Visual Perception - Formative Assignment

Visualisation and VR IDS Module

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"*The visual sense gives us timely knowledge of our spatial surroundings, near and far, identifying all the objects in it to our consciousness. The world we see is inside us, an illusion, but we all share the same internal perception of a real and physical universe outside us. The sense is so well adapted to its purpose that we normally assume that what we perceive are the actual objects, as if by touching, and it was exceedingly difficult for philosophers to overcome this erroneous belief. The visual world is another illusion, like the movement of the sun and moon across the sky, where it is an effort to realise that it is the earth that is moving, not the heavens. What is apparent is not always true. The visual sense intimately combines memory with external stimulation.*" (J.B Calvert, from [3]).

1 Introduction

Perception is the process by which humans, and other organisms, interpret and organise sensation in order to understand their surrounding environment. Perception is used to describe the ultimate experience and interpretation of the world and usually involves more processing of the sensory input. Vision is a complicated process that requires numerous components of the human eye and brain to work together.
[2]. It is a curious and interesting subject, but also a quite wide one and it encompasses several sciences, like philosophy, psychology, medicine, physics, and, now a day, even computer science and visualisation.

The attempt of this paper is to explain in a general way how visual perception works in humans and to highlights some of its features in order to exploit their effects in a useful way.

2 Visual Perception and the Human Visual System

The visual system is a very interesting and maybe the most important human sensory capability. It consists of several parts, but simplifying we can say that the human visual system consists of two fundamental organs: the eyes and the brain (Fig. 1) [4].

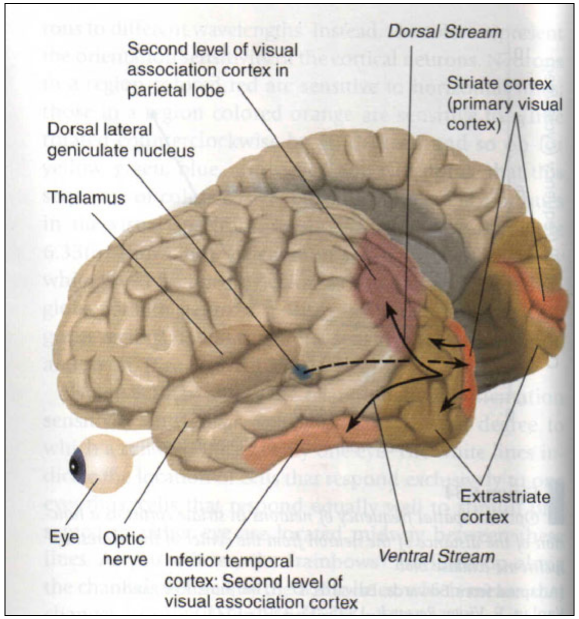


Fig. 1 – The human visual system

The human eye consists of a spherical organ with a transparent lens, and a photosensitive region filled with several different types of photoreceptor cells [4].
Throw the eye, electromagnetic radiation from our environment enters the visual system, exciting a flood of information from the distorted, two-dimensional image cast upon these sensitive cells of the *retina*. Here the signals from neighbouring receivers are compared and a coded message dispatched on the optic nerves to the occipital cortex, behind the

ears, where the information is formatted and made available to the processing activities of the brain [3].

As we will explain in the following sections, it is here in the brain that most of vision process take place takes place.

3 How do we perceive the world?

When we observe the external world, there are different sensations that we can perceive. For example, we can see if an object is closer than another object (*distance perception*), or we can realise if an object is moving or not (*motion perception*). The factors that affect the "appearance" and the perception of an object in the space are many and they are related to each others.

In this section we try to analyse some of them and we try to explain how they collaborate to provide us information about the appearance of one particular object.

Distance perception

The factors that influence whether one object appears closer than another are many. First of all we can say that the further an object is from the viewer the smaller they are on the retina. To say it technically, the *visual angle* subtended by the object gets smaller the further away it is.

The fact that we have two eyes (*binocular vision*) also provides information on distance. One of these binocular distance cues is called *convergence*. Convergence refers to the turning in of our eyes as objects come closer to our eyes.

