NEURAL NETWORK IN NONVERBAL BRAIN - RECOGNIZE HOW AN OBJECT IS VISUALLY POSITIONED IN HUMAN BRAIN

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ABSTRACT

Research is giving much more valuable information about the way the human brain works and how human learn. As we know that our human brain is divided into two halves or hemispheres (Left and Right). The Left brain thinking is verbal (logic, analysis, computation and other functions). Whereas Right brain thing is Non-Verbal (creativity, imaginary, intuition, Visualization and other functions).The objects that are captured by human eyes sight are stored as an image in their brain; in contrast it was stored as binary format in Neural Network. Vision is perhaps the most remarkable of all our intelligent sensing capabilities. Through our visual system, we are able to acquire information about our environment without direct contact. And also gain information at a phenomenal rate and at resolutions that are most impressive. The recognition of visual object is known to be one of the best applications in Artificial Neural Network, which is also partially imitated human thinking in the province of Artificial Intelligence. Neuroscience plays an important role here for explaining brain activities. In this article a simplified neural network approach to recognition of visually stored objects in human brain are depicted and discussed.

Keywords: Artificial Neural Network (ANN), Hemisphere, Non-verbal brain, Neuron, Neuroscience, verbal brain, vision, Visual cortex.

I. INTRODUCTION

Solving the problem of converting light into ideas or images, of visually understanding features and objects in the world is a complex task far beyond the abilities of the world's most powerful computers. Vision requires distilling foreground from background, recognizing objects presented in a wide range of orientations, and accurately interpreting spatial cues. The neural mechanism of visual perception offer rich insight into how the brain handles such computationally complex situations [1]. The recognition of visually positioned image from human brain has been a challenging problem that has received much attention in the fields of neural network, Image processing, Pattern recognition and Artificial Intelligence (AI) [2]. Despite decades of research, scientists have yet to create an Artificial Neural Network (ANN) capable of rivaling the speed and accuracy of the human Visual Cortex. Humans are remarkably good at deciphering handwritten text and spotting familiar faces in a crowd. This ability stems from the Visual Cortex, a dedicated area at the rear of the brain that is used to recognize patterns and images, such as letters, numbers and facial features. This area contains a complex network if neurons that work in parallel to encode visual information, learn spatiotemporal patterns and classify

objects based on prior knowledge or statistical information extracted from patterns [3]. Neuroscience learned a lot about the way the brain processes visual information. During the last twenty years, advertisers have learned to exploit these insights to increase their appeal to the consumer. Conventional wisdom tells us that we have five sensory systems: Vision, Hearing, Tactile (touch), Olfaction (smell) and taste. In fact however, we have many more sensory systems, including heat, cold, proprioception (the sense of the relative position of parts of the

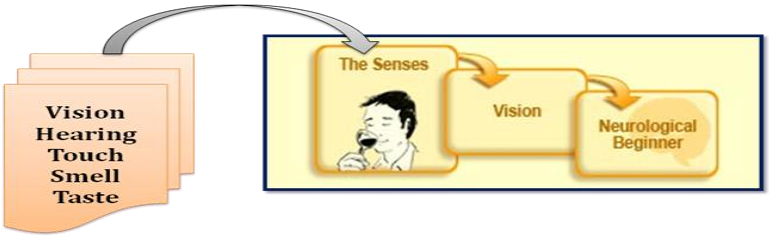

Figure.1 Connection leading from Vision to Brain

body, the vestibular sense (an awareness of body balance and movement) among others. Furthermore, researchers have begun to realize that some senses consist of a combination of two or more sensory systems that get fused together by our experience. For example, "*our experience of vision is the result of two distinct systems that operate concurrently but independently*" [4]. Positioning of an object is the ability to perceive an object's physical properties (such as shape, color and texture) and apply semantic attributes to the object, which includes the understanding of it use, previous experience with the object and how it relates to others [5].

III. VISUAL NETWORK OF HUMAN

Vision is an organic system is the process of sensing a pattern of light energy and developing an interpretation of those patterns. The sensing part of the process consists of selectively gathering light from some area of the environment, focusing and projecting it onto a light sensitive surface, and converting the light into electrochemical pattern of impulses. The perception part of the process involves the transformation and comparison of the transmitted impulse patterns to other pre-stored patterns together with some form of inference [19].

2.1 How Vision Works

Solving the problem of converting light into ideas, of visually understanding features and objects in the world, is a complex task far beyond the abilities of the world's most powerful computers. Vision requires distilling foreground from background, recognizing objects presented in a wide range of orientations, and accurately interpreting spatial cues. The neural mechanisms of visual perception offer rich insight into how the brain handles such computationally complex situations [1].

Visual perception begins as soon as the eye focuses light onto the retina, where it is absorbed by a layer of photoreceptor cells. These cells convert light into electrochemical signals, and are divided into two types, rods and cones, named for their shape. Rod cells are responsible for our night vision, and respond well to dim light. Rods are found mostly in the peripheral regions of the retina, so most people will find that they can see better at night if they focus their gaze just off to the side of whatever they are observing. Cone cells are concentrated in a central region of the retina called the fovea; they are responsible for high acuity tasks like reading, and also for

color vision. Cones can be subcategorized into three types, depending on how they respond to red, green, and blue light. In combination theses three cone types enable us to perceive color [1].

Signals from the photoreceptor cells pass through a network of interneuron's in the second layer of the retina to ganglion cells in the third layer. The neurons in these two retinal layers exhibit complex receptive fields that

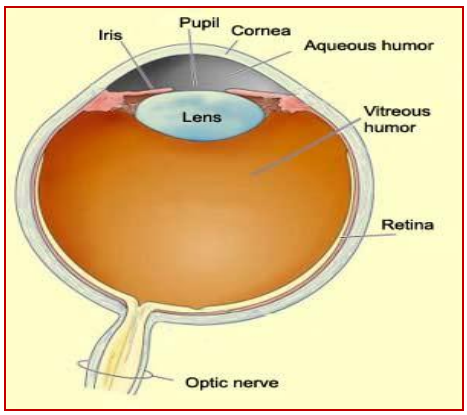

Figure.2 The Human Eye

enable them to detect contrast changes within an image; these changes might indicate edges or shadows. Ganglion cells gather this information along with other information about color, and send their output into the brain through the optic nerve[20].

