Peripheral Vision

Related terms:

Virtual Reality, Computer Graphics, Deconstruction, Virtual Reality Application, Virtual Reality Experience, Virtual Reality System

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Vision

Jeff Johnson, Kate Finn, in Designing User Interfaces for an Aging Population, 2017

Narrowing of peripheral vision

Peripheral vision is the ability to see things where you are not directly looking—"out of the corner of your eye." Even in young people with normal vision, peripheral vision is poor [Johnson, 2014]. It's just how human eyes are: we have high-resolution vision only in a small area in the very center of each eye's visual field—an area called the "fovea" that is about 1% of the total visual field (see box **Human Vision Is Mostly Low Resolution**). Most of our visual field—the other 99%—has very low resolution: it sees the world as if through frosted glass [Eagleman, 2011] (see Figure 3.3).

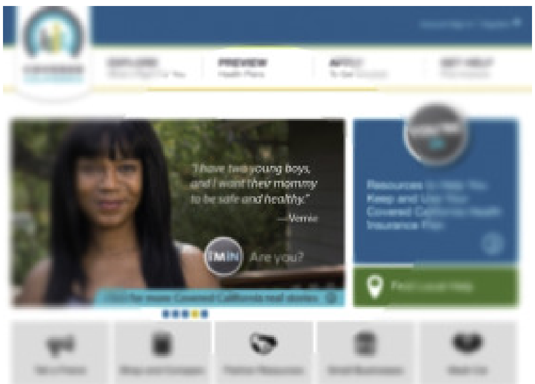

Figure 3.3. Only the very center of our visual field has high resolution; the periphery has low resolution.

Human Vision Is Mostly Low Resolution

The fovea—the 1% of your visual field at the center that has high resolution—is small. To see how small, hold your arm out, stick up your thumb, and focus on your thumbnail. At arm's length, your thumbnail is about the size of your fovea. The rest of your visual field can be considered peripheral vision, with significantly lower resolution [Johnson, 2014].

As bad as peripheral vision is in young adults with normal vision, it gets worse with age. Our field of useful vision gradually narrows, so we can't take in as much in one glance as we used to [Mitzner et al., 2015]. How much worse? It varies, but on the average, we lose about 1–3 degrees from the edges of our visual field every 10 years. By 70–80 years of age, most of us have lost 20–30 degrees from the edges of our visual field. Like age-related farsightedness, this gradual narrowing of our field of vision is common and considered normal.

Sometimes, I don't even notice things on the edges of the screen.Carolina

Obviously, peripheral vision is needed to notice on-screen content that is not where our gaze is focused. Reduced peripheral vision increases the chance of people missing error messages, warnings, or other information that appears away from where they are looking [Hawthorn, 2006]. It also reduces peoples' ability to detect motion at the edges of their vision.

Age-related narrowing of peripheral vision also has a negative effect on reading. As we read, our eyes focus on one group of words, take them in, and then jump[1] ahead several words to take in the next group [Johnson, 2014]. Our peripheral vision prescans text ahead of our point of focus, providing information to our brain about what lies ahead, how far ahead to jump, which words to skip over, and where to pause. As our peripheral vision narrows, the scanning becomes less effective, which slows our reading [Legge et al., 2007].

Glaucoma is a medical condition that can cause sudden and/or drastic loss of peripheral vision, sometimes called "tunnel vision" (see Figure 3.4) [Haddrill and Heiting, 2014].The greater your age, the greater your risk of developing glaucoma [National Eye Institute (NIH), n.d.]. It afflicts just under 1% of the population, or about 80 million people by 2020 [Quigley, 2006].

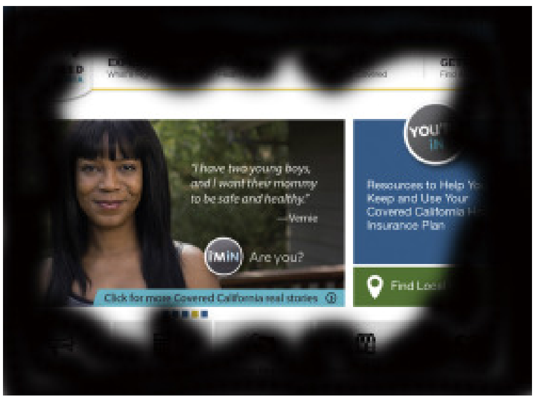

Figure 3.4. CoverCA.com viewed with peripheral vision reduced by glaucoma.

