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Physics-Based Transfer Learning and Artificial Intelligence

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***Abstract*— *The Product forms a brain-to-machine-interface (BMI) that facilitates direct brain-control.The Product is designed to facilitate direct control of space/surface vehicles without the use of the limbs. This works perfectly for persons having a handicap that hinders motor skills or for health persons who may prefer not to use limbs. The operators of this device can issue instructions to these vehicles with direct input from the brain. The Vehicles will receive instructions to direct its movement and operations. Users will be able to connect wired or wirelessly to the vehicles.*

***Keywords*— Artificial Intelligence, BMI.**

I. INTRODUCTION

Transfer learning (TL) is a research problem in machine learning (ML) that focuses on storing knowledge gained while solving one problem and applying it to a different but related problem. Physics-Based Transfer Learning is where one trains a model to perform one task and then uses the information/knowledge acquired in the completion of another task. It deeply involves the transferal of information from one experience and applying such to another situation under a similar heading. This greatly will improve efficiency of a learning agent. For example, knowledge gained while learning to recognize cars could apply when trying to recognize trucks...reusing or transferring information from previously learned tasks for the learning of new tasks.

II. THE HUMAN BRAIN: NEURO-TRANSMITTANCE

The brain exhibits localization of functional areas, in that each brain region has a specific role, in sense. Most animal behaviour demands the collaborative and motor control areas of the brain and the activities of sensors. As the brain sensors undergo modification, the communication among brain areas adjusts depending on circumstances. When a new person is met, memorization his or her face (encoding information) takes place, however when seeing the person again his or her face becomes recognizable and several events are associated with this person hence information retrieval. With the respective synaptic transmission between neurons, information processing is brought into effect. It is important to grasp that synaptic modulation can change communication among brain domains.

Dopamine, serotonin, or acetylcholine are critical in the brain’s state-dependent modulation. These neurotransmitters/neuromodulators are conjured and dispatched from specialized neurons (small in number) located in forebrain, mid-brain and brain-stem of the brain. Synaptic contacts with varied areas of the brain are made with long-range neuro-transmitting connections. Neuromodulators dispatched from synaptic terminals are able to travel over 10 μm and acts on receptors distanced from release sites. Neuromodulators released from synaptic terminals are also capable of diffusing over substantial distances (>10 μm) (volume transmission; Venton et al., 2003; Zoli et al., 1998). [1] The information from neuromodulation/ neuro-transmitting neurons are propagated to large area(s) of the brain at the apparent cost of spatial selectivity. As such, activity changes in a small number of neurons can exert a broadcast influence on many brain areas, coordinating a functional change across areas (Hasselmo, 1995). [1]

The activities of the brain are recognized as varied frequencies of multiple oscillations in electroencephalograms. There have been studies linking brain functions with specific oscillatory activities. These oscillatory activities are not just epiphenomena, but the brain appears to utilize them for information coding (Engel et al., 2001; Varela et al., 2001). [1][5] Selecting activities locked in phases and information binding in the cortex of the brain, are typical examples.Brain oscillations is vital in the regulation of information traffic. Therefore, it is necessary to assess neural network and the manner in which they respond to frequency stimulation.

The proportion of the postsynaptic response effected as a result of presynaptic excitation is internally dependent on stimulation frequency in monosynaptic transmission. The

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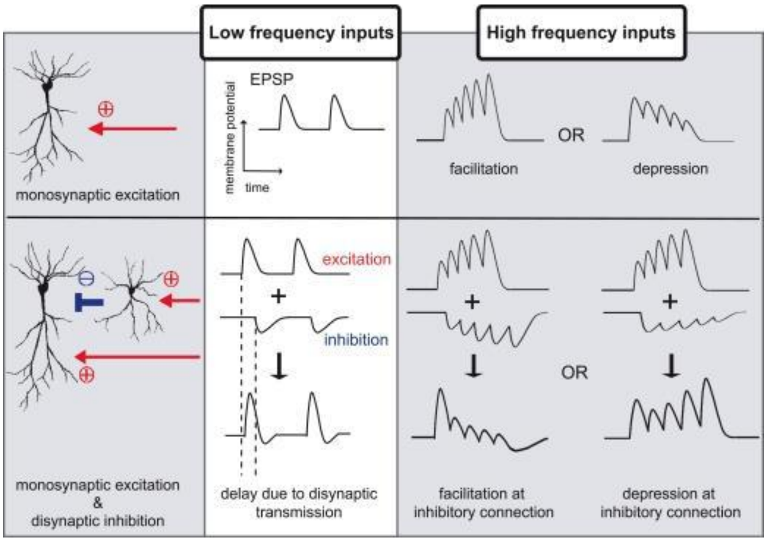
magnitude of the postsynaptic response evoked by presynaptic stimulation is intrinsically dependent on stimulation frequency (Markram et al., 1998). [1] In the delivery of several stimuli within close periods of time, the size of postsynaptic nerves increases in size, a condition called paired-pulse depression. Both presynaptic and postsynaptic mechanisms have been implicated in these processes. [1] Changes in neurotransmitter provides possibility of readily dischargeable reservoirs of synaptic vesicles. Postsynaptic receptor desensitization (Koike-Tani et al., 2008). [1] Frequency-dependent modulation of synaptic transmission has been proven to be brought into effect by the mobility of postsynaptic receptors.