2.2. Target of the Optic Nerve

The optic nerve, composed of the axons of the retina's ganglion cells, then transmits these impulses from the eye to the first visual relay in the brain. The optic nerve is the pathway that carries the nerve impulses from each eye to the various structures in the brain that analyze these visual signals. The optic nerves of the two eyes emerge from their optics discs and intersect at the 'optic chiasm'. The axons from the nasal side of each retina cross sides in the optic chiasm so that the left half of the field of vision is perceived by the right cerebral hemisphere and vice versa. But because the visual information that reaches the temporal side of each retina comes from the opposite side of the visual filed to begin with, the axons from this side of the retina do not need to cross sides. Instead they proceed straight ahead through the 'optic tract'. The nerve fibers in the optic tract project to the 'Lateral Geniculate Nucleus (LGN)'. The LGN is the main relay in the pathway to the primary visual cortex. The projection from the LGN to the visual cortex is called the 'Optic Radiation' [20].

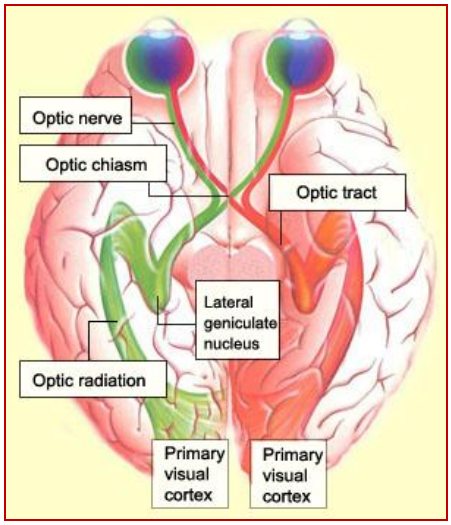

Figure.3 Target of the Optic Nerve

2.3. Visual Cortex

The visual cortex of the brain is the part of the cerebral cortex responsible for processing visual information. The visual cortex is located in the occipital lobe (one of the four major lobes of the cerebral cortex) which is in turn located at the back of the head or skull. The visual cortex is made up of different visual cortex areas like V1 (primary Visual Cortex or Striate Cortex) and V2, V3, V4, and V5 (secondary Visual Cortex or Extrastriate cortex) [21].

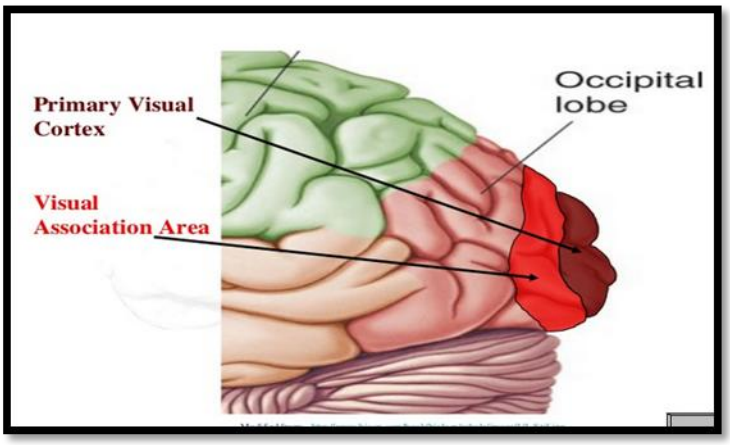

Figure.4 Positing of Visual Cortex

The image captured by each eye is transmitted o the brain by the optic nerve. This nerve terminates on the cells of the Lateral Geniculate Nucleus (LGN) the first relay in the brains visual pathways. The cells of the lateral Geniculate nucleus then project to their main target, the 'Primary Visual Cortex'. It is in the primary visual cortex (V1) that the brain begins to reconstitute the image form the receptive fields of the cells of the retina. The primary visual cortex is also known as 'Striate Cortex' and this is located in the most posterior portion of the brain's occipital lobe. In fact, a large part of the primary visual cortex cannot be seen from the outside of the brain, because this cortex lies on either side of te calcarine fissure. The primary visual cortex also corresponds to Area 17 described by the anatomist Brodmann in the early 20th century. The primary visual cortex sends a large

proportion of its connections to the 'Secondary Visual Cortex' (V2), which consists of Brodmann's areas 18 and 10. Though, most of the neurons in the secondary visual cortex have properties similar to those of the neurons in the primary visual cortex [20].

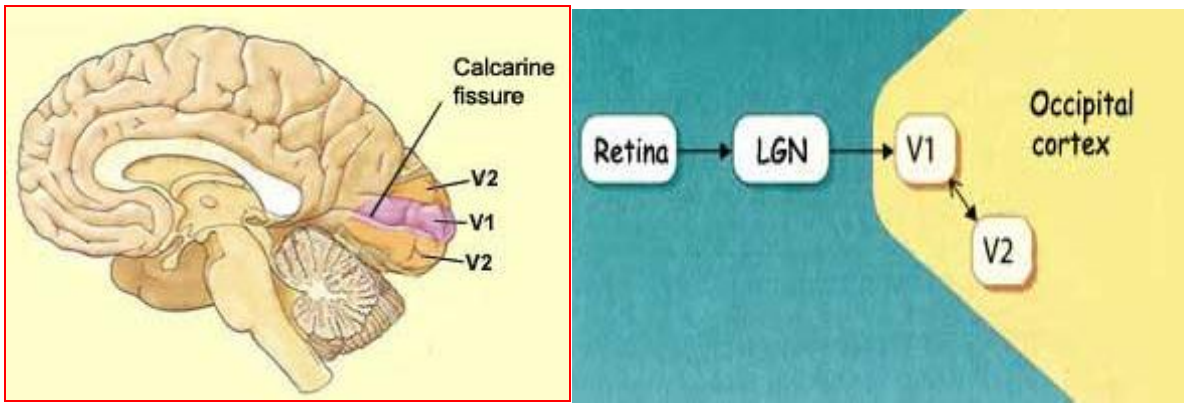

Figure.5 Various Visual cortexes (V1, V2) of Occipital Lobe

2.4. Ventral and Dorsal System

This section addresses the Ventral and Dorsal model of the visual cortex. Each V1 transmits information to two primary pathways, called the Ventral stream and the Dorsal stream [23]. The analysis of visual stimuli begins in V1 and V2 and continues through two major cortical systems for processing visual information. The first is the Ventral pathway, which extends to the temporal lobe and is thought to be involved in 'recognizing objects'. The second is the Dorsal Pathway, which projects to the parietal lobe and appears to be essential for 'locating objects '[20].