The other thing that happens as objects come closer is that our *accommodation* changes. There is a change of focus that occurs when the lens gets fatter for nearby objects. Another cue to distance perception, especially for more complex scenes in which there are multiple objects, is *binocular disparity* [5].

Yet another cue to distance is motion parallax (http://www.yorku.ca/eye/Motion%20Parallax.htm). As you move from one location to another objects at various distances will move in a direction dependent on where you are fixating.

Finally, it turns out that *colour* and *brightness* (http://www.yorku.ca/eye/thejoy.htm) can have an effect on how far away something appears.

Stereopsis and 3D Perception

Visual perception makes use of a large number of clues - many of which have been discussed in the previous paragraph - to create its three-dimensional picture from the two-dimensional retinal images. Strong clues are the apparent *size* of objects of known size, *overlapping* and *parallax*, *shadows* and *perspective*. Weaker clues are *atmospheric perspective* (*haze* and *scattering*), *speed of movement*, and *observed detail* [3]. The strongest clue of all, however, is *stereopsis* [3]. Stereopsis - in Greek "solid sight" – is an interesting mechanism that combines the view form of the left and the right eyes into a solid three-dimensional view [1].

The interpretation of retinal images to produce stereopsis is entirely mental, and must be learned. When the images on the eyes are consistent with the observation of a single object, the two flat images *fuse* to form a vivid three-dimensional image. With practice, fusion can be achieved with two pictures side by side and the eyes voluntarily diverged so that each eye sees its picture straight ahead, though accommodated for the actual distance. Both the original pictures remain in view, but a third, fused, image appears before them when the concentration is diverted to it that appears strikingly solid. The brain regards this fused image as the real one, the others as mere ghosts.

By the use of a *stereoscope*, we can achieve fusion without diverging the eyes, or focusing on a close object with the eyes so diverged, so no practice or skill is required. A stereoscope mainly changes the directions in which the two images are seen so that they can both be fixated by normally converged eyes. The two images are called a *stereopair* [6].

Fig. 2 (Portrait of Cecilia Gallerani, 1848, Leonardo Da Vinci) and Fig. 3 are examples of stereoscopic images.

Fig. 2 - Stereoptic portrait of Cecilia Gallerani of Leonardo Da Vinci

Fig. 3 – Stereoptic landscape image

Size Perception

Like distance perception, the perceived size of objects depends on a number of factors. Perhaps the most important of these is the visual angle (http://www.yorku.ca/eye/visangle.htm) subtended by the object on the retina. All other things being equal, the object that subtends the larger visual angle will appear larger. The visual angle is dependent on two main factors: the actual size of the object and the distance the object from the eye.

Another factor effecting perceived size is *size constancy*. This phenomenon results in objects of known size tending to appear constant in size regardless of their distance; or better, if the distance is large, enough known objects will appear smaller. For example, this is the effect that you can have if you look at the ground from the Eiffel Tower or similar very tall edifices. From up there you would notice that people on the sidewalks and cars in the streets look very small, indeed. They almost appear as ants.

Another factor that can influence perceived size is *perspective*. http://www.yorku.ca/eye/perspect.htm One of the situations where this could be experienced is in a tunnel. The bricks lining the walls of the tunnel will subtend small and smaller visual angles the further they are from your eye. In fact, these converging lines are often used by artists to create the illusion of distance in their paintings.

Shape Constancy

Have you ever noticed, for example, when you approach the dinner table that the shapes of the plates do not change? When you look at them from some distance away from the table, the shapes of the round plates are elliptical on your retina. The only time that the image of a round plate is approximately round on your retina is when you look at it straight on.

The same situation occurs with a rectangular door. When it is closed and you stand in front of it the image on your retina is approximately rectangular. But when you open the door it will become trapezoidal on your retina.

This phenomenon of your perceiving the "real" shapes of objects regardless of their retinal projections is called *shape constancy* http://www.yorku.ca/eye/shape.htm . It is one of the several perceptual constancy that one encounters.

