Mechanical Engineering Research; Vol. 10, No. 1; 2022
ISSN 1927-0607 E-ISSN 1927-0615
Published by Canadian Center of Science and Education

Processing Structures for Computer Simulation of Human Movement

Hooshang Hemami[1]

[1] Retired, The Ohio State University, USA

Correspondence: Hooshang Hemami, The Ohio State University, USA. E-mail: hooshanghosu@gmail.com

Received: April 15, 2022 Accepted: June 3, 2022 Online Published: June 11, 2022

doi:10.5539/mer.v10n1p1 URL: https://doi.org/10.5539/mer.v10n1p1

Abstract

Based on the dynamics, structure and properties of imbedded multi-stack systems, certain functions of the central nervous system (CNS) can be modeled and computer programmed. These models imitate the natural system at some level and can be integrated in future more comprehensive models of the CNS in studies of human movement. Several CNS functions are discussed here. The involvement of the reticular formation (RF) in identifying objects and their properties by touch is addressed. The vision system is discussed in sensing and storage of planar images. The creation of periodic motions for dance or sport is modeled. Mental processing in is the writing or drawing of images is formulated.

The touch problem addressed here is the mechanisms to explore, probe, grope and identify an object that is not visible. The object of enquiry may be part of another object, lie under another object or be part of a bigger thing. It may also be involved in the early dynamics of touch in the new-born where the vision dynamics have not yet fully developed.

How the central nervous system (CNS) may pursue these tasks is one objective. One elementary attempt is to develop larger structures that can handle CNS functions, how thoughts are formulated, expanded, summarized or abandoned. Multiple Stack System seem to be convenient for handling information flowing from the sensory channels to the cerebrum and the cerebellum. By considering specific tasks, the paper focuses on several functions, connections, and structures that are involved in movement.

Keywords: tactile exploration, reticular formation, Purkinjie cells, multiple stack structures, learning, creative images.

1. Introduction

Many functioning of CNS neural structures can be described by multi-dimensional stacks that are computer programmable. a number of different CNS functions are presented here to illustrate this behavior, The reticular formation has many activities (Angevine & Cotman, 1981), Chapter 11, involved with human movement. Conceptually, it can duplicate the vision system in tactual sensing.

Seams or wedges, embedded in surfaces, but unseen by the eyes are to be explored or identified. The conceptual issues for tactually guided exploration and shape perception are presented in detail in (Hemami, Bay, & Goddard, 1988). The neural networks for simulating the human reach-grasp coordination are addressed in (Ulloc & Bullock, 2003). The dynamics of touch and the role of fingers are considered by (Kandel, Schwarrtz, & Jessell, 1991).

Two other areas that relate to touch are mechanically constrained systems where known objects are held, manipulated or released (Hemami & Wyman, 1979); and reaching an object (Tomovic, Popovic, & Stein, 1991). Touch is more complex than vision because it involves more complex motor control by guiding the fingers or the palm of the hand on the object and stay in touch with the object. It can happen that the contact with the object gets distorted and the fingers lose touch with the object. In this situation, the machinery of maintenance of touch must be abandoned. A second movement involving search for the object must be initiated with its own mechanisms for search and coverage of potential areas. Therefore the effort involves interruption of movement and resumption of the original movement once the object is recovered, i.e., new contact is established. This methodology of touch may be involved in newly born. Philosophical issues arise about the strategies of unconscious and conscious learning, the role of the Purkinjie cells - in thought processes - a new thought or abandoning an older thought. Creative thought processes involving imagination, etc. are another example.

A second objective may be the identification of size, shape and other attributes of an object. This effort may involve the fingers and the palm and modeling of the skin and tissues. Presumably, the fingers must glide smoothly without exerting too much force on the object. Better understanding of receptor-laden skin and tissue is desirable. Stacks (Robert, 2022) may be a useful mechanism for this purpose. When multi-fingers are in touch with the object. simultaneous control of all the contact forces is another objective. The strategy of search is initiated by the CNS and learning, experience and circumstances are involved. This issue is worth an independent exploration and is not further pursued here (Robert, 2022; Bay & Hemami, 1987). Other stacks seem to function in the CNS. In the brain one can envision stacks that are involved in the creative processes of writing, drawing, etc. These CNS stacks do not seem to have elaborate stability and functional processes of the RF. For this reason, one may explore some of the functions of the stacks involved in creative work. These upper level stacks can also be very complex. Imagining three-dimensional dance movements and imagined motions that do not exist in reality would be challenging stack processes that are beyond knowledge at this time. A simple two-dimensional stack involved in creative drawing is a structure that perhaps can illustrate some of the structure and functions involved in mental drawing of figures.

In what follows, the reticular formation and certain of its functions involved in touching and movement are addressed Section 2. Visual Perception of a Planar Object is presented in Section 3. CNS Learning by trial and error, as applied to certain sports and creation of repeating oscillatory patterns are addressed in Section 4. Creative Writing and Drawing Efforts are addressed in Section 5. Discussion and Conclusions are presented in Section 6.

2. The Reticular Formation and Functions

The RF is involved in many functions of humans and animals (Angevine & Cotman, 1981; Role & Kelly, 1991; Shepherd, 1979). The primary communication channel of the RF with the rest of the body is by the dozen Cranial nerves. A brief list of their functions are summarized here:

- Sense of smell (Garoutte, 1981), page 188,
- Optical nerve (Garoutte, 1981), Chapter 8,
- Movement of the Eyes,
- Facial sensation and proprioception for chewing,
- Lateral eye movements,
- Motor mechanisms for facial expression and sensory machinery for tongue and saliva,
- Vestibulo-Cochreal nerve in equilibrium and hearing,
- Motor in swallowing,
- Vagus: somatic sensation and motor for Pharynx and Larynx,
- Motor for Sternomastoid and upper trapetios muscles,
- Motor machinery for the tongue.