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Rich Internet Applications

Pawan Vora, in Web Application Design Patterns, 2009

Why

Because our peripheral vision is attuned to detect movement (Faraday and Sutcliffe 1997; Peterson and Dugas, 1972), using animation to direct users' attention to changes on the page is a useful and effective technique, especially for RIAs, where the page does not refresh with changes in the page's content.

Animations and transitions also have an aesthetic value that cannot be ignored. They make web applications appear interactive and dynamic and contribute to the characterization of RIAs as "cool," an attribute commonly lacking in traditional web applications, which are limited to relatively static images and layouts in their visual designs.

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Our Peripheral Vision is Poor

Jeff Johnson, in Designing with the Mind in Mind (Second Edition), 2014

Function 1: Guides fovea

First, peripheral vision provides low-resolution cues to guide our eye movements so that our fovea visits all the interesting and crucial parts of our visual field. Our eyes don't scan our environment randomly. They move so as to focus our fovea on important things, the most important ones (usually) first. The fuzzy cues on the outskirts of our visual field provide the data that helps our brain plan where to move our eyes, and in what order.

For example, when we scan a medicine label for a "use by" date, a fuzzy blob in the periphery with the vague form of a date is enough to cause an eye movement that lands the fovea there to allow us to check it. If we are browsing a produce market looking for strawberries, a blurry reddish patch at the edge of our visual field draws our eyes and our attention, even though sometimes it may turn out to be radishes instead of strawberries. If we hear an animal growl nearby, a fuzzy animal-like shape in the corner of our eye will be enough to zip our eyes in that direction, especially if the shape is moving toward us (see Fig. 5.4).

FIGURE 5.4. A moving shape at the edge of our vision draws our eye: it could be food, or it might consider us food.

How peripheral vision guides and augments central, foveal vision is discussed more in the "Visual Search Is Linear Unless Targets 'Pop' in the Periphery" section later in this chapter.

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Our Peripheral Vision is Poor

Jeff Johnson, in Designing with the Mind in Mind, 2010

Resolution of the Fovea Compared to that of the Periphery

The spatial resolution of the human visual field drops greatly from the center to the edges. Each eye has approximately six million retinal cone cells. They are packed much more tightly in the center of our visual field—a small region called the *fovea*—than they are at the edges of the retina (see Fig. 6.1). The fovea is only about 1% of the retina, but the brain's visual cortex devotes about 50% of its area to input from the fovea. Furthermore, foveal cone cells connect 1:1 to the ganglial neuron cells that begin the processing and transmission of visual data, while elsewhere on the retina, *multiple* photoreceptor cells (cones and rods) connect to each ganglion cell. In technical terms, information from the visual periphery is compressed (with data loss) before transmission to the brain, while information from the fovea is not. All of this causes our vision to have much, *much* greater resolution in the center of our visual field than elsewhere (Lindsay and Norman, 1972; Waloszek, 2005).

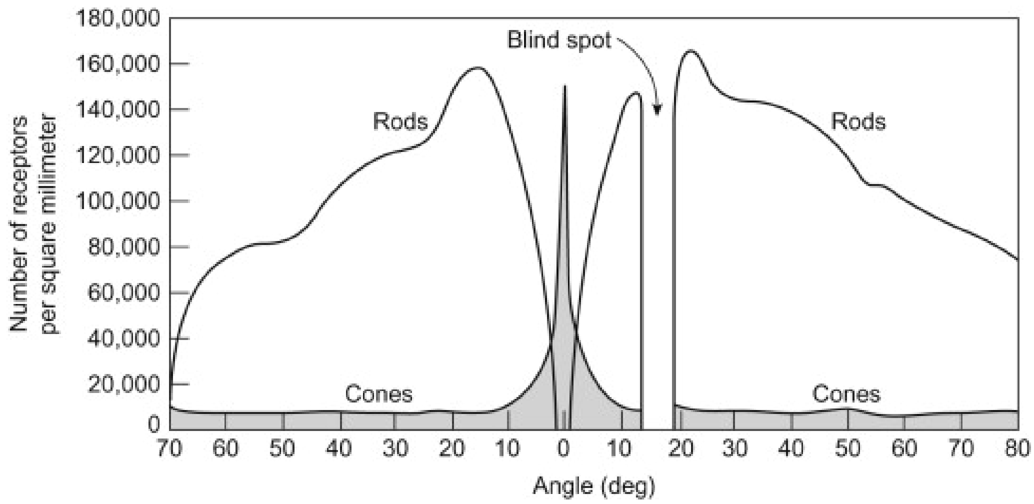

Figure 6.1. Distribution of photoreceptor cells (cones and rods) across the retina.-Lindsay and Norman, 1972.