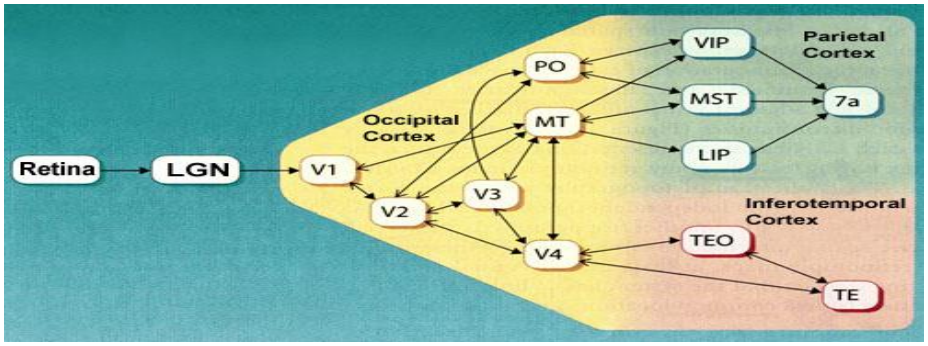

Figure. 6 Ventral and Dorsal processing stream in human visual cortex

2.4.1. Ventral Stream (Recognizing Objects)

The Ventral Stream begins with V1, goes through visual area V2, then through visual area V4 and to the inferior temporal cortex. The ventral stream sometimes called the "What Pathway" is associated with form recognition and object representation. It is also associated with storage of long-term memory [23].

2.4.2. Dorsal Stream (Locating Objects)

The dorsal stream begins with V1, goes through Visual area V2, then to the dorsomedial area (DM/V6) and Visual area MT(Middle Temporal/V5) and to the posterior parietal cortex. The dorsal stream, sometimes called the "Where Pathway" or "How Pathway", is associated with motion, representation of objects locations, and control of the eyes and arms, especially when visual information is used to guide saccades or reaching [23].

2.5. Visual System: From Retina to Dorsal pathway in Occipital lobe

In the second half of the 19th century, many motifs of the nervous system were identified such as the neuron doctrine and brain localization in the brain, respectively. These would become tenets of the fledgling neuroscience and would support further understanding of the visual system. The notion that the cerebral cortex is divided into functionally distinct cortices now known to be responsible for capacities such as touch (somatosensory cortex), movement (motor cortex) and vision (visual cortex) was first proposed by Franz Joseph Gall in 1810. David Ferrier proposed that visual function was localized to the parietal lobe of the brain in 1876. In 1881, Hermann Munk more accurately located vision in the Occipital lobe, where the Primary Visual Cortex is now known to be [24].

The visual system is the part of the central nervous system which gives organisms the ability to process visual detail, as well as enabling the formation of several non-image photo response functions. It detects and interprets information from visible light to build a representation of the surrounding environment. The visual system carries out a number of complex tasks, including the reception of light and the formation of monocular representations; the buildup of a nuclear binocular perception from a pair of two dimensional projections; the identification and categorization of visual objects; assessing distances to and between objects; and guiding body movements in relation to the objects seen.

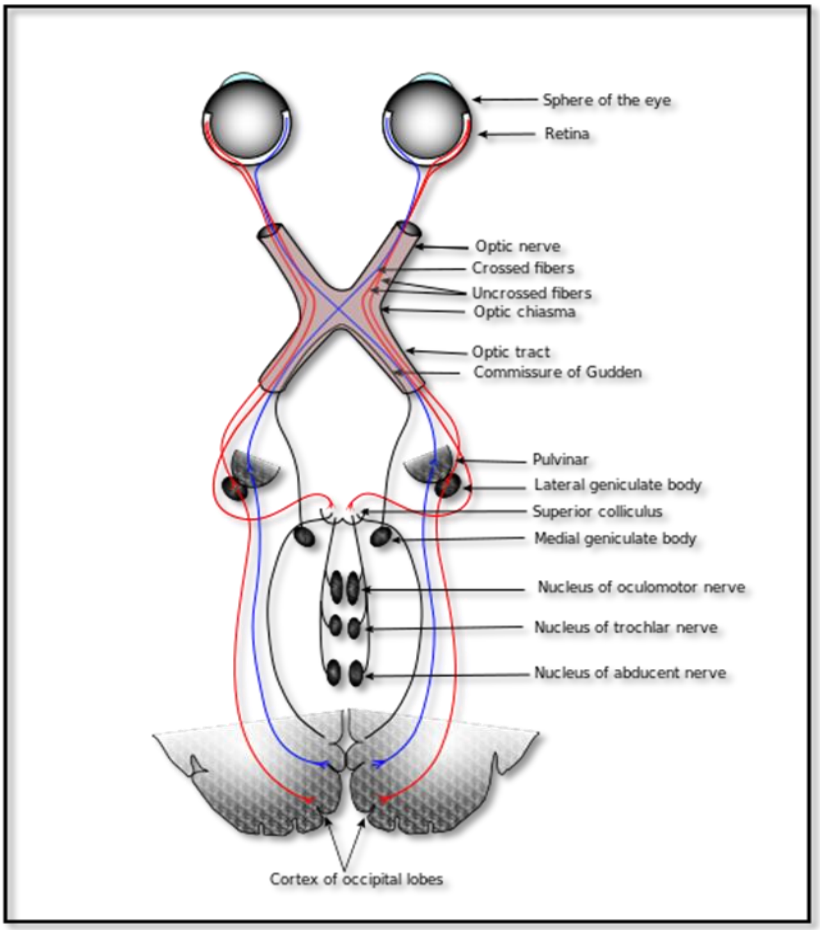

Figure.7 The visual system includes the eyes, the connecting pathways through to the visual cortex and other parts of the brain.

III. NEURAL NETWORK OF THE HUMAN BRAIN

In recent years, it has become clear that an understanding of the brain's neural networks is a critical requirement for understanding normal brain function. In addition, an understanding of how neural networks are altered in Central Nervous System (CNS) is yielding improved insights on the mechanism of converting from eye sight vision to brain understandable image [8].

3.1. Brain Structure and their Functions

The brain is the structural and functional properties of interconnected neurons [18]. How does the brain work? What does it actually do? These questions have fascinated and challenged countless on human beings over many centuries. At last, however, we now have the expertise to tackle what might arguably be regarded as the final frontier in human understanding. Normal mental activities were not associated at all with the brain, changed with a great discovery made by Alcmaeon of Croton. *"Alcmaeon showed that there were actual connections leading from the eyes to the brain"*. Surely, he claimed, this are must be the seat of thought [6]. The brain is one of the largest and most complex organs in the human body. It is made up of more than 100 billion nerves that communicate in trillions of connections called synapses [9]. The nervous system is your body's decision and communication center.