The sensations for the face could come from touches to the face, unseen by the eyes. Insects could be in motion, or the wind may be blowing. More pleasant libidinal events such as touches or kisses could be involved (Angevine & Cotman, 1981), Chapter 12. The limbic system is involved in visceral functions that are "central to emotional expression and influence mechanisms essential in perception and perhaps in thought." The RF receives raw data and "alarming bulletins" that are relayed to the sensory and nuclei of the brainstem. The eighth cranial nerve is involved in sounds of ice breaking, twirls moving in the wind, gun shot sound and all movement reactions (Angevine & Cotman, 1981), page 240.

Two functions are related to facilitation of human movement. Efferent processes transmitted from the CNS to the cerebellum and to the musculoskeletal system. The afferent touch-related processes from the rest of the body to the CNS is another function. These descending and ascending subsystems (Livingston, 1967), page 509, Figures 6 and 7 are described by (Angevine & Cotman, 1981).

Another function of RF is to synchronize motions that are located at different physical distances from the brain. one such motion is to move the lips, fingers and toes to the same rhythm. The function of implementing a number of simpler CNS neural strategies into a purposeful and desirable human effort, has been articulated and formulated by (Kornhuber, 1971; Kornhuber, 1973) as "readiness potential". To accommodate different delays, The RF introduces delays to motor units closer to the brain or shortens the transmission paths to the farthest motor units by faster transmission lines. Other applications In tactile sensing and exploration, the skin and tissue displacements as well as the skin tangential and normal forces are needed for identification purposes Further, spatial and temporal behavior of the fingers have to be monitored for exploratory, recognition and continuation of the effort.

More challenging and difficult conceptual issues are when the whole hand embraces and moves on the unknown object in order to identify it and its shape. Not only good mechanical and physical model of the hand (Mason & Salisbury, 1985) are needed, but all tissue on fingers and palm of the hand have to be realistically modeled. To touch a wall in the dark for an electrical switch or a coat hanger is another example. A more detailed description of RF functions is given in (Angevine & Cotman, 1981), Chapter 11: establishment and maintenance of arousal and alerting states, regulation of peripheral sensory inputs, regulation of spinal motor activity and activation of sleep-like states. Many of these vital functions are learned. The learning may be unconscious. Lack or failure of some can be observed in new-borns and children where the internal CNS structures and body systems have not yet yet developed fully or matured. The RF functions in muscular control can fail when the child uses uncontrolled excessive muscular force or cannot relax. This may lead to frustration and/or losing control and getting angry. The role of RF in control of and awareness of emotions has been recognized, among many other functions of the RF. According to (Angevine & Cotman, 1981), page241, the output of the RF is so wide-reaching, it is no wonder that so many functions of the nervous system are affected by it.

Henneman (Henneman, 1980) considers examples of descending functions of the RF involved in movement. Many “alerting bulletins” are delivered by RF. Establishment and maintenance of arousal, alerting and libidinal systems are other functions of RF. Self aware-ness and consciousness (Livingston, 1967; Bernstein, Penner, Clarke-Stewart, & Roy, 2006) are two ares. Other systems as in the control of vomiting, are coordinated by the reticular formation (Garoutte, 1981).

One of the major functions of the RF is in “self awareness” (Angevine & Cotman, 1981) or “consciousness ” (Bernstein, Penner, Clarke-Stewart, & Roy, 2006), Chapter 9. A model of the self may have many dimensions or attributes. An initial model is in neural construction in the newborn (Hemami, 2017) from the touch system. This model gradually grows and has many human attributes.

This self model is not physical or chemical. It is distributed in the CNS, but the CNS may have pointers to the self that may be needed for a particular purpose - good or bad. The CNS seems to have capabilities to repress, suppress, deny or ignore parts of the self.

It is known (Mountcastle, 1980), Chapter 7, that the whole self may be mixed or mingled with other objects. It is known (Angevine & Cotman, 1981), page 244 that the physical self can be related to the internal coordinate system or to the external coordinate system one can envision or imagine the whole body in some position (lying in bed, throwing a basketball or riding s bicycle. The person can consider the self as one whole single item or entity or multi-entities that may not be close or connected together, One may think of the lips, the finger of the right hand and the toes of the left foot as one entity. If these three parts of the body had to move to music or coordinated in other ways, the RF is a major facilitator.

An intellectually challenging issue is how one can put together an image of the body as all connected together or put an image of many parts that are not physically, or mechanically connected together. The RF provides some or all of the visual properties of the objects in tactual reach. The RF sends information about the contacts with the environment in the upward channels to the brain stem and above. It also send feedback signals downstream to the Cerebellum, and motor neurons (Kandel, Schwarrtz, & Jessell, 1991). The Purkinjie cells perhaps carry on the most important and unique function of the CNS. If an issue important to the CNS is in progress, the CNS has channels to allow further exploration or termination of the search or effort - all unconsciously carried out. An example is the involvement of the cerebellum in any movement. Through early life, a human learns many valuable and successful involvement of the cerebellar structures and routines.

To the extent that the CNS is satisfied with the outputs of the musculoskeletal system, these processes are to be closed to further effort and exploration. The CNS uses Purkinjie cells to stop further search or effort. That is why all outputs of the cerebellum, are from Purkinjie cells.