Dark and Light Adaptation

Dark adaptation and light adaptation are the effect you can observe when for example you go from a very bright area to a very dark one and, vice versa, when you go from a dim area to a bright one. In the first case it would be very difficult for you to see for several minutes, while in the second one you would probably feel your eyes hurting for a while and the scene would appear very bright to you (Fig. 4).

One of the major differences between dark adaptation and light adaptation is their time course. Whereas dark adaptation takes about 30 minutes to be complete, light adaptation happens very quickly, usually in less than a minute.

Another difference between these to type of adaptation is that when you are light adapted and then go into a very dark room for a while you may not see anything at all. As you dark adapt more and more things become visible. When you go from a darker area to a very bright one you usually are not temporarily blind. It is just that your vision temporarily is not very good. In technical jargon, your contrast sensitivity is poor until you become light adapted. By that we mean that you will have difficulty in perceiving areas of low contrast. It is like every thing is all washed out. But as you quickly light adapt the darker areas become darker and the lighter areas become easier to see.

Fig 4 – Light adaptation effect

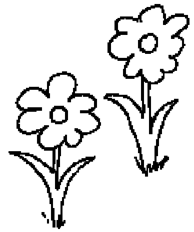
4 Depth Reproduction and Perspective

As we mention before, perspective is one of the important elements in providing information about the way in which we perceive an object. In particular, perspective can be very useful when we want to reproduce reality and we want to provide some depth to our image – no matter if it is a painting or a digital image -, and give a "3D-impression".

In this section, we describe some "tricks" that can be uses when we want to add some depth to a 2D-image and that come directly from the principles of linear perspective were formalised in the early 15th century.

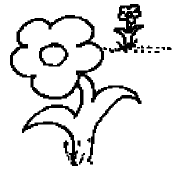
Placement

Without getting too deep into the concept of the horizon, it should be noted that objects higher in an image tend to look farther away. Without the use of some other trick, this technique will not create great depth, but it can help to distinguish spatial relationships to some small degree. This trick works best when the picture is meant to be seen below eye level. This trick does work, but usually in conjunction with some other trick.



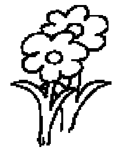
Size

Shapes that should be about the same size if they were real, will appear smaller as the become farther away. This is the law of diminution we explained above. It works best when whoever views the picture has an expectation of relative sizes, like when a bunch of people should be about the same height. Any change in that expectation causes a shift of perceived perspective.



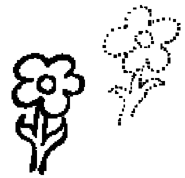
Overlapping

When one image obscures another, there is little doubt which is meant to be in front, and which behind. This can be as simple a process as erasing the parts that should not show. When one shape effectively cancels what we see of another, the interposed one always seems to be in front.



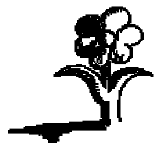
Density

The closer something is to us, the more detail we can perceive. By selectively eliminating detail, we can force objects to seem to disappear in a haze. The next time you are walking or driving in fog, notice how things fade more quickly, and the feeling of perspective becomes enhanced. This principle is less noticeable, but also present without fog, and occurs naturally over great distances where the landscape fades in the distance.



Shading

Simply by adding proper shadows, a flat image seems to acquire mass. When shadows are cast on and by objects, a strong feeling of spatial relationships is created. Without mass and perspective, shadows are meaningless. The converse is also true. Meaningful shadows create an illusion of mass and perspective.



Foreshortening

This is a catch all concept that illustrates the fact that as an object is turned away from the viewer, the overall shape seems to distort. Closer surfaces may take on emphasis in size and detail, while parts turned away will become smaller and even disappear from sight. Circles become ovals and ellipses, and squares become rectangles, while previously unseen surfaces may become prominent.

Color

Adding color to an image can make a great difference in how it is perceived. Darker or "cooler" colors like violets and blues often tend to seem to recede, while "warmer" colors like red and yellow will tend to pop forward. Colors that are hazy in appearance may bring the trick of density into play as well.

[7]

5 Perceiving Pattern and Shape

Visual perception is an active process. Our brains are constantly searching for structure in the patterns of light imaged on our retinas. Under normal conditions the patterns come from real objects like (e.g. a table, a tree, etc.) and the processes that go on in our brains are undetectable. However we can create simple meaningless patterns like the one below that reveal these processes at work.