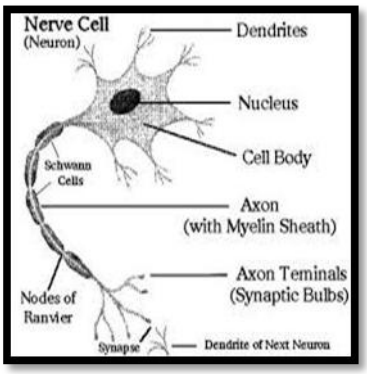

Figure.8 Body of the Nerve Cell of Neuron

The Central Nervous System (CNS) is made of the brain and the spinal cord and the Peripheral Nervous System (PNS) is made up of nerves. Together they control every part of your daily life, from breathing and blinking to helping you memorize facts for a test. Nerves reach from your brain to your face, ears, eyes, nose and spinal cord and from the spinal cord to the rest of your body. Sensory nerves gather information from the environment; send that information to the spinal cord, which then speed the message to the brain. The brain then makes sense of that message and fires off a response. Motor neurons deliver the instructions from the brain to the rest of your body. The spinal cord, made of a bundle of nerves running up and down the spine, is similar to a superhighway, speeding messages to and from the brain at every second [11].

The brain is made of three main parts: the forebrain, midbrain, and hindbrain. The forebrain consists of the cerebrum or cortex, thalamus, and hypothalamus (part of the limbic system). The midbrain consists of the tectum and tegmentum. The hindbrain is made of the cerebellum, Pons and medulla. Often the midbrain, Pons, and medulla are referred to together as the brainstem.

The Cerebrum: The Cerebrum or Cerebral cortex or Cortex is the largest part of the human brain, associated with higher brain function such as thought and action. The cerebral cortex is divided into four sections, called "lobes": the frontal lobe, parietal lobe, occipital lobe, and temporal lobe. Here is a visual representation of the brain anatomy and lobes of the Cerebral cortex [11]:

- Frontal Lobe- associated with reasoning, planning, parts of speech, movement, emotions, and problem solving
- Parietal Lobe- associated with movement, orientation, recognition, perception of stimuli
- Occipital Lobe- associated with visual processing. It encompasses the posterior portion of the human cerebral cortex and is primarily responsible for vision. The surface area of human occipital lobe is approximately 12% of the total surface area of the neocortex of the brain. Direct electrical stimulation of the occipital lobe produces visual sensations. Damage to the occipital lobe results in complex or partial blindness or visual agnosia depending on the location and severity of the damage [14].
- Temporal Lobe- associated with perception and recognition of auditory stimuli, memory, and speech

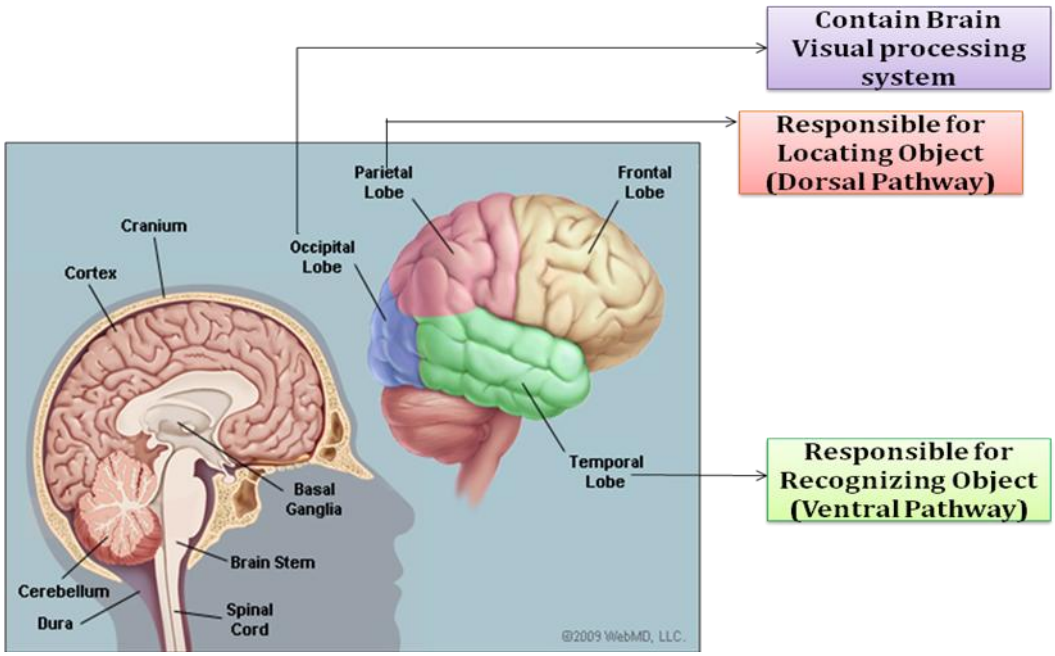

Figure.9 Brain anatomy and Lobes of the Cerebral Cortex

Neocortex: It occupies bulk of the cerebrum. This is the six layered structured of the cerebral cortex and only found in mammals [11]. This is responsible for integrating intellectual data. This is the most recent part of the brain. It appears in rudimentary form in the lower mammals and reaches full development in humans. It occupies 85 percent of the volume of the brain and is made up of more than ten billion neurons (nerve cells) and each having more than one hundred thousand connections with other neurons. It has three important functions: Memory storage, Thinking and Reasoning and sensory perception and motor control [12].

The Cerebellum: The cerebellum, or "little brain", is similar to the cerebrum in that it has two hemispheres and has a highly folded surface or cortex. This structure is associated with regulation and coordination of movement, posture, and balance. The cerebellum is assumed to be much older than the cerebrum [11]. Limbic System: The

limbic system, often referred to as the "emotional brain", is found buried within the cerebrum. This system contains the thalamus, hypothalamus, amygdala, and hippocampus [11].Brain Stem: Underneath the limbic system is the brain stem. This structure is responsible for basic vital life functions such as breathing, heartbeat, and blood pressure. Scientists say that this is the "simplest" part of human brains because entire animals' brains, such as reptiles resemble our brain stem [11].

The brain naturally associates one thing with another. It can access information based on contents rather than on sequential addresses as in the digital computer. The associative or content-addressable memory accounts for fast information retrieval and permits partial or approximate matching. The brain seems to be good at managing fuzzy information because of the way its knowledge is represented [7].