This kind of behavior, either to allow the search, enquiry or effort to continue or to stop, seems to be perhaps the most important part of human thinking. Suppose an idea has evolved to the current stage, the Purkinjie cell either allows the process to grow into the next stage of neural processing (and this is unknown, because due the distribution of neurons) or this trend of thinking ends at the current stage. If this hypothesis holds, it points to an indefinite intellectual and mental resource of the human brain. This phenomenon points to an intellectual resource of the human mind. It points out to an infinite resource of intellectual capacity. Similar channels may be available to the physical growth of humans and how these phenomena are, naturally, terminated when the process of growth has reached the satisfactory or acceptable level of size.

The involvement of the Purkinjie cell in the processes of touch in the RF or the cerebellum is more physical. Inherent learning and satisfaction with the outcome of the involved processes are more physical and automatic. To summarize, an event or process can, through the implement of the Purkinjie cell, stop development and progress of another event or allow a one-step further expansion or development of it. Such processes have not been so far mathematically formulated. Perhaps the most important activity of humans and animals is the interactions with the external environment.

2.1 Exploratory Contact with the Environment

A simple case of exploratory contact by the skin and tissue is presented here to illustrate the function of the RF. Suppose a finger is to explore a planar surface and follow a seam, an edge or a crack without being able to see the surface. The finger is to find the seam and track it. The RF is to facilitate the tracking and forward the trajectory of the seam to the CNS. The contact with the seam does not support the weight of the system or any other function as in many constrained systems. A rough horizontal surface, next to the body, is to be explored by hand, the index finger or the palm and the fingers for finding a smooth seam or wedge.

There are two steps to the effort: finding the seam, and repeated incremental motion on the seam. Finding the seam starts with moving the finger or the palm of the hand on the surface, at some level of force, that allows moving the finger. This amounts to exploration of the surface at some detailed level. This is a full execution of some motion pattern by the CNS. The pattern of motion can be circular, moving back and forth, moving on an expandable helix, etc. There are two choices for following the seam. One of the two must be selected. The RF stack records the coordinate x, y of the next point on the seam. This information has to be communicated to the CNS so that the finger can follow the seam. The finger must be pressed to the seam with the vertical and the directional forces. For simplicity, we assume the person exploring the unseen surface is lying on the ground. and the seam is imbedded in the same horizontal plane. The plane is the yz plane of the body: x is the pitch axis (extended left hand) and the z-axis is the trunk axis (foot to head). There may be two choices for following the seam when the seam continues in both directions. One of the two must be selected. The RF stack records the coordinate x, y of the point on the seam. This information has to be communicated to the CNS so that the finger can be guided on the seam, i.e., the motion of the finger follow the seam.

The strategy of search is initiated by the CNS and learning, experience and circumstances are involved. This issue is worth an independent exploration and is not further pursued here (Robert, 2022; Bay & Hemami, 1987). Other stacks seem to function in the CNS. In the brain one can envision stacks that are involved in the creative processes of writing, drawing, etc. These CNS stacks do not seem to have elaborate stability and functional processes of the RF. These upper level stacks are involved in creative work. These stacks can be very complex. Imagining three-dimensional dance movements and imagined motions that do not exist in reality would be challenging stack processes that are beyond knowledge at this time. A simple two-dimensional stack involved in creative drawing is a structure that perhaps can be modeled.

Suppose a rough horizontal surface, next to the body, is to be explored by hand, the index finger or the palm and the fingers for finding a smooth seam or wedge. There are two steps to the effort: finding the seam, and repeated incremental motion on the seam.

Finding the seam starts with moving the finger or the palm of the hand on the surface, at some level of force, that allows moving the finger. This amounts to exploration of the surface at some detailed level. This is a full execution of some motion pattern by the CNS. The pattern of motion can be circular, moving back and forth, moving on an expandable helix, etc.

To keep the palm or the hand in contact with the surface, touching and feeling the surface, one introduces a small rotation in the plane of upper and lower arm. This small excursion, i.e., the rotation of the plane can be periodic, random or of some arbitrary positive and negative small rotation to allow sensory information to be extracted from the surface.

As long as the seam is not found, no information is stored in the stack. and a strategy of search must be repeated. The strategy of search is initiated by the CNS and learning, experience and circumstances are involved. This issue is worth an independent exploration and is not further pursued here (Robert, 2022; Bay & Hemami, 1987). Other stacks seem to function in the CNS. In the brain one can envision tacks that are involved in the creative processes of writing, drawing, etc. These CNS stacks do not seem to have elaborate stability and functional processes of the RF. For this reason, one may explore some of the functions of the stacks involved in creative work. These upper level stacks can also be very complex. Imagining three-dimensional dance movements and imagined motions that do not exist in reality would be challenging stack processes that are beyond knowledge at this time. A simple two-dimensional stack involved in creative drawing is a structure that perhaps can illustrate some of the structure and functions involved in mental drawing of figures.

Once the finger is in touch with the seam, confirmed from processing sensory data in the RF and summarizing the result in RF. These results, i.e., the just discovered segment of the seam, are added to the previous trajectory of the seam and the this position is communicated to the CNS. The CNS starts moving the finger further on the seam. This second motion is planned by the CNS and the processing of the sensed data takes place in the RF where an additional segment is added to what is already discovered. This process gets repeated again and again to discover further segments of the seam. The RF, for detection and storage of the surface information, as the palm or finger moves on the surface, is modeled as a two-dimensional stack.

In the current discussion, this issue proceeds as follows and becomes relevant.

To not lose the seam, the human should use the palm and the fingers as a larger sensory apparatus. Once the mission of the search is achieved, i.e., the seam and its location are determined, the CNS will suppress and delete the body of currently acquired sensory information. This ability to create and get help from presently desirable but shortly redundant information is one of the “redundancy” abilities of the CNS that has not yet been much explored.