5.1 Searching for structure: Perceptual Organisation

If you look for a while at the grid pattern on the left of Fig. , at first it just looks like a chicken-wire fence or maybe the tiles on a bathroom floor. But if you keep looking

eventually you'll start to see the grid divide up into a shifting mosaic of designs like the ones on the right. If you look long enough you'll notice that the designs keep changing and you can see many of them alternatively. This is because our brain is continuously trying to figure out if there's anything meaningful hidden in the pattern. First it tries one approach, then another, then another until it finds something it can recognise. Psychologists call this process *perceptual organisation*.

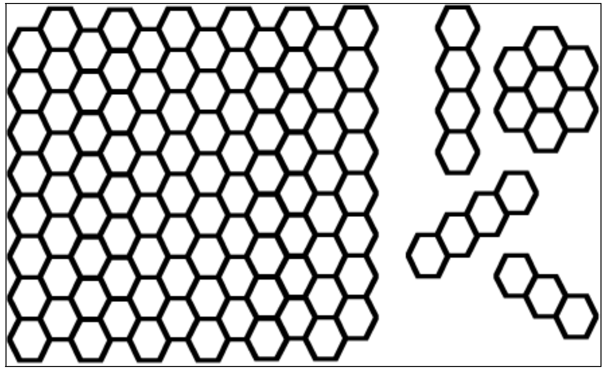


Fig. 5– Perceptual organisation

Perceptual organisation is not just an interesting phenomenon, it's essential to our survival. Among other things, it lets us see potential predators or prey that might have protective colouring that camouflages them against the background. Fig. 6 represent an interesting example of this principle.

Fig. 6 – Dalmatian dog

Have you been able to find the dog in the picture above? Does it help to know that it's a Dalmatian? How about if you know that it's a Dalmatian exploring a leave covered forest floor? Now that you see the dog, do you find it hard to see the picture as a simple pattern of black and white?

5.2 The rules of perceptual organisation

A group of psychologists in the 1930's and 40's, known as the *Gestalt school*, studied the processes of perceptual organisation. Gestalt is a German word that means “whole”. These psychologists believed that through perceptual organisation, the simple sensations produced by the eye are grouped together into meaningful percepts. The Gestaltists wanted to understand how perceptual organisation works so they did experiments using simple patterns to discover the rules of perceptual organisation.

Figure and ground

The most fundamental rule of perceptual organisation is the idea of *figure and ground*. When we look around in the world we see objects like lamps and cows and aeroplanes. When we look at these objects they seem distinct and separate from the table or field or sky we see them against. We normally pay attention to the objects and more or less disregard the background. However we can shift our attention to the background, but then the object becomes indistinct.

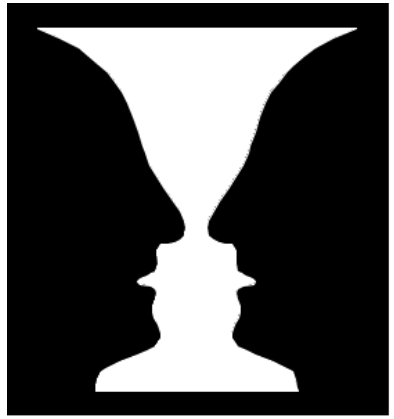


Fig. 7 – Figure and ground

Rubin created the image shown in Fig. 7 to demonstrate the idea of figure and ground. What do you see when you look at the picture? Do you see a vase? Do you see two faces? Does what you see flip/flop back and forth between these two alternatives? This shows the figure/ground process at work. When you see the white vase, the white area is the figure and the black is the ground. When you see the black faces, the reverse is true, now the black makes up the figure and the white is the ground. If you look long enough you'll notice that it's impossible to see both the vase and the faces at the same time. The figure/ground process is exclusive. A pattern can't be seen as a figure and as a background at the same time.