To visualize how small the fovea is compared to your entire visual field, hold your arm straight out and look at your thumb. Your thumbnail, viewed at arm's length, corresponds approximately to the fovea (Ware, 2008). While you have your eyes focused on the thumbnail, everything else in your visual field falls outside of your fovea on your retina.

In the fovea, people with normal vision have very high resolution: they can resolve several thousand dots within that region—better resolution than many of today's pocket digital cameras. Just outside of the fovea, the resolution is already down to a few dozen dots per inch viewed at arm's length. At the edges of our vision, the "pixels" of our visual system are as large as a melon (or human head) at arm's length (see Fig. 6.2A and B).

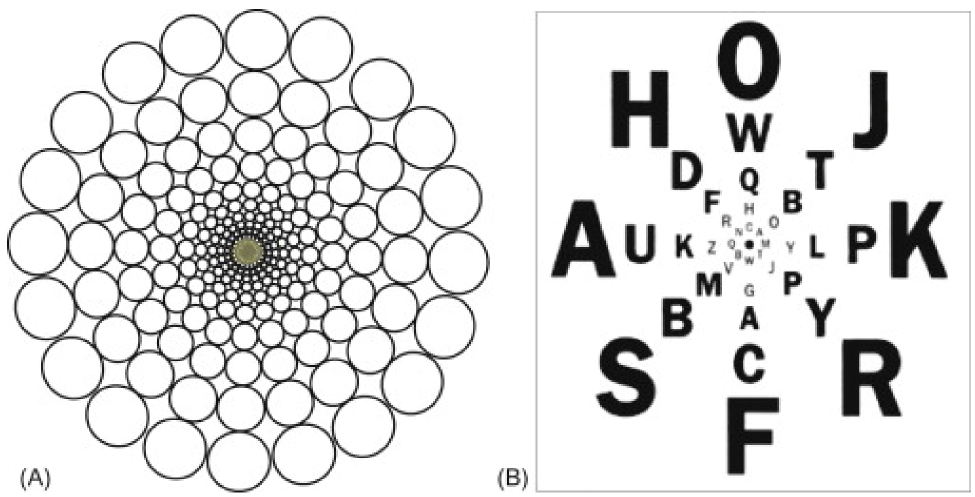

Figure 6.2. The resolution of our visual field is high in the center but much lower at the edges.(B) Image from Vision Research, Vol. 14 (1974), Elsevier.

If our peripheral vision has such low resolution, one might wonder why we don't see the world in a kind of tunnel vision where everything is out of focus except what we are directly looking at now. Instead, we seem to see our surroundings sharply and clearly all around us. We experience this illusion because our eyes move rapidly and constantly about three times per second even when we don't realize it, focusing our fovea on selected pieces of our environment. Our brain fills in the rest in a gross, impressionistic way based upon what we know and expect.[1] Our brain does not have to maintain a high-resolution mental model of our environment because it can order the eyes to sample and resample details in the environment as needed (Clark, 1998).

For example, as you read this page, your eyes dart around, scanning and reading. No matter where on the page your eyes are focused, you have the impression of viewing a complete page of text, because, of course, you are. But now, imagine that you are viewing this page on a computer screen, and the computer is tracking your eye movements and knows where your fovea is on the page. Imagine that wherever you look, the right text for that spot on the page is shown clearly in the small area corresponding to your fovea, but everywhere else on the page, the computer shows random, meaningless text. As your fovea flits around the page, the computer quickly updates each area where your fovea stops to show the correct text there, while the last position of your fovea returns to textual noise. Amazingly, experiments have shown that people *do not notice* this: not only can they read normally, they still believe that they are viewing a full page of meaningful text (Clark, 1998).

Related to this is the fact that the center of our visual field—the fovea and a small area immediately surrounding it—is the only part of our visual field that can read. The rest of our visual field cannot read. What this really means is that the neural networks starting in the fovea, running through the optic nerve to the visual cortex, and then spreading into various parts of our brain, have been trained to read, but the neural networks starting elsewhere in our retinas cannot read. All text that we read comes into our visual system after being scanned by the central area, which means that reading requires a lot of eye movement. Of course, based on what we have already read and our knowledge of the world, our brains can sometimes predict text that the fovea has not yet read (or its meaning), allowing to us skip reading it, but that is different from actually reading.