3.1.1. Brain Hemispheres

The human brain is made up of two halves. These halves are commonly called the Right Brain and the Left Brain, but should more correctly be named as 'Hemispheres'. For some reason, our right and left hemisphere control the opposite side of our bodies. So the right hemisphere controls our left side and processes what we see in our left eye while the left hemisphere controls right side and processes what our right eye sees. The concept of right and left brain talk was developed from the research in the late 1960 by an American psycho-biologist Roger W. Sperry. He discovered that the human brain has two very different ways of thinking. One(the right brain) is visual and processes information in an intuitive and simultaneous way, looking first at the whole picture then the details. The left brain is verbal and process information in an analytical and sequential way, looking first at the pieces then putting them together to get the whole [10].

3.1.2. Left Brain (Vs) Right Brain

In general, the left and the right hemispheres of our brain process information in different ways. In our everyday lives, we have natural tendency towards one way of thinking, the two sides of our brain work together. The right brain thinking is non-verbal and focuses on the visual portion, and processes information in an intuitive and simultaneous way, and looking first at the whole picture then the details. The left brain thinking is verbal and analytical, and processing information in an analytical and sequential way, looking first at the pieces then putting them together to get the whole [10].

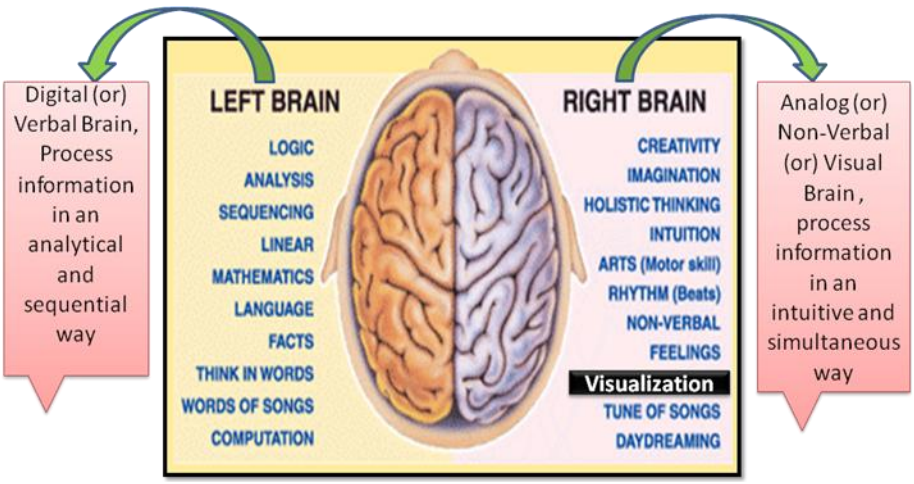

Figure.10 Basic characteristic of Left and Right Brain

These hemispheres communicate with each other through a large bundle of nerve fibers called the corpus callosum, and through several smaller nerve pathways. The right side of the brain more visual oriented, involved in activities such visual imaginary and face recognition. And this side of the brain is involved in special abilities, such as judging the position of things in space and knowing your body position. The lift side of the brain process information logically or sequentially. The left side of the brain is dominant in understanding and using languages, including listening, reading, speaking and writing [13].

3.2. Neural Networks

Neurons are cells within in the nervous system that transmit information to other nerve cell (see fig.2 and 6), muscle or gland cells. Most neurons have a cell body, an axon and dendrites. The cell body contains the nucles and cytoplasm. The axon extends from the cell body and often gives rise to many smaller branches before ending at nerve terminals. Dendrites extend from the neuron cell body and receive messages from other neurons. Synapses are the contact points where one neuron communicates with another. The dendrites are covered with synapses formed by the ends of axons from other neurons [18]. In the brain nerve cells never work alone. In a neural circuit, the activity of one cell directly influences many others. To gain insight into how these interactions control brain function, researchers are exploring the connections between nerve cells and how they change over time. This insight could lead scientist to a better understanding of how the nerve system develops and the ways disease or injury disrupts the natural rhythms of brain cell communication [15].

3.2.1. The Biological and Artificial Neuron

The basic computational unit of the brain is a 'neuron'. Approximately 86 billion neurons can be found in the human nervous system and they are connected with approximately 10^14 – 10^15 synapses [16]. In neuroscience, a biological neural network is a series of interconnected neurons whose activation defines a recognizable linear pathway [22].

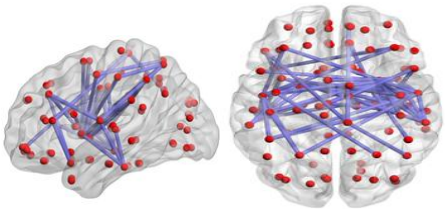

Figure.11 An example of Neural Network in Human Brain

The neural system of human body consists of three stages: Receptors, a neural network, and effectors. The following figure shows the bidirectional communication between stages.

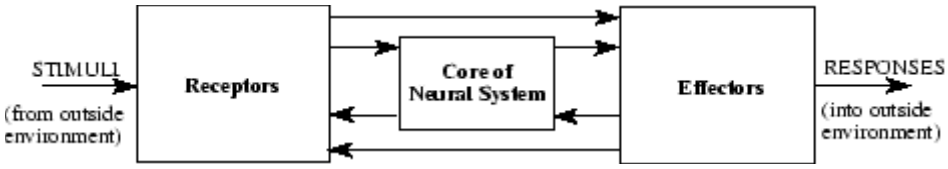

Figure.12 Three Stages of Biological Neural System

The receptors receive the stimuli either internally or from the external world, and then pass the information into the neurons in a form of electrical impulses. The neural network then processes the inputs then makes proper decision of outputs. Finally, the effectors translate electrical impulses from the neural network into responses to

the outside environment [17]. The fig.6 below shows a cartoon drawing of a biological neuron and a common mathematical model. Biological neurons transmit electrochemical signals over neural pathways. Each neuron receives input signals from its dendrites and produces output signals along its axon. The axon eventually branches out and connects via synapses to dendrites of other neurons.