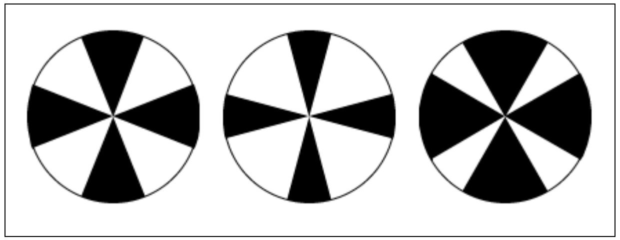


Fig. 8 - Disks

One of the important aspects of a pattern that determines whether it will be seen as a figure or ground is the amount of area the pattern takes up. If you look at the disk of Fig. 8

you can see that the white and black sections have equal area so it's possible to see the it as either a black cross on a white background or a white cross on a black background. Changing the relative areas of the black and white sections makes it easier to see the pattern one way or the other. In general the sections with the larger area will be seen as the background and the sections with the smaller area will be seen as the figure, so the middle disk tends to look like a black cross on a white background and the right disk tends to look like a white cross on a black background.

5.3 Perceptual Grouping

Perceptual grouping is another important principle investigated by the Gestalt psychologists. Perceptual grouping means that depending on how a pattern is laid out, we tend to see certain elements of the pattern as belonging together.

Proximity

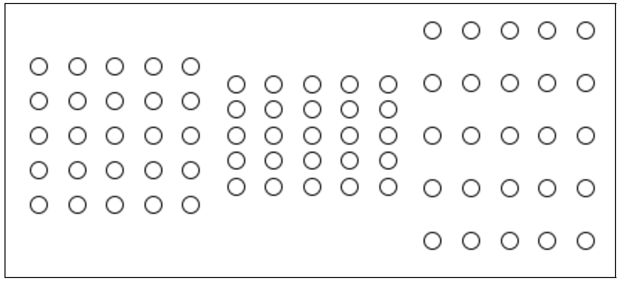


Fig. 9 - Proximity

Proximity (Fig. 9) is one of the factors that influences perceptual grouping. Grouping based on proximity means that elements that are closer together tend to be seen as a group. In the dot pattern on the left all the dots are equally spaced horizontally and vertically. In the middle dot pattern the dots are closer vertically and we tend to see this pattern as five columns of dots. In the dot pattern on the right the dots are closer horizontally and we tend to see this pattern are five rows of dots.

Colour, Size and Orientation

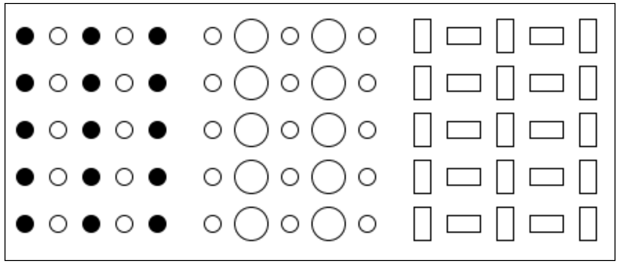


Fig. 10 – Colour, size and orientation

The *colour, size and orientation* (Fig 10) of pattern elements also influences perceptual grouping. In the pattern on the left the dots are different colours. We tend to see this pattern as alternating columns of black and white dots. In the middle pattern the bigger and smaller dots group together into columns, and in the rightmost pattern the horizontal and vertical rectangles also form columns. One important thing to notice is that in some cases grouping based on colour, size or orientation can override grouping based on proximity. If you look at the black and white dot pattern on the left you can see that the pattern looks like columns even though the dots are further apart vertically, and should look like rows on the basis of proximity alone.

Closure

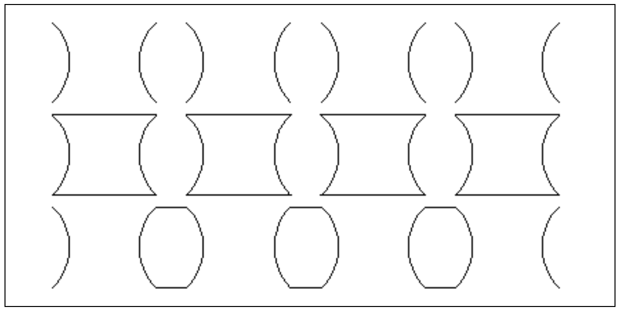


Fig. 11 - Closure

Closure (Fig. 11) is another factor in perceptual grouping. Pattern elements that form a closed shape, tend to be grouped together and seen as figures. The pattern on the top is ambiguous. It can be seen as either a row of spools or a row of barrels. By drawing horizontal lines connecting different parts of the pattern we can make it look either way. In the middle pattern, you can see that connecting the segments that face away from each makes the spools appear. On the bottom you can see that connecting facing segments makes the barrels appear.