The fact that retinal cone cells are distributed tightly in and near the fovea, and sparsely in the periphery of the retina affects not only spatial resolution but color resolution as well. We can discriminate colors better in the center of our visual field than at the edges.

Another interesting fact about our visual field is that it has a gap—a small area in which we see nothing. The gap corresponds to the spot on our retina where the optic nerve and blood vessels exit the back of the eye (see Fig. 6.1, above). There are no retinal rod or cone cells at that spot, so when the image of an object in our visual field happens to fall on that part of the retina, we don't see it. We usually don't notice this hole in our vision because our brain fills it in with the surrounding content, like a graphic artist using Photoshop to fill in a blemish on a photograph by copying nearby background pixels.

People sometimes experience the blind spot when they gaze at stars. As you look at one star, a nearby star may disappear briefly into the blind spot until you shift your gaze. You can also observe the gap by trying the exercise in Figure 6.3. Some people have other gaps resulting from imperfections on the retina, retinal damage, or brain strokes that affect the visual cortex, but the optic nerve gap is an imperfection everyone shares.

+ @

Figure 6.3. To "see" the retinal gap, cover your left eye, hold this book near your face, and focus your right eye on the +. Move the book slowly away from you, staying focused on the +. The @ will disappear at some point.

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Exploiting Human Visual Perception in Visualization

ALAN CHALMERS, KIRSTEN CATER, in Visualization Handbook, 2005

41.4 Conclusions

For visualization applications in which the task is known *a priori*, the computational savings made by exploiting visual attention can be dramatic.

Lower-quality peripheral vision and inattentional blindness are fundamental features of the human visual system. We can use these to our advantage to meet the demand for HQ images of increasingly complex content in less time.

High-level *task maps* and low-level *saliency maps* do indeed tell us where an observer will be looking in an image. This knowledge enables us to selectively render those parts attenuated to in high quality while the rest of the images can be rendered in low quality. The time taken to selectively render the image is significantly lower than the time taken to render the whole image in high quality. The key is that when the user is performing a visualization task within the scene, he or she will simply fail to notice this difference in quality.

Visual perception can thus be exploited to significantly lower overall rendering time while maintaining the same perceptual quality of the resultant images. Such perceptually HQ images have the potential to provide powerful real-time visualization tools to a wide range of disciplines, including archaeology.

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Our Peripheral Vision is Poor

Jeff Johnson, in Designing with the Mind in Mind (Third Edition), 2021

Function 3: lets us see better in the dark

A third function of peripheral vision is to allow us to see in low-light conditions—for example, on starlit nights, in caves, around campfires, etc. These were conditions under which vision evolved and in which people—like the animals that preceded them on Earth—spent much of their time until the invention of the electric light bulb in the 1800s.

Just as the rods are less functional in well-lighted conditions (see Chapter 4), the cones don't function very well in low light, so our rods take over. Low-light, rods-only vision is called *scotopic vision*. An interesting fact is that because there are no rods in the fovea, you can see objects better in low-light conditions (e.g., faint stars) if you don't look directly at them.

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What video can and cannot do for collaboration: a case study

Ellen A. Isaacs, John C. Tang, in Readings in Multimedia Computing and Networking, 2002

4.3 Using peripheral cues

We observed many instances during face-to-face meetings in which the participants used their peripheral vision to notice a change in each other's body, head, or eye position and then responded by coordinating their own activity. In our DVC, the video window on the screen was a small part of a participant's visual field. A participant who was not looking at or near that window was much less likely to notice motion in the window. Even large-scale motion on the other end, such as moving an arm to the face, translated into a small change in the remote participants' field of view and could easily be missed if that person was not looking near the video window. Changes in eye gaze were particularly unlikely to be noticed through peripheral vision.

For example, during a 30 s sequence of Jeff and Kate's face-to-face interaction, Jeff w as talking and Kate was looking down as she took notes. Three times, Jeff looked up at Kate for confirmation, and each time, she nodded or replied “Yeah,” without looking up or interrupting her writing. She was obviously able to sense his head position and eye gaze and recognize that he was seeking a response.

We did not see this kind of subtle coordination based on peripheral cues in DVCs. If anything, we saw many instances when the participants just missed each other's glances. [See (Heath and Luff 1991) for a discussion of similar problems.] In one typical example, Jeff glanced at Kate as he finished speaking, but looked away too soon to catch Kate's nod in response. At another point, Jeff missed Kate's smile, so he responded to her comment seriously.