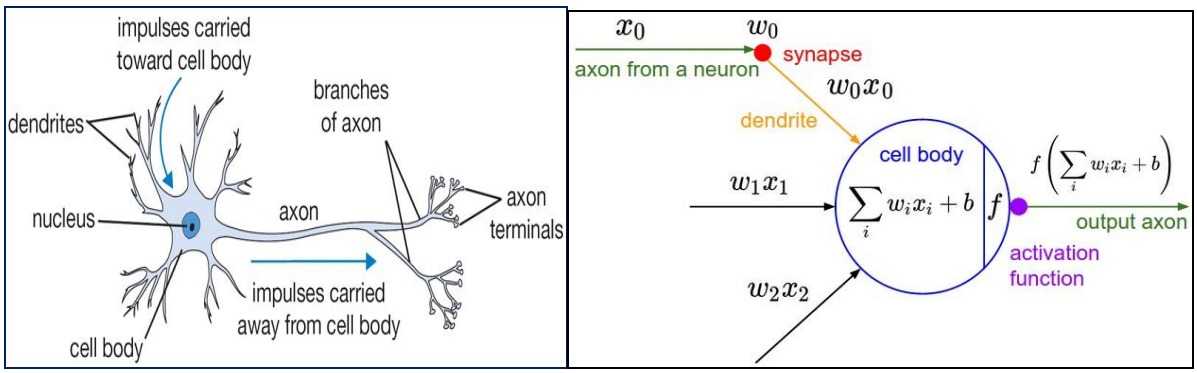

Figure.13 The Biological neuron (left) and its mathematical model (right)

An artificial neuron models these simple biological characteristics. Each artificial neuron receives a set of inputs. Each input is multiplied by a weight analogous to a synaptic strength. The sum of all weighted inputs determines the degree of firing called the activation level [7].In the computational model of a neuron, the signals that travel along the axons (e.g. x0) interact multiplicatively (e.g. w0x0) with the dendrites of the other neuron based on the synaptic strength at that synapse (e.g. w0). The idea is that the synaptic strengths (the weights w) are learnable and control the strength of influence (and its direction: excitory (positive weight) or inhibitory (negative weight)) of one neuron on another. In the basic model, the dendrites carry the signal to the cell body where they all get summed. If the final sum is above a certain threshold, the neuron can *fire*, sending a spike along its axon. In the computational model, we assume that the precise timings of the spikes do not matter, and that only the frequency of the firing communicates information. Based on this *rate code* interpretation, we model the *firing rate* of the neuron with an **activation function** f, which represents the frequency of the spikes along the axon. Historically, a common choice of activation function is the **sigmoid function** σ, since it takes a real-valued input (the signal strength after the sum) and squashes it to range between 0 and 1 [16].

IV. VISUALLY POSITIONING AN OBJECT IN HUMAN BRAIN AND IN NEURAL NETWORK

In fig.14 it was depicted that how an object is visually positioned or located from eye to the connecting pathways through to the visual cortex and other parts of the brain. The same process was depicted in neural network with the help image recognition technology in section 4.1.

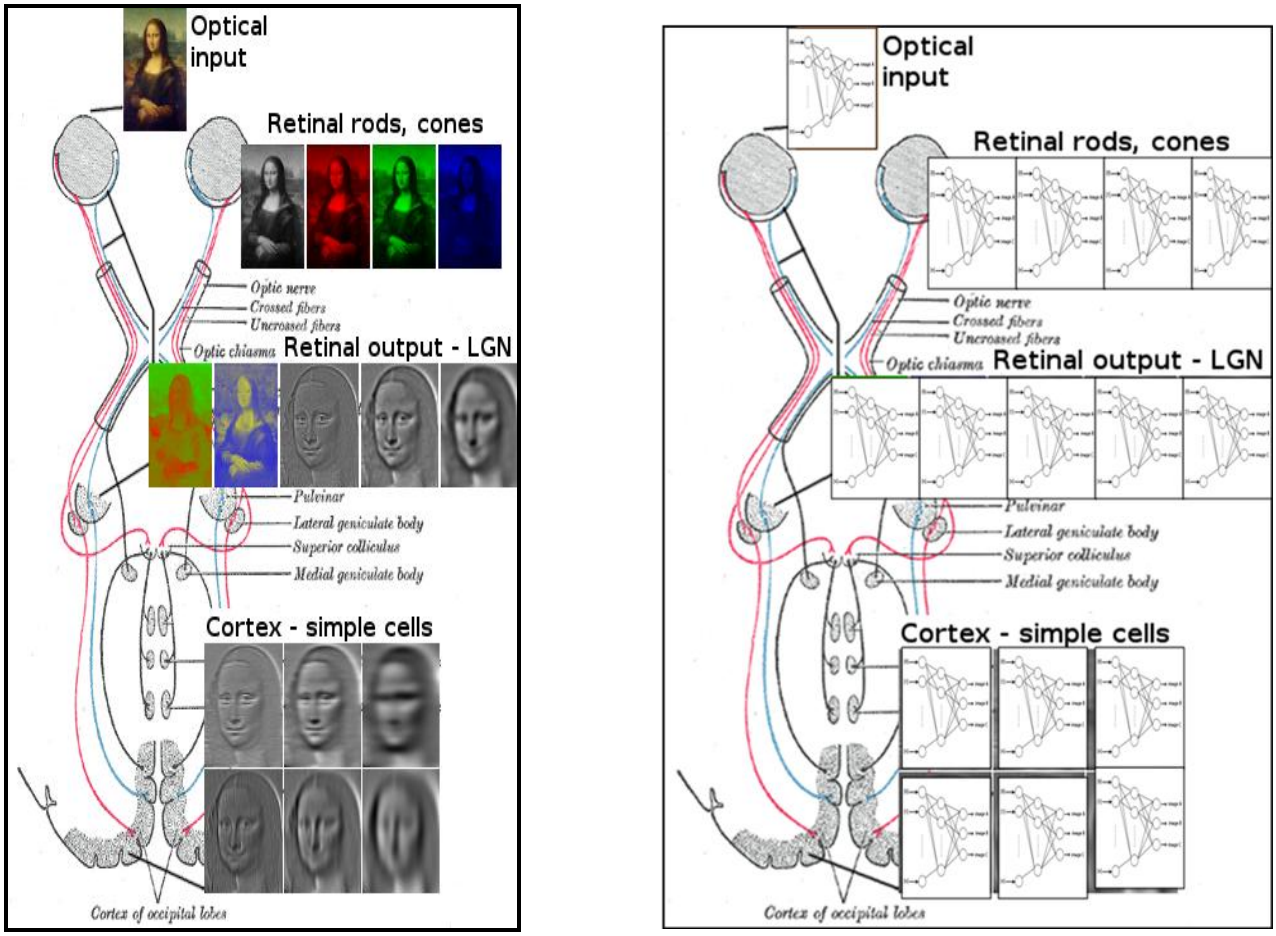

Figure. 14 Visually positing an object in Human Brain and in Neural Network

4.1. Visually positing of an object in Neural Network through Image Recognition with Multi Layer Perceptron

Neural network are one technique which can used for image recognition. Every image can be represented as two-dimensional array, where every element of that array contains color information for one pixel. The example is as follow:

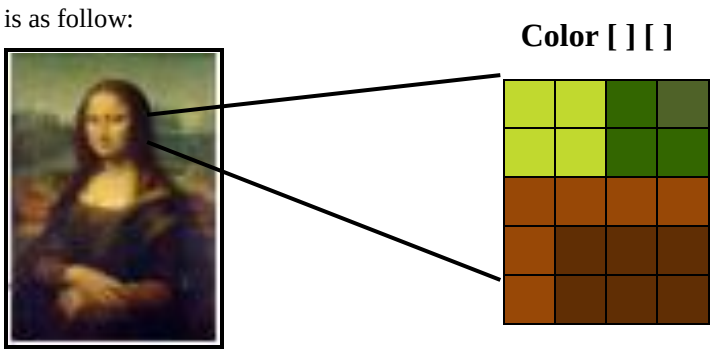

Figure . 15 Image Colors

Each color can be represented as a combination of three basic color components: Red, Green, Blue.

Figure. 16 RGB color system

So, to represent some image in a RGB system we can use three two-dimensional arrays, one for each color components, where every element corresponds to one image pixel. int[ ][ ] revalues; int[ ] [ ] greenvalues; int [ ] [ ] bluevalues. for example, if pixel a location[20, 10] has color RGB[33, 66,181] we have redvalues[10][20] =33; greenvalues[10][20] =66; bluevalues[10][20]=181. The dimensions of each of these arrays are [imageHeight * imageWidth * 3]. We can merge these three arrays into a single one-dimensional array so it contains all red values, then all green and at the end all blue values. That's the RGBvalues [n] = height * width * 3. Now we can use this one-dimensional array as input for neural network, and to train neural network to recognize or classify them. Multilayer perceptrons are type of neural network suitable for this task. Image recognition can be done in full color mode or in binary black and white mode. Te binary black and white mode represents pixel as [0,1] and so it uses less number of input neurons. For some application like 'Character Recognition' binary black and white mode may be optimal solution [25].

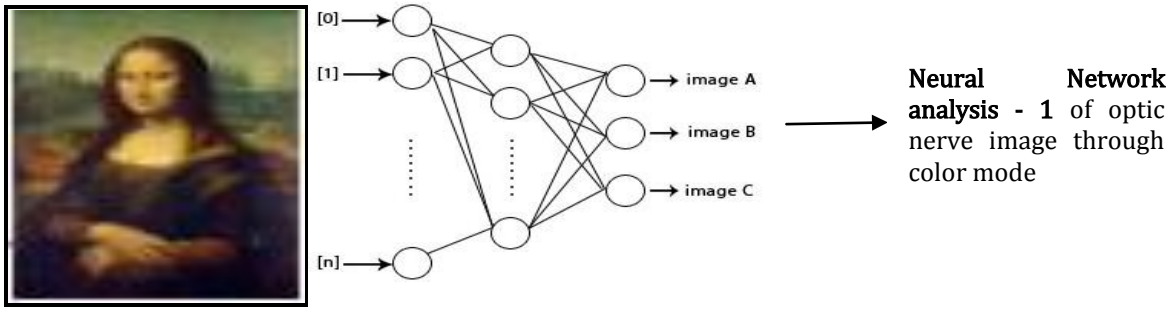

Figure. 17 RGBvalues [n] :where n = height * width * 3 and Neural network architecture

Each input neuron corresponds to one color components (RGB) of one image pixel at a specific location. Each output neuron corresponds to one or image class. So if network output is [1,0,0] that means that input is recognized as 'image A'.

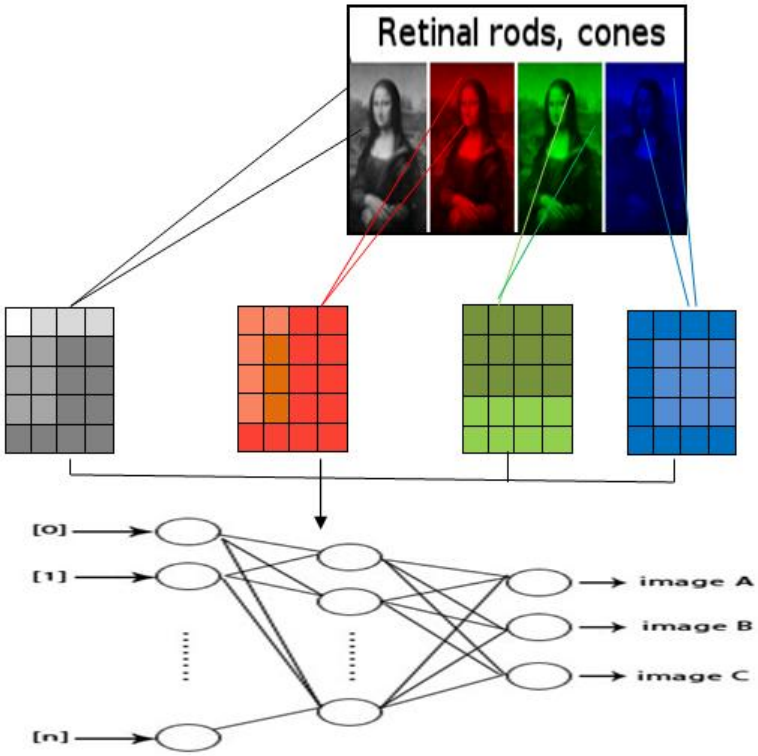

Figure.18 Neural Network analysis - 2 of Retinal rods, cones image through Black and White mode and color mode

we have already discussed the black and white mode and color mode in Neural Network analysis-2 , so no need of discuss in Retinal output LGN. So move on to cortex simple cell