This ability to use the sensory apparatus more efficiently is inherent and is not learned. The use of hands and larger contact is perhaps involved in maximizing pleasure and exchanges of love, affection and pleasure. These abilities or endowments of the human system are also transparent in the functioning of the joints such as the knee joint where gliding, rolling and locking are completely programmed and do not need any conscious effort. They take place automatically! Brooks (Brooks, 1986), page 220 discusses excitation and inhibition induced by stimulation of part of the arm. The excitation field shrinks after the inhibition is initiated. It seems there is a measure of assurance in the CNS for insurance that the excitation is taking place. Once the whole process (excitement and inhibition) is in effect the excitation somewhat subsides.

Other examples are cited (Brooks, 1986), page 237, where during arousal from inattention to attending a novel stimulus, i.e. corticospinal neurons) (Brooks, 1986), page 231, get involved. These neurons are made more responsive for the forthcoming action by clearing busy input lines. This process is called disfacilitation.

The cerebellum and the Vestibular system play important roles in energizing the muscles in exploratory movement. The Vestibular system identifies the position of the trunk relative to the external world and can integrate the gravity involvement in the extremity movement. The cerebellum provides the needed muscular forces.

Suppose a person’s body is lying on the ground. The axes of the body are as follows. The frontal axis x now into the ground. The horizontal ground plane is the yz plane: the y axis is along the stretched left arm and the z axis is along the spinal cord from the body through the head. The motion of reaching is achieved with the coordination of the upper and lower arms. The hand and fingers are fixed relative to the lower arm. To allow exploration and touching the surface. The xy plane is given a small rotation about the z axis. This small motion can be sinusoidal, other back and forth movements or random movements. The upper arm and the lower arm rotate about the x axis in the yz plane in order to define the extent of the reach in the horizontal plane.

The same procedure can repeat many times until the area of interest on the floor is covered. Every motion starts from where the upper and lower arm are and the rotational motions of the two segments allow an area of the surface to be scanned to be covered. The whole arm slightly moves to detect features of the surface.

Thus the exploring arm has three rotational degrees of freedom that the CNS programs. The hand, as stated before, through the programmed random rotation of the arm comes in contact with the features of the object (or the surface to be explored). The features are identified by the tactual sensors, tracked and recorded by the RF to be transmitted in the CNS or recorded in memory.

The method described above separates the two issues of controlling the motion of the arm on the surface and detection of the features of interest. This may not be the physiological procedures of the CNS, but it allows us to describe the RF involvement. The sensory apparatus records two set of contact point parameters:

- The two pressure forces felt by the skin and tissue, the horizontal force against the direction of motion and the vertical force against the skin and the tissue, and
- The three - components of the local velocity of the point of contact in the ICS system.

These features are forwarded to two FIFO stacks that are part of the RF - one for the trajectories and one for forces. Consider the three-dimensional stack of the trajectories. Before storage of the three velocity components, a certain cleaning and elimination of neighboring clusters of data is necessary, similar to the vision system (Robert, 2022) to reduce the relevant velocity information to three numbers - the components of local velocity at the point of interest. This procedure is detailed in the previous reference and is not repeated here. These three components are stored in the stack. The stored information is a track of the important information for storage of the track in memory and other purposes.

The same elimination of redundant data and storage could also take place for the force stack. The same procedure could be applied to three – dimensional surfaces, inclusion of more muscles, hand, palm and fingers and more. The basic implementation of the CNS control could follow that of (Bay & Hemami, 1987). Alternative strategies have been proposed by synergy models (Szentagothai & Arbib, 1974), page 471.

3. Visual Perception of a Planar Object

The visual perception of a planar object or image is modeled here. The model demonstrates the role of stacks in processing. The abstract operation of perception here is as follows. The boundary of the image is divided into a large number of small linear segments, e.g. 50. The objective of the vision system is to identify the location and orientation of each of the 50 segments in a mental planar image. Each of the 50 segments is modeled by a rectangle. All the rectangles are mapped onto the retina by the visual system. Every mapped rectangle is projected onto 50 vision rods that represent the totality of rods excited by the mapped segment. The overlap of the incoming rectangle with each of the 50 excited rods and the one rod with maximum overlap with the incoming segment is identified. The position and orientation of the rod with maximal overlap is transferred to a permanent storage plane in memory.

The interesting fact about the above processing is that all the fifty incoming segments and all the processing involved with each segment could be done in parallel. Through the above processing an image of the planar object is generated and can be transferred to the visual cortex or elsewhere in the CNS. The stacks needed for this task are planar, i.e., two-dimensional Stack structures are a convenient mechanism for modeling simpler neural processes in living systems. If programmable forms of such stacks can be developed, such neural processes can be simulated and possibly compared with the natural behavior and performance of the living systems. Development of the neuronal models would be very valuable in CNS research.

The simplest stacks are the standard LIFO and FIFO stacks of dimension one. They are used in current computers for implementation of interrupts and multi-level interrupts. Every computer register sits on top of a stack that is both a FIFO and a LIFO. The computer has two instructions: PUSH and POP.