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Autonomous Mobile Robot Navigation based on Wide Angle Vision Sensor with Fovea

Sohta Shimizu, ... Jian-ming Yang, in Human Friendly Mechatronics, 2001

3 Gaze and Tracking based on Combination of Central Vision and Peripheral Vision

Gaze and tracking control of a camera to a human face based on *cooperative* combination of central vision and peripheral vision, each of which has a simple processing method, is proposed. Figure 4 shows a flow chart of the proposed method. In this method, *face area extraction* using *color* (HSV) information in the local central area of the visual field and *person area extraction* using object motion information based on difference images from gray scale images (V) in the whole visual field, are defined as central vision and peripheral vision respectively. Use of WAF lens realizes high accuracy tracking and wide-angle moving object capturing by a single camera. In addition, the object motion information is utilized for *intruder detection* as another peripheral vision. These three kinds of image processing are carried out repeatedly with different processing period by WAFVS (Fig.5). This paper does not describe in more detail each of image processing algorithm characterized by the resolution property of WAF lens, because of limited space. Gaze and tracking is executed under rules in the following.

Figure 4. Flow chart of gaze and tracking

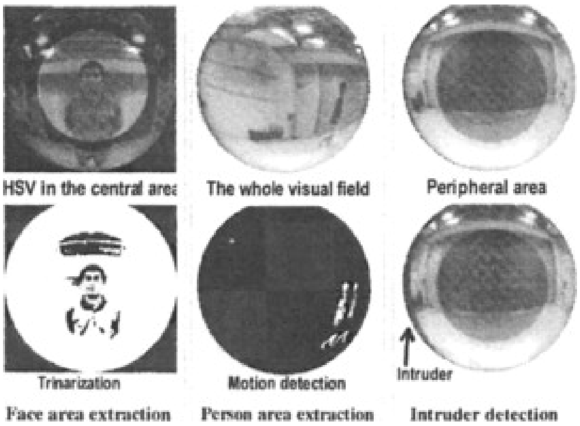

Figure 5. Three kinds of image processing for gaze and tracking

(1) gaze at the extracted face area likely with pursuit, when it exists in the central area

(2) gaze at the extracted person area likely with saccade, when no face area exists

(3) gaze control is not carried out, when neither a face area nor a person area exists

(4) gaze at an intruder is carried out prioriy likely with saccade, when it is detected

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Light, the Retinal Image, and Photoreceptors

Orin Packer, David R. Williams, in The Science of Color (Second Edition), 2003

2.6.4 OFF-AXIS IMAGE QUALITY AND RETINAL SAMPLING

Under normal viewing conditions, foveal vision is protected from aliasing by optical filtering. However, Figure 2.32 shows that the same is not true for peripheral vision because optical bandwidth declines only slowly with increasing eccentricity (Jennings and Charman, 1981; Navarro *et al*, 1993; Williams *et al*, 1996) while the center to center spacing of the cones increases rapidly. At just a few degrees of retinal eccentricity, the Nyquist limit of the cone mosaic (dashed line) drops below the optical cutoff (filled symbols). We have used as an estimate of the optical cutoff, the spatial frequency at which the modulation transfer function drops to 0.10, using the data of Williams *et al.* (1996) for a 3 mm pupil. Energy at spatial frequencies above the Nyquist limit but below the optical cutoff can then produce detectable aliasing under normal viewing conditions (Smith and Cass, 1987; Thibos *et al.*, 1987; Anderson and Hess, 1990; Galvin and Williams, 1992; Artal *et al.*, 1995; Thibos *et al.*, 1996).