(Erin M. Schuman, 2008)

Fig. 1: Brain Synaptic Nerves

Dopamine is a neuromodulator responsible for playing a crucial roles learning, motor control and memory along with addictive behaviour development. Most dopaminergic neurons are based in two nuclei, substantia nigra compacta and the ventral tegmental area. Exciting of these neurons in animal learning has been well characterized in mammals. Schultz and colleagues examined the live activities of dopaminergic neurons in certain tasks for training. In the study conducted, the activity of dopaminergic neurons seems to display internal expectations and outcomes for anticipation of failure. Hence, the dopamine system gives information with respect to environmental stimuli for information capture and synthesis.

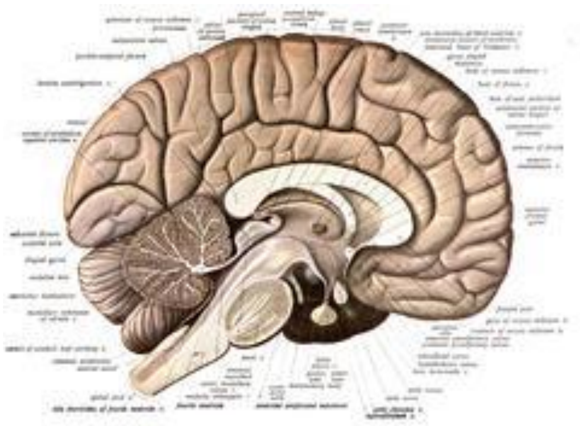


Fig 2: Brain Midsection

III. THE PRODUCT: BMI CONTROLLER

With the above scientific data/information in perspective, the design of the BMI Controller is such that human safety is paramount while fulfilling its objective.

The Controller is designed as such that there will be an implantation of a micro-processing device/receptor in the midsection of the brain (just at the surface (can be on either hemisphere)) to enhance its capability to receive signal output from the brain.

This chip will have receptors made of polyvinyltoluene/polystyrene plastic with a length between 0.2mm to 1cm (size depends on brain density of the

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subject). The reason for choice of those plastics is that they are flexible which is a positive because they create leverage to facilitate easy brain movements without negative side effects (eg. Seizures). Also, evidential research has proven that photons are very high in these plastics and when placed with fiber, the photons increase by over 15%.

Subsequent laser cooling on the dipole-allowed $^1S_0$-to-$^1P_1$ transition at 461 nm and the dipole-forbidden $^1S_0$-to-$^3P_1$ transition at 689 nm allowed us to load a new ensemble of atoms into the optical lattice roughly every 2 s. [3]

This is significant as it allows for scalability and improves bandwidth through the increase of wavelengths on the fiber.

The atoms were spread over roughly 1 mm along the cavity axis, corresponding to around 2000 occupied lattice sites. [3]

At 698 (813) nm, the 4-cm-long cavity mode had a waist size of 74 (80) μm…100 μK, the frequency of axial (radial) motion in the trap was 170 kHz (270 Hz), giving a Lamb-Dicke parameter $\eta = 0.16$ in the axial direction. [3]

These plastic receptors will then be connected/attached to a fiber-based sheath with silicon coating. These become effective as it will facilitate greater throughput in conversion from binary to analog and vice versa because there will be greater capabilities to create/draw data buses in nanometric context on the circuit while matching wavelengths will exist on the analog side of the device.

For the $|e\rangle$ to $|g\rangle$ transition studied here, $C = 0.33$, and the single-photon Rabi frequency was $2g = 2 \times 2\pi \times 3.7$ Hz for a maximally coupled atom. [3]

From what studies show, we will be able to acquire a bandwidth of 10nHz (Nano-Hertz) from these receptors, and also able to achieve more. This fully surpasses the 10 Micro-Hertz threshold for general neuro-communication.

Sample Analog to Digital Conversion:

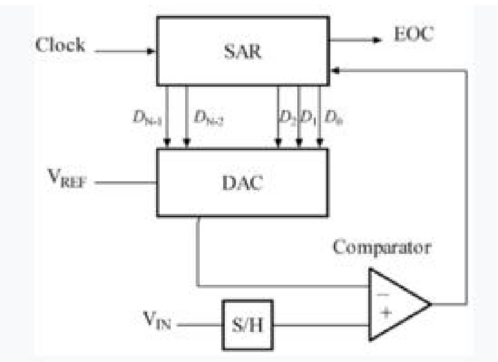

Fig. 3: ADC Block Diagram

Key

DAC = digital-to-analog data converting device

EOC = conversion's end

SAR = successive approximation register

S/H = sampling and holding circuitry

V_{in} = volt inputted

V_{ref} = volt referenced

The micro-processingdevice/ receptor will connect wired or wireless to an external device attached to the subject's ear or place of choice. There will be a hard (burnt-in) and soft address to facilitate security concerns. Therefore, the internal chip will only communicate with that specific external device unless they are officially programmed otherwise. With respect to data communication, 5G (and higher) data communication will be required to guarantee proper sync between internal and external device. The BMI device will use the same to make communication with the Avionic Systems.