The Push instruction pushes down the content of all registers for the current program in the stack. All registers will be filled with the values needed for the higher priority program to be executed. After the latter program is completed, the LIFO is popped to proceed with the program that was interrupted. If a movement is pushed in a stack and then popped, the signals can be reversed in time. In actual human interruption of movement, the whole CNS may be involved. If carrying a cup of coffee is to be interrupted, the CNS has to handle the setting down of the coffee as a gentle constrained motion, and the CNS must remember where the cup was placed. There are also elements of learning involved. If the interrupted movement has been well learned, the implementation is quicker and may be implemented more quickly in parallel. Otherwise, the implementation is slow and is serially carried out. Another application of first order stacks is in compensation for neural delays. The CNS introduces delays in different neural paths in order to impose synchronization of terminal effects. One may wish to move the fingers, the lips and the toes synchronously to music.

Many activities that require synchrony with other internal or external events benefit from this kind of processing. If learning is to take place, the cerebellum may be involved.

The stacks of dimension two are used in many neural, chemical and processing activities of the CNS. Some of the more interesting examples are in the vision system. Writing, art and creative and imagination part of the brain. Three simpler two-dimensional stacks are: amplification and/or attenuation of a two-dimensional image size, rotation and translation of a planar image, and coloring or painting an image, The object can be rotated, translated or imbedded in a larger or smaller plane to induce attenuation or enlargement.

An example of a three dimensional stack is a mental image of a sequence of buildings on a street. Such images may be recalled for different purposes such as drawing, coloring or painting.

An image of the length of a street with a variety of buildings can be stored in a four dimensional stack - the buildings are the three -dimensional stored objects and the length of the street is the fourth longitudinal dimension of the stack.

Alternatively, a three-dimensional building in construction or in demolition can be stored in a four- dimensional stack.

In a different mental application, a person can watch dance or other simple or complex human movements of another human being, and, based on his knowledge, learning and previous experience, may be able to imitate and repeat the same observed motion. The pattern Recognition involved is an area for exploration and the role of vision and stacks in such mental efforts is beyond the present work.

4. Mental Creation of an Image

This application of stacks is important in all creative, imaginative and artistic activities of the brain. It applies to other creative traits such as production of music, literature, and other creative talents. This section is involved with creation of planar images and shapes as well as combining images into painting assemblies of images. The transformations involved here are multi-faceted and involved. The image may be transferred to a stack of higher or lower dimension, it may be amplified in size or reduced, colored differently or rendered into a periodic or time-varying image or structure that repeats itself as in dance or other periodic images. Only production of periodic brain signals is addressed here, such signals are prototypes of CNS signals that energize the musculoskeletal dynamics.

The body may be stationary and stable in the inertial coordinate system (ICS) on the ground or in a boat. The upper arm performs a desired periodic movement. The hand and fingers may hold an object such as a visible cup.

The image of ghe cup may not be in the visual field. These movements require different capabilities from the CNS, the sensory system and the musculoskeletal system. Part of the body is used as a platform. The Vestibular system deter- mines the location of the body in space and relative to gravity. Then part of the body is used as a stable stationary platform, and part of the body is used for tracking, touching and exploratory purposes. This approach require complete maturity of the human physical system. The CNS may use the same rubbing or exploratory movement pattern repeatedly to detect and record segments of the seam or wedge to be discovered. Another situation, different from the above, involves early touch and discovery of objects that is vital to the infant or young individual and also may have libidinal, affective and limbic dimensions and characteristics both in infants and grown-ups. All these movements require separate abilities, neural, physiological and psychological and deserve elaborate studies.

It appears that identification of objects by the visual system or the tactile system may both have similar structures and processing. It is also possible that the hearing system for voice and music may have similar processing mechanisms. Also in the realm of creative work, mental construction of physical and imaginative forms, the proposed RF structure is very powerful. A somewhat basic structure of this module is presented here in some detail. The basic module is a three -dimensional stack that can represent an arbitrary three-dimensional physical object or structure. This structure can be modified and advanced in time by a ‘push’ signal. The push signal is analogous to one clock pulse in the current computers. The “pop” signal commands a reverse step in time and a “hold” signal does maintain most of the current values of the stack at their current values. Only a designated part of the stack (a specified sub-stack) may be modified by a special processor that implements the needed transformation. A mental example may clarify this process. The CNS may hole an image of a house in the stack. Actually the stack is a memory element now. The windows of the house are sub-stacks and assume they are all yellow. Suppose one wishes to make the windows red. One way to do this is to take the windows one by one and subject the sub-stack to the sub-stack processing of turning the yellow color to red. Computer stacks can be designed to confirm and verify the functions, structures and collaboration of stacks in different physical and mental missions. Therefore, in the computational module every sub-stack can be subjected to moving forward in time as it is modified, held in time with no change or moved back in time with a sub-stack pop. The sub-stack may have conventional clocks to sequentially evolve the process of changing the sub-stack. The sub-stack can have more hardware and allow a parallel, rather than sequential, change, i.e., the whole window is simultaneously turned to red.

The above double stack structure - the main stack being composed from many sub-stacks and each sub-stack having its own processing “sub-routines” is the computational module. Each stack may be in charge of its clock frequency, i.e., it may speed up or slow its processes down. It may have to communicate with neighboring stacks that it is done with its current job. All these properties and functions will be programmed with conventional and current software so that the computer module can imitate natural: physiological and neural modules with a successful imitation, one may have some more accurate ideas about what the neural assemblies do to perform that function. The stacks are suited to do a particular CNS function: sensory, motor, perception, and neurochemical. The stack to model the Thalamus is discussed in some detail here.

The Thalamus carries important sensory signals from the RF to higher CNS centers. This information is tactile, visual, audio and olfactory. These special signals carry messages for part of the cortex. Other similar signals may be for the whole CNS, the cerebellum, etc.