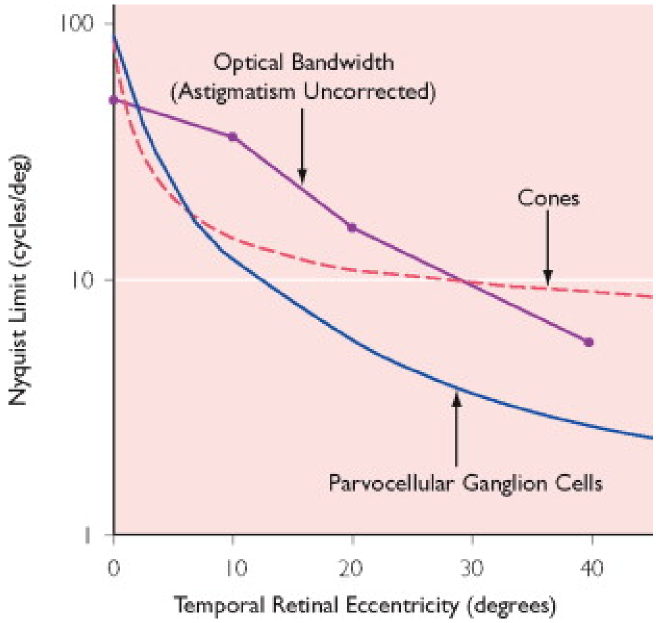

Figure 2.32. The Nyquist limit of the cone and parvocellular ganglion cell mosaics (Curcio *et al.*, 1990; Curcio and Allen, 1990) as a function of retinal eccentricity in degrees. Also plotted is the optical bandwidth as a function of eccentricity from Williams *et al.* (1996: Fig. 6a). The optical bandwidth is taken as the spatial frequency at which modulation transfer has dropped to 0.10. Pupil size was 3 mm and the modulation transfer function was obtained when the eye was focused at the circle of least confusion, without correction for astigmatism. The sampling density of the mosaics falls off much more quickly than the bandwidth of the optics, setting up the possibility of aliasing at eccentricities exceeding a few degrees.

The parvocellular ganglion cell mosaic, which subserves our detailed spatial vision, also samples the retinal image by collecting signals from the cones that make up its receptive fields. The sampling characteristics of the parvocellular ganglion cell mosaic can be estimated from ganglion cell density (Curcio and Allen, 1990) which declines much more rapidly with retinal eccentricity than that of the cone mosaic. This makes the peripheral retina even more susceptible to ganglion cell aliasing than to cone aliasing. Figure 2.32 shows that the Nyquist limit of the parvocellular ganglion cell mosaic (solid line) crosses the optical cutoff at about 2° of eccentricity. At eccentricities exceeding 5°, there is energy in the retinal image at spatial frequencies above the Nyquist limits of both the cone and parvocellular ganglion cell mosaics (Williams *et al.*, 1996).

In spite of these sampling mismatches, peripheral aliasing is not a particularly troubling phenomenon. There are several possible reasons for this. First, although peripheral aliasing can be detected in the laboratory, its salience depends quite strongly on the optical quality of the eye.

Aberrations of the peripheral optics such as oblique astigmatism do reduce the power of those spatial frequencies that would otherwise alias. Additionally, disorder in the cone and ganglion cell sampling arrays (Yellott, 1982, 1983), lateral chromatic aberration (Thibos, 1987), defocus caused by accommodative lag, and the relative lack of high spatial frequencies in natural scenes (Field, 1987; Galvin and Williams, 1992) all combine to minimize the effects of peripheral aliasing on visual experience. In fact, Snyder *et al.* (1986) argue convincingly that evolution should drive the cutoff o f the eye's optics to frequencies higher than the Nyquist limit. This is because the resulting improvement in image contrast at spatial frequencies below the Nyquist limit more than offsets the deleterious effects of any aliasing of spatial frequencies above the Nyquist limit. Along similar lines, it is at least theoretically possible that functional coupling through the gap junctions known to interconnect cones could be used by the visual system to improve sensitivity to lower spatial frequencies without significantly reducing visual resolution or increasing the deleterious effects of aliasing (Hsu *et al.*, 2000).

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Humanoid robot “DB”

Shin’ya Kotosaka, ... Stefan Schaal, in Human Friendly Mechatronics, 2001

3.2 Binocular vision system

Each eye of the robot’s oculomotor system consists of two cameras, a wide angle (100 degrees view-angle horizontally) color camera for peripheral vision, and second camera for foveal vision, providing an narrow-viewed (24 degrees view-angle horizontally) color image. This setup mimics the foveated retinal structure of primates (see Fig.3).The weight of each eye is only around 160 [g] without cables. This feature is essentially required to implement saccades, a very fast mechanism of gaze control (1000 [deg/s] in monkeys and 700 [deg/s] in humans) to change overt visual attention, because saccadic motion with heavy cameras can perturb other body parts such as the head. For visual processing, we are using Fujitsu tracking vision boards in a VxWork-Tomado/VME system, Hitachi image processing boards in the a PC/Linux system, and a QuickMag, a commercial stereo color vision system.

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