Symmetry

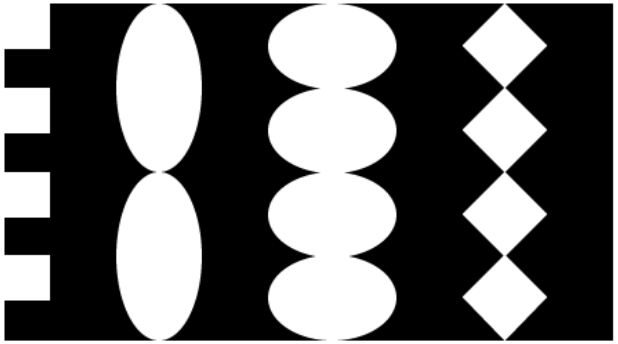


Fig. 12 - Symmetry

Symmetry (Fig.12) is another factor in perceptual grouping. Symmetric contours tend to be grouped together into figures. In the pattern above you can see that the white areas stand out as figures from the black background because the adjacent white contours are mirror images of each other. In contrast, the adjacent black contours are different so they don't group and therefore look like background.

Good Continuation

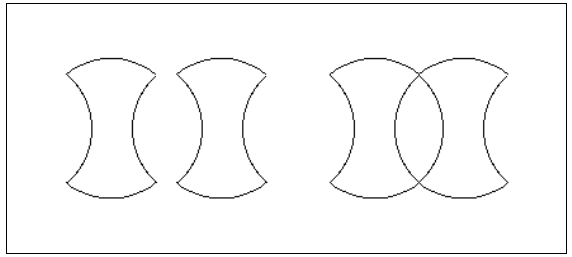


Fig. 13 – Good continuation

A line that continues across a break is another pattern feature that is used by our perceptual grouping processes. In the pattern above (Fig. 13) you can see that the closed figures on the left look like two solid ax blades, but when we make them touch, the organisation changes and they now look like overlapping bent wire hoops. The way the curved edges continue smoothly across the points where the figures touch changes the way the visual system interprets which edges belong to which figure.

5.5 Organising Patterns in Three Dimensions

The world around us is three dimensional. Real objects are not flat like pictures, but have height. width, and depth. Our visual system is predisposed to interpret patterns in three dimensions. Many of the rules of perceptual organisation we looked at above also apply to patterns that are more easily interpreted in three dimensions.

Proximity in three-dimensions

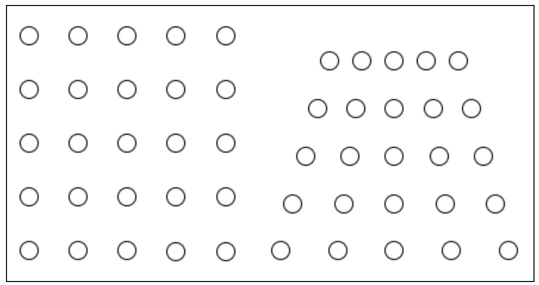


Fig. 14 - Proximity

The pattern on the left of Fig. 14 looks like a vertical grid of dots. The pattern on the right looks like the same grid of dots tilted back in depth. Notice that even though the dots get closer and closer in proximity in the image, we interpret the change as a change in depth, and not as a change in the regular grid pattern. The rule of proximity in perceptual organisation works in a three-dimensional context.