The Thalamus integrates the sensory information and transmits it to other CNS components or stacks that need it. According to (Angevine & Cotman, 1981): the thalamus functions are roughly of three types: discriminative, affective and integrative. When the gains are not proper, tremors movement disorder result. The cerebellum controls many gains involved in feedback paths of movement. the basal ganglia may control the gains involved in efferent, i.e., forward and down stream gains. The flow from the RF allows the Thalamus to control consciousness, alertness and attention (Angevine & Cotman, 1981), page 168. Precisely, how this is done is not well known.

To clarify the structure and sub-structures a number of mental exercises of creative, artistic and imagination processes are presented here.

Writing of alphabetical lower case letters is considered here. A more detailed discussion of writing see (Boren, Zheng, Hemami, & Che, 2013). Consider the task of drawing a flower with five circular petals. The process needs a two-dimensional stack. Each petal is produced by a sub-stack and a stack assembles the five petals. For simplicity assume the sub-stack computational program is a standard mat-lab program to place and draw the circle. Once the circle is plotted, i.e., the petal is drawn, the stack must select the location (the second sub-stack) for the second petal and so forth. If leaves and branches are to be added to the flower, other subroutines are needed and other assimilation and extension programs are needed for the stack.

For a drawing, more elaborate efforts and creative steps may be needed. In the CNS every sub-stack has its own bundle of processors and control inputs. Some of the processors may even be very fast requiring parallel processing. Animals use all fingers to hold some object (Kandel, Schwarrtz, & Jessell, 1991), page 546.

According to Heins Kohut (Kohut, 1971), page 185, in narcissistic personalities, there may be vertical and horizontal splits of certain energies. The separation of the mental space of interest in two parts necessitates drawing of boundaries and lines around psychological and neural boundaries. Physical shape of many man-made structures and buildings, etc. are examples of splitting carried out consciously or unconsciously.

A relevant example is the part of the brain involved with creative work. The image of the form in progress, must be captured to be done later in time. The gradual involvement of the brain in the creation of any image, real or imagined, is an example.

Cerebellar models are involved in coordination of movement. Another function is learning which will not be considered here. As stated earlier, if movements of lips, fingers and tore are to be in synchrony with music, sub-stacks have to advance some signals and delay some signals relative to others that are not delayed or advanced. The cerebellum can do this with stacks and sub-stack structures as envisioned in this paper. The predictive part of the cerebellum has been previously modeled

The regulation of the chemistry, and all other body needs (Kandel, Schwarrtz, & Jessell, 1991), and automatic observation and control of all vital life saving processes could perhaps be modeled by multi-level stack sub-stack structures that can represent all such functions of the reticular formation. Another advantage is that these structures can be modeled by standard computer programs and simulated. If physical and experimental measurements and observations are available, this could be a new way to confirm functions of many subsystems of the CNS. There are other approaches to reaching, goal-directed movements and tracking movements with and without vision have been subject of other approaches (Tomovic, Popovic, & Stein, 1991).

The RF and the vision system have similar ascending channels and paths to the brain. The descending paths to the parts of the human system involved in motion control, emotional and libidinal issues, chemical and neuro-chemical activities are much more involved than the vision system. Computer models and structures of the RF are desirable for two reasons. They provided a more precise structure that can be investigated physically and neurally investigated. They allow simulations of the natural processes for further and future scientific studies.

A variety of different activities can be cited in this regard. Monitoring the performance of different subsystems is one activity. Detecting vomiting and taking charge of what has to be done (Garoutte, 1981) is an example of this class of activities. Tracking tactile structures and identification and manipulation of objects is a second area. Coordination of different movements - simultaneous movement of lips, fingers and toes to music, in a task, is a third area. transmitting the information to the right destination in the CNS is a fourth area. Information processing such as detection of rough surfaces and many other examples of such processing may be another area. Often, the processing involves delivering the data to the right processor. Interruption of one task by a higher priority task and resumption of interrupted task (or tasks) is another example. Synchronization of body movement events with external events is another one. Many other examples can be cited that could involve keeping track of the internal chemical activities and their proper execution. A major question is whether the RF activities are learned by unconscious trial and error or over-programmed and then cut to size.

In what follows a standard computer structure is modified to account for some of the RF processes involved in movement. The main motivation for a computer model is that the architecture of the computations and the computational modules and functions can be simulated and the results compared with experimental and neurophysical measurements. Some of the functions are easy to recognize.

• All computer registers that store states are modified to simple last-in-first-out (LIFO) stacks. This structure allows programs (such as a motion in progress) to be interruptible. Upon receiving a signal to interrupt, all current registers are pushed into the stack and wait for the higher priority interrupting program to get executed. When the latter activity is completed, the LIFO pops and the previous registers are loaded and ready to execute the original program. The LIFO structure allows many interrupts within interrupts and is very powerful.

• The clock rate is not constant and depends on the time interval necessary for completion of the current task. Therefore, the computer has a local timing, for cleaning extra calculations and deleting them and the FIFO clock to summarize and store present results in the FIFO.

• There may be involved two FIFO's for the RF. One for storage and recording of the trajectories of specific states of position and velocity. This is a three - dimensional stack. Another three dimensional stack is needed for storage of contact forces: tangent to trajectory of touch, normal to the surface and lateral to the seam or wedge to be followed.

• There is local processing at every stage of stack processing. The computations to identify the net state of processing and the deletion of computations not needed anymore and preparing the local processor for the next step.

• Articulation of visceral, chemical and higher integrative functions of RF.

• Different delays are introduced in the "readiness segment" of the brain in series with the neural paths to the muscles. These compensating delays modify the paths to all muscles such that all paths introduce a single delay for all involved muscles. The movements involved are at the same latency and the movements are synchronous and coordinated.