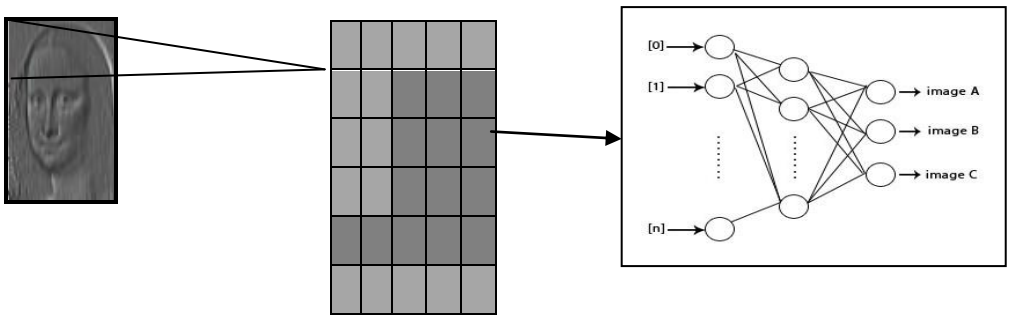

Figure. 19 Neural Network analysis - 3 of Cortex simple cell image through Black and White mode

4.2. Perceptrons

Perceptrons mimic the basic idea behind the mammalian visual system. They were mainly used in pattern recognition even though their capabilities extended a lot more. The term Perceptron was coined by Frank Rosenblatt and turns out to be an (McCulloch and Pitts) MCP model (neuron with weighted inputs) with some additional, fixed, pre-processing. Units labeled A1, A2, Aj, Ap are called association units and their task is to extract specific, localized featured from the input images [27].

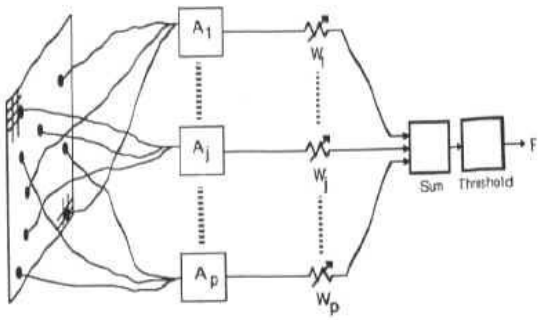

Figure. 20 Perceptron Model

V. REAL TIME APPLICATIONS

There is lot of applications supporting visual positioning of an object in human brain, but the best suitable one is "Advertising and Marketing Media". In the business world today, the printed word reign supreme. Ideas projects and marketing programs are all spelled out in a blizzard of words. When it comes to executing a marketing program, no wonder business executives focus on the words alone. Words are what they use the mist and are most familiar with. Yet there is a lot of evidence that visuals play a far more important role in marketing than do words [26]. Neuroscience has learned a lot about the way that the brain processes visual information. During the last twenty years, advertisers have learned to exploit these insights to increase their appeal to the consumer. You can like or dislike theses techniques. You can find them annoying or even exploitive. But they are also effective at grabbing our attention and we in the learning community should be aware of them [20]. In today global economy, a strong visual positing is a particularly valuable asset. Unlike a verbal idea, a visual positing can cross International border with no translations necessary. In essence, it's a rebus, a visual symbol that is a substitute for a brand name. Laura Ries a leading brand strategist, briefly explained in her book Visual Hammer about how we can reach human brain through non-verbally. For example: Monster entered the energy-drink market by positioning itself as the opposite of Red Bull. Monster also made a good visual choice. Claw marks in the shape of an "M" send a subtle message of 'strength' and 'danger' in a simple and effective way. As a result, you remember the Monster visual [26].

Figure.21 Visual of Monster energy drink

VI. CONCLUSION

Humans have several orders of magnitude visual resolution than a TV and the more remarkable ease is human's sense and perceives a variety of visual images. In this research paper an easy way of understanding approach for positing of visual object in human non-verbal or right brain using Neural Network has been described. The

advantages of visual positing in brain over Advertising and Marketing media have been outlined. In future it will become increasingly important to study the interconnectivity of the ventral and dorsal streams and how they influence each other throughout development.

REFERENCES

[1] http://www.brainhq.com/brain-resources/brain-facts-myths/how-vision-works

[2] Shashank Araokar, Visual Character Recognition using Artificial Neural Networks, Computing Research Repository(CoRR), abs/cs/0505016, 2005.

[3] http://phys.org/news/2014-07-neural-networks-function-human-visual.html

[4] http://www.learningsolutionsmag.com/articles/1486/brain-science-the-visual-system-and-learning

[5] https://en.wikipedia.org/wiki/Cognitive_neuroscience_of_visual_object_recognition#mw-head

[6] Susan Greenfield, *The Human Brain: A Guide Tour* (Hachette UK, 2014).

[7] LiMin Fu, *Neural Networks in Computer Intelligence* (Tata McGraw Hill, 2003).

[8] Carl Faingold, Hal Blumenfeld, *Neuronal Networks in Brain Function, CNS Disorders, Therapeutics* (Academic Press, 2013).

[9] http://www.webmd.com/brain/picture-of-the-brain

[10] http://www.ucmas.ca/our-programs/whole-brain-development/left-brain-vs-right-brain/

[11] http://serendip.brynmawr.edu/bb/kinser/Structure1.html

[12] Madeleine Turgeon, N.D., Right Brain-Left Brain Reflexology (Inner Traditions International,1998)

[13] http://www.kidport.com/reflib/science/HumanBody/NervousSystem/BrainHemispheres.htm #BrainHemispheres

[14] Kalanit Grill-Spector. in the Encylopedia of Neurological Sciences, Editords Aminoff, M. Daroff, R., Academic Press, 2003, 1-7.

[15] http://www.brainfacts.org/brain-basics/neural-network-function/

[16] http://cs231n.github.io/neural-networks-1/

[17] http://osp.mans.edu.eg/rehan/ann/2_2%20Biological%20Neural%20Networks.htm

[18] http://www.brainfacts.org/brain-basics/neuroanatomy/articles/2012/the-neuron/

[19] Dan W.Patterson, Introduction to Artificial Intelligence and Expert Systems (Prentice Hall of India Private Limited, 1990).

[20] http://thebrain.mcgill.ca/flash/d/d_02/d_02_cr/d_02_cr_vis/d_02_cr_vis.html#2

[21] https://en.wikipedia.org/wiki/Visual_cortex#Visual_cortex

[22] https://en.wikipedia.org/wiki/Biological_neural_network#mw-head

[23] https://en.wikipedia.org/wiki/Visual_cortex#Visual_cortex

[24] https://en.wikipedia.org/wiki/Visual_system

[25] http://neuroph.sourceforge.net/image_recognition.html

[26] Laura Ries, Visual Hammer (Kindle, 2012)

[27] http://www.doc.ic.ac.uk/~nd/surprise_96/journal/vol4/cs11/report.html