Skew symmetry

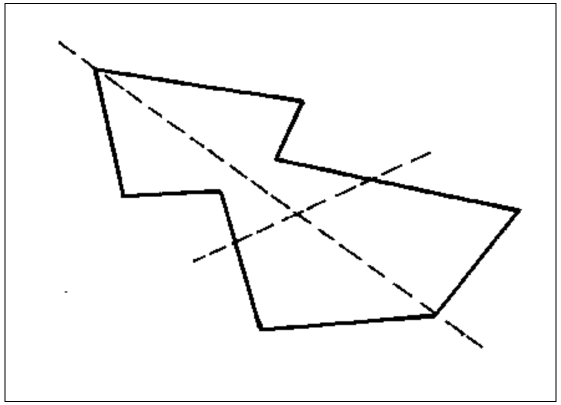


Fig. 15 – Skew symmetry

The way we perceive symmetry in patterns also seems to operate in a three-dimensional context. In the two-dimensional picture of Fig. 15, none of the lines or angles are equal, but because we see the picture as a representation of a three-dimensional object, we perceive a symmetric object slanted off in depth. Psychologists call this *skew symmetry*.

Simplicity

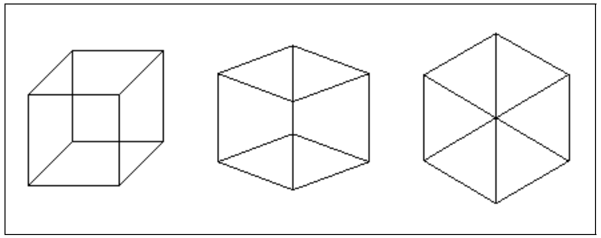


Fig. 16 – Simplicity in 3D

One of the important principles of perceptual organisation in three dimensions is *simplicity*. Our brains are always searching for regularities in patterns, and these regularities can be in two or three dimensions. Look at the two patterns above (Fig 16). Both are perfectly good drawings of a cube, but the only the one on the left looks three-dimensional, the one on the right looks like a flat wedge pattern. We see the left pattern as a 3D cube because it is simpler to understand it that way than to see it as a flat pattern of triangles and quadrilaterals. Similarly, we see the right pattern as flat because it is simpler to see it that way, than to think of it as a cube turned on end.

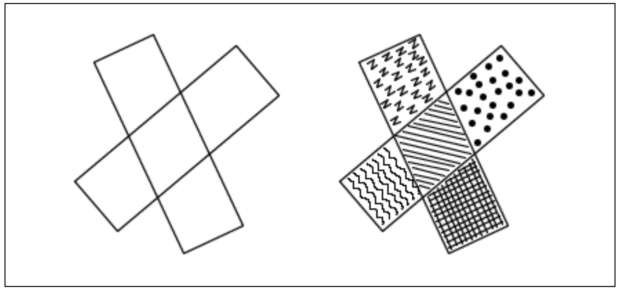


Fig. 17 – Simplicity in 2D

The idea of simplicity applies to transparency as well as three-dimensional shape. It is simpler to see the pattern on the left of Fig. 17 as two overlapping wire-frame or transparent rectangles than it is to see it as the complicated two-dimensional pattern of abutting shapes shown on the right.

5.6 Perceiving Patterns in the Real World

The simple pictorial patterns shown above are designed to highlight some of the rules of perceptual organisation investigated by the Gestalt psychologists. When we look around the real world, the patterns of light that are much more complex, and all the organising principles outlined above are involved allowing us to perceive the meaningful features of the environment.

Segmenting Textures

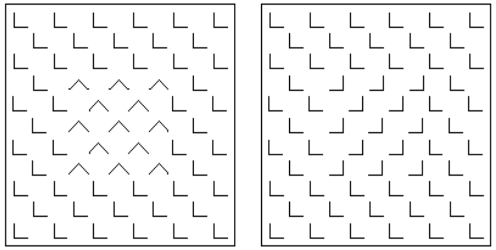


Fig. 18 – Segmenting textures

One of the ways we distinguish the boundaries of objects in the real world is by perceiving differences in surface texture. Hard, soft, rough, and smooth objects can all be distinguished visually on the basis of their texture. But there are limits to how well we can perceive differences in texture. The two patterns of Fig. 18 are made of "L" shaped texture elements. In the pattern on the left it is easy to perceive a difference in texture and visually segment the pattern into surrounding and inset areas. But even though the texture elements in the pattern on the right are the same it is much more difficult to distinguish the inset from the surround because the inset and surround textures are symmetric and tend to be grouped together. People and animals make use of the limits of perceptual texture segmentation to protect themselves by becoming blending in with the background. This technique is known as *camouflage*.