• Integration of touch, vision and sound coming from the same physical vicinity - awareness of some attributes of the physical world around the body.

• Detection of desirable or undesirable events happening around the person.

• Specification of feed forward (downstream) and feedback (upstream to CNS) (Wolpert & Kawato, 1998).

• Role of the Purkinjie cells in termination or expansion of search, thought processes, imagination or creative efforts. also involve learning [(Kandel, Schwarrtz, & Jessell, 1991),Chapter 64] but the learning is not addressed here.

A fourth example here is the interruption of a movement by the person and serving or performing a higher priority movement. After the priority movement is completed, the original movement resumes. All the variables that are important for the resumption of the original movement are pushed into a LIFO stack.

These variables serve two purposes. They are needed to return the limb to its original position and then resume the original movement. Exactly, how the CNS carries out the intermediate motion of the limb to its interrupted state is not known. Once the CNS is ready to proceed with the execution of the original motion, the stack has to be popped to reset the initial states for resuming the original motion.

The operation of the stacks is relatively simpler to describe for simpler movement as in the conditional response.

The hypothetical computer here is made of a number of stacks. These stacks are analogous to registers in a standard computer. For simplicity, only one- dimensional stacks are considered. Also we consider a simple stack (called stack1) needed in the brain for creative efforts. The effort here is mental drawing of flower images. Let us assume the flower is made of five circular petals. The lower is to be mentally drawn on a sheet of paper We assume the brain has in storage a circle of some size in some stack (stack2) that can be recalled into stack1 for the flower. The circle is brought to stack1 by an instruction of stack transfer, analogous to register transfer:

$$\text{Stack2} \rightarrow \text{stack1}$$

Instructions are needed to enlarge or shrink the size of the circle

Assuming the circle is of the right size, it has to be transferred to the right location on the page. Then the two circles must be combined o form two petals.

The above class of register transfers are easy to understand and implement.

More difficult and involved transfer functions are the ones involving in time coordination, i.e. set of physical or movement activities end at the same time. Or, as stated before, parts of the body, at different neural distances from the brain, are to do movement in synchrony. We assume a solution from having learned how to start some motions earlier and others later such that neural transmission delays and advances add to the same for all sub-motions. Possibly Kornhuber's “readiness potentials” of (Kornhuber, 1973) may be involved in this class of transfer functions. These capabilities have been learned and stored in the CNS.

5. Discussion and Conclusions

In this article several simpler functions of the Reticular Formation related to movement and to physical contact are modeled and formulated. An important part of these simpler functions are implemented with stacks of different structure and complexity.

The Reticular formation has more complex and more vital roles in the chemistry of the body and structures involved in creativity, imagination and involvement in uncontrolled and unbounded activities of the CNS. Two such areas relate to integration of the sensory machinery of vision, touch and sound. Two specific aspects of this integration are security and physical emotional happiness. Security means including part of the immediate vicinity of the environment in the model of the self - the whole body being part of the self model. Happiness means imagining or actually performing real or imagined movements of parts of the body that may or may not be physically connected together.

Well-defined and well-structured neural networks are needed to perform as parts of CNS. Stacks are used here to define certain functions of the Reticular Formation in tactual exploration of unseen surfaces or objects. The stacks must have flexible variable speed and faster speed rates for local stack processing.

The stacks can also find applications in creative pursuits in art, imagination, synthesis of structures and shapes. The stacks may also provide a base for larger neural structures that are time-dependent. Similar structures may be also useful in description and processing of speech, music and sound mechanisms and may allow sensory integration and assembling of multi-processor approaches to sensory integration.

6. Appendix Simple Programmable Stack Structures

Stack structures are a convenient mechanism for modeling simpler neural processes in living systems. If programmable forms of such stacks can be developed, such neural processes can be simulated and possibly compared with the natural behavior and performance of the living systems. Development of the neuronal models would be very valuable in CNS research. subsection Stacks of Dimension One the simplest stacks are the standard LIFO and FIFO stacks of dimension one. They are used in current computers for implementation of interrupts and multi-level interrupts. Every computer register sits on top of a stack that is both a FIFO and a LIFO. The computer has two instructions: PUSH and POP. The Push instruction pushes down the content of all registers for the current program in the stack. All registers will be filled with the values needed for the higher priority program to be executed. After the latter program is completed, the LIFO is popped to proceed with the program that was interrupted. If a movement is pushed in a stack and then popped, the signals can be reversed in time. In actual human interruption of movement, the whole CNS may be involved. if carrying a cup of coffee is to be interrupted, the CNS has to handle the setting down of the coffee as a gentle constrained motion, and the CNS must remember where the cup was placed. There are also elements of learning involved. If the interrupted movement has been well learned, the implementation is quicker and may be implemented more quickly in parallel. Otherwise, the implementation is slow and serially carried out.

Another application of first order stacks is in compensation for neural delays. The CNS introduces delays in different neural paths in order to impose synchronization of terminal effects. One may wish to move the fingers, the lips and the toes synchronously to music. Many activities that require synchrony with other internal or external events benefit from this kind of processing. If learning is involved, the cerebellum may be involved.

6.1 Stacks of Dimension Two

The stacks of dimension two are used in many neural, chemical and processing activities of the CNS. Some of the more interesting examples are in the vision system. Writing, art and creative and imagination part of the brain. Three simpler two-dimensional stacks are briefly described here.

- Amplification and/or attenuation of a two-dimensional image size,

• rotation of a planar image,

• translation of a planar image,

• drawing a curve,

• color or paint an image,

• write a word in small letters,

All these efforts merit systematic CNS studies. One approach, not pursued further here, is to treat the image as an object that can be rotated, translated or imbedded in a larger or smaller plane to induce attenuation or enlargement. Many other creative mental activities can be imagined.

