люди продолжали прибывать.

1. Viewers can use their inherent physiological mechanisms for depth perception to gain more accurate **understanding** of the virtual 3D scene.
2. We investigate interaction techniques for volumetric display interfaces through the development of an interactive 3D geometric model **building** applications.
3. The 3D volumetric display generates a 3D volumetric image by **sweeping** a semi-transparent 2D image plane around the up axis.
4. The display can be viewed from any direction around the hemispheric dome without **requiring** the user to wear any hardware.
5. In addition to **tracking** the location of the markers in 3D space, the system can identify and label each marker according to its position on a user's fingers.
6. Our prototype uses four cameras for **tracking**.
7. We detect static postures and dynamic gestures of the fingers by **examining** the relative distance between the markers.
8. We wanted to avoid **using** additional input devices like keyboards.
9. For **interacting** in three dimensions we need to support a variety of basic operations.
10. The SurfaceBrowser displays various objects by **organizing** them into cells of a 2D array.
11. The arrays allow the user to easily interact with the objects by **touching** the surface of the enclosure directly above them.
12. Rotation is initiated by **touching** the display with the dominant hand's index finger.
13. **Moving** the hand in any direction moves the model the same distance in that direction.
14. **Sliding** the fingers further apart on the surface increases the scale while **sliding** them together decreases it.
15. The direct finger **tracking** allows users to perform high degree of freedom operations with multiple fingers.
16. A volumetric display device permits the generation, absorption, or **scattering** of visible radiation from a set of localized and specified regions within a physical volume.
17. Human persistence of vision is capable of **integrating** a series of 2-D slices – arranged like slices of an apple around its core – into a volume-filling 3-D image.

II. Translate the following text into English.⁴²

⁴² The text was translated from preprint of the original paper of T.Grossman, D.Wigdor, R.Balakrishnan, "Multi-finger gestural interaction with 3D volumetric displays" [14].

С точки зрения технологии объемные дисплеи (volumetric displays), в общих чертах, можно разделить на три категории.

Голографические дисплеи генерируют трехмерные изображения, управляя дифракцией света с помощью динамических микроскопических структур. Дисплеи со статическим объемом создают излучающие воксели, непосредственно возбуждая точки внутри физически существующей трехмерной основы. Дисплеи с крутящимся экраном вращают плоское, изменяющееся во времени изображение вокруг оси на достаточно высокой скорости, что позволяет зрительной системе человека воспринимать объемное изображение путем объединения последовательных двумерных изображений в одно трехмерное.

Поскольку до недавнего времени объемные дисплеи не были легко доступны, возможности их эффективного интерактивного использования еще недостаточно изучены.

Vocabulary Notes:

from a technology viewpoint – с точки зрения технологии

broadly – в общих чертах

microscopic pattern – микроскопическая структура

emissive voxels – излучающие воксели

directly – непосредственно

excite points – возбуждать точки

physical 3D substrate – физически существующая трехмерная основа

swept-screen display – дисплей с крутящимся экраном

time-varying – изменяющееся во времени

fuse together – объединять

successive – последовательный

III. Read the text and reproduce it in English in short.⁴³

While performing any of the transformations, a colored 3D icon is drawn at the center of the model, indicating which transformation is currently being applied. The icons are displayed oriented towards the user's current hand positions to facilitate viewing. If the transformation has not yet been initiated, the icon is white, indicating to the user that the posture of their hands is close to that required to begin the corresponding transformation.

For example, if both of the user's hands are close to touching the surface of the display, the scale icon will be displayed in white. Once both fingers make contact with the surface the icon will become colored. This provides a nice way to guide users into appropriate postures for transformation actions, and also to reduce accidental triggering of transformations.

Vocabulary Notes:

accidental – случайный

trigger – инициировать, давать начало

IV. Read the text and render it in Russian.⁴⁴

⁴³ The text was adopted for language learning purposes from preprint of the original paper of T.Grossman, D.Wigdor, R.Balakrishnan, "Multi-finger gestural interaction with 3D volumetric displays" [14].

⁴⁴ The text was adopted for language learning purposes from preprint of the original paper of T.Grossman, D.Wigdor, R.Balakrishnan, "Multi-finger gestural interaction with 3D volumetric displays" [14].

On 2D or stereoscopic displays, users have a single viewpoint of the 3D scene at a given time. As a result, users have to rotate the scene frequently to view the parts occluded from the current viewpoint, or to enhance depth perception through motion. Head tracking can enable more fluid viewpoint changes, but only within the limited range of the display's field of view. Furthermore, most interaction occurs relative to the current viewpoint.

In contrast, volumetric displays allow the user to walk around it, or move their head appropriately, to dynamically adjust their viewpoint in a fluid manner much like they would when viewing a physical object in the real world. Furthermore, users can also reach around and interact with the 3D scene from all directions around the display, regardless of their current viewpoint (assuming a moderately sized display). These properties can allow for new interaction techniques beyond what is possible in other display environments and should be exploited to maximal benefit.

Vocabulary Notes:

occlude – скрывать

fluid – плавный

appropriately – соответствующе

adjust – приспособливать

exploit – использовать

V. Reproduce the main text.

VI. Write an annotation on the text.

VII. Topics for discussion.

1. Multi-user interaction.

In this research ideas of using surface menus and motion tracking for direct manipulation with 3D data were implemented only for single-user interaction. How would it be possible to organize multi-user interaction with 3D volumetric display with the help of these ideas? What kinds of strategies can be applied to allow two or more people to work together using gestural interaction techniques on such a display? What difficulties may arise? If there are multiple users, at what orientation should a text be displayed?

2. New interaction techniques.

The purpose of the research was to enable direct manipulation with 3D data without using additional input devices like keyboards. Shown implementation achieves this with the help of surface menus and gestures tracking. What other techniques may be offered for achieving this purpose? Try to suggest more variants and modifications. How could it be possible to make display's enclosure touch sensitive without motion tracking?

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