Camouflage

Fig. 19 – Toad Camouflage

Can you see the toad in the picture of Fig. 19? You may find it difficult because the texture pattern on the toad's skin almost exactly matches the woody background. This shows one type of camouflage, where it is hard to distinguish two objects because their patterns are very similar.

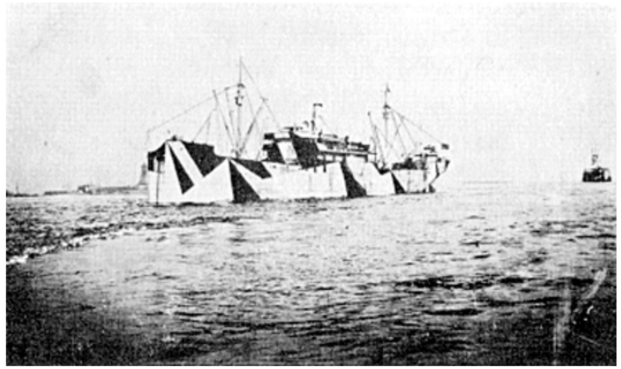


Fig. 20 – Ship camouflage

Another type of camouflage is shown above, in Fig. 20. Here the ship is painted with a random areas of black and white. This texture pattern breaks up the visual outline of the ship when it is seen across the water, and makes it more difficult to tell which way the ship is pointed. Can you tell if the ship is coming toward you or going away? This kind of camouflage doesn't hide the ship, but it makes it more difficult to figure out where it is and where it's going.
[8]

6 Computer Graphic and Vision

Computer graphics is a rapidly growing computer fields. It has become a common element in user interfaces, vehicle and architectural design, lighting simulations, data visualisation, entertainment - games and motion pictures, advertising - television commercials, art, education, training and many, many other applications.

Hardware devices and algorithms have been developed for improving the effectiveness, realism, and speed of picture generation, and the current trend in computer graphics is to incorporate more physics principles into three-dimensional graphics algorithms to better simulate the complex interactions between objects and the lighting environment.

But do we mean when we talk about Realistic Computer Graphics (RCG) and Virtual Reality (VR)? We can define realistic image synthesis as the computation of images that are faithful representations of a real scene.

For computer generated imagery to be predictive and have use beyond illustration and entertainment then realism is the key. Generally the overall level of accuracy required is determined by the application. For certain applications where viewers simply need to be convinced the scene could be real, such as children's education, entertainment and games, empirical models of light simulation may be sufficient. However, for predictive applications such as accurate reconstruction, training & industrial simulation where the aim is to present the user with the same visual experience as if they were actually in the scene then physically based models are used. An example of such a physical based model iss Radiance. The big disadvantage with these "realistic" physical models is that they take a long time to render the results.

The major challenge, therefore, in Virtual Reality is to achieve this realism whilst keeping the computational time small and keeping up with real time control movements made by the user. One obvious way to solve this is by using a far more powerful system, but the economic constraints often preclude this. Perceptual research can provide the information to help accomplishing this task [2]. and help to create virtual environments which are closer to reality we know.

Visual perception is a field that attracted and still attracts the interest of many scientists from different scientific areas. The experiments that have been made on this subject are many and many are also the results that have been achieved, but there aspects of the human perception process which still remain unknown or unexplored. Nevertheless, we can still use our knowledge on visual perception in a useful way – connection between vision and visualisation is in fact becoming closer every day . For example, until recently we didn't know that a poorly chosen colour scheme would cause messages from the colour channel of our vision system to conflict with messages from the form channel, and thus cause visual artifacts. Knowing about the differences between the two channels now we can better select colour schemes for visualising complex scientific problems so as maximally exploit the capabilities of out system [1]. Again, by understanding better the deficiencies of our visual system and by using the tricks we described above, we could

reduce computational resources and concentrate only on the aspects of our reality reproduction that the human system is able to capture.

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