6.2 Stacks of Dimension Three

An example of a three dimensional stack is perhaps a mental image of a sequence of buildings on a street. Such images may be recalled for different purposes such as drawing, coloring or painting.

6.3 Stacks of Dimension Four

An image of the length of a street with a variety of buildings can be stored in a four-dimensional stack - the buildings are the three -dimensional stored objects and the length of the street is the fourth longitudinal dimension of the stack. Alternatively, a three-dimensional building in construction or in demolition can be stored in a four- dimensional stack.

In a different mental application, a person can watch dance or other simple or complex human movements of another human being, and, based on his knowledge, learning and previous experience, may be able to imitate and repeat the same observed motion. The pattern Recognition involved is an area for exploration and the role of vision and stacks in such mental efforts is beyond the present work.

Acknowledgments

The author is very grateful to Darla L. Peelle, N. K. Brooks, Phil Peer, and the support of the Fundamental Research Laboratories (FRL) of Honda R&D Americas, Inc. The author also is grateful for the encouragement of professors Yuan F. Zheng, Fusun Ozguner, and Joel Johnson, Chairs of the Department of Electrical and Computer Engineering at The Ohio State University. The author also is grateful to professors Robert Garbacz, Vadim I. Utkin, Patrick Roblin, Robert Mayhan, and Lee Potter for emotional and intellectual support.

References

Angevine, J. B., & Cotman,C. W. (1981). *Principles of Neuroanatomy* (2nd ed.). Oxford: Oxford University Press.

Hemami, H., Bay, J., & Goddard, R. (1988). A conceptual framework for tactu-ally guided exploration and shape perception. *IEEE Trans. on Biomedical Engineering, 2,* 99-109. https://doi.org/10.1109/10.1345

Ulloc, A., & Bullock, D. (2003). A neural network simulating human reach - grasp coordination by continuous updating of vector positioning commands. *Neural Networks, 16,* 1141-1160. https://doi.org/10.1016/S0893-6080(03)00079-0

Kandel, E., Schwarrtz, J., & Jessell, T. (1991). *Principles of Neural Science* (3rd ed.). Elsevir.

Hemami, H., & Wyman, B. (1979). Modeling and control of constrained dynamic systems with application to biped locomotion in the frontal plane. *IEEE Trans. on Automatic Control, 24*(4), 526-535. https://doi.org/10.1109/TAC.1979.1102105

Tomovic, R., Popovic, D., & Stein, R. (1991). *Nonanalytical Methods for Motor Control*. World Scientific.

Plantz, R. G. (2022). *Introduction to Computer Organization, NoStack Press, San Francisco*.

Bay, J., & Hemami, H. (1987). Modeling of a neural pattern generator with coupled nonlinear oscillators. *IEEE Trans. Biomedical Engineering, 34*, 297-306. https://doi.org/10.1109/TBME.1987.326091

Role, L., & Kelly, J. P. (1991). *The Brain Stem: Cranial Nerve Nuclei and the Mono-aminegic Systems* (3rd ed.). Elsevir.

Shepherd, G. (1979). *The Synaptic Organization of the Brain* (3nd ed.). Oxford: Oxford University Press.

Garoutte, B. (1981). *Survey of Functional Neuroanatomy*. Jones Medical Publications.

Livingston, R. B. (1967). *Brain Circuitry Relating to Complex Behavior*. The Rockefeller Univ. Press.

Kornhuber, H. H. (1971). Motor functions of cerebellum and basal ganglia: The cerebellocortical saccadic (ballistic) clock, the cerebellonuclear hold regulator, and the basal ganglia ramp (voluntary speed smooth movement) generator. *Kybernetik, 8*(4), 157-162. https://doi.org/10.1007/BF00290561

Kornhuber, H. H. (1973). Cerebral corex, cerebellum, and basal ganglia: And introduction to their motor functions. *The Neurosciences, III*, 267-280.

Mason, M., & Salisbury, J. K. (1985). *Robot Hands and the Mechanics of Manipulation*. M.I.T. Press.

Henneman, E. (1980). Motor functions of the brain stem and basal ganglia. In V. Mountcastle (Ed.), *Medical Physiology* (pp. 787-812). The C.V. Mosby Company.

Bernstein, D., Penner, L. A., Clarke-Stewart, A., & Roy, E. J. (2006). *Psychology*. Houghton Mifflin Company.

Hemami, H. (2017). Toward a computational model of the upper extremity. *Mechanical Engineering Research, 7*(2), 40-52. https://doi.org/10.5539/mer.v7n2p40

Mountcastle, V. (1980). Neural mechanisms in somesthesis. In V. B. Mountcastle, (Ed.), *Medical Physiol-ogy* (348-390), The C.V. Mosby Co.

Brooks, V. (1986). *The neural basis of motor control*. Oxford University Press.

Szentagothai, J., & Arbib, M. (1974). Conceptual Models of Neural Organization. *Boston: M.I.T., 12*.

Boren, L., Zheng, Y., Hemami, H., & Che, D. (2013). Human like robotic hand-writing and drawing. *The 2013 IEEE International Conference on Robotics and Automation*, 4927 -4932.

Kohut, H. (1971). *The Analysis of the Self*. International universities Press, Inc.

Wolpert, D., & Kawato, M. (1998). Multiple paired forward and inverse models for motor control. *Neural Networks, 11*, 1317- 1330. https://doi.org/10.1016/S0893-6080(98)00066-5

Copyrights

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (http://creativecommons.org/licenses/by/4.0/).