IV. THE BMIC ARCHITECTURE

The Brain-Machine-Interface Controller consists of the Micro-processing Implantation and an External Device, these have option of speaking wired/wirelessly with each other and the External Device to speak wired/wireless with an external control (computer terminal/interface or machine). The Micro-processing Implantation consists of Stimulation, Electrode Diagnostics, Power Management, Analog Amplifiers, Analog-to-Digital Converters, Processing Logic, Radio Frequency (RF) Transceiver and/Sensor Feedback. This connects to a Charging and Data Transfer Coil, which Connects to an External Device (effectively a wearable computer) that relates wired/wirelessly to a computer terminal.

The Cable Connectors will be placed just under the scalp. The External Device consists of an Operating System (preferably Linux),(1TB) Hard Drive (Solid State), Microprocessor (Intel 7th Generation Pentium Processor),Bio-Sensors, Input Device (Both Bio-Sensors and Input Device work to detect a computer terminal and position cursor on the screen through mental operations on the part of the user),(DDR 4) Random Access Memory (RAM), Battery Power (Lithium Ion, 4800mAh, 11.1 volts), Global Position System (that user could determine their location and also the Manufacturer or whoever the user gives express permission to)and Radio Frequency (RF) Transceiver (5G (and higher) similar to the one above).

The Manufacturer would have the right based on user request to remotely troubleshoot any technical issues that may develop during use of the Device and the greater Controller (where necessary), or user could go in for in-person fixtures to the Controller and Device. However, the BMIC would be programmed as such to automatically raise a flag in the event of any technical issues that may develop during use of the Controller and Device.

The Microprocessing Implantation consists of twelve (12) Application-Specific-Integrated Circuits (ASICs) each containing 500 to 1000 electrodes. This results in 6, 000 to 12, 000 individually programmable amplifiers and 6,000 to 12,000 channels overall. This will enhance better reception of analog signals to the brain and transmission of signals thereto. The Language of choice is C++. Overall, there will be four (4) Microprocessing Implantations in the brain and as a result 24,000 to 48,000 electrodes from the Sensors to the External Device.

4.1 STIMULATION

Brain stimulation therapies can play a role in treating certain mental disorders…therapies involve activating or inhibiting the brain directly with electricity.[5] The electricity is applied through electrodes inserted in the head or placed on the scalp of the subject. It is possible also for electricity to be induced through the use of magnetic propagations to the head. This is beneficial because it has been proven to help persons with neurological disorders. From the Scientific Data/Information presented under “THE HUMAN BRAIN: NEURO-TRANSMITTANCE”, the synaptic nerves respond to different frequency levels. Hence, the Stimulation Engine would be so designed that 6 ASICs (with their respective electrodes) would be placed among monosynaptic nerves and 6 ASICs (with their respective electrodes) would be placed among disynaptic nerves.

When the sensors detect communication from the synaptic nerves the Microprocessor Implantation will detect such lapses and is automatically configured to generate the appropriate frequencies to stimulate such nerves. From research disynaptic nerves responds best to frequencies in the range of 50 to 200 Hertz, while monosynaptic nerves respond best to frequencies in the range of 10 microhertz and lower. In disynaptic nerve communications lapse, the Stimulation Engine will generate 50 to 200 Hertz to stimulate activity. It will do this over a 30 second to 2 minutes period. It will automatically increase by the tens until positive responses are detected. While in monosynaptic nerve communications lapse, the Stimulation Engine will generate in the range from 10 microhertz to10 nanohertz to stimulate activity. The Stimulation Engine in this situation will do continuous (non-time specific) frequency propagation until positive responses are detected.

The reason for the above approach, is that research has shown that monosynaptic nerves respond best to low continuous frequencies and disynaptic nerves respond best to short periods of high frequencies. Even though low frequency monosynaptic nerve(s) stimulation does trigger disynaptic nerve(s), the disynaptic nerves themselves respond to higher frequencies.

General Formula:

$$S_{AM} = -0.5[\cos(2\pi(f_c + f_m)t) + \cos(2\pi(f_c - f_m)t)], \quad (1)$$

$$S_{FM} = \sin(2\pi f_c t + M \sin(2\pi f_m t)) \quad (2)$$

Where AM is Amplitude Modulation, FM is Frequency Modulation, f_c is Carrier Frequency, $f_m$is Message Frequency, t is period (in time) and M is Modulated Signal.

4.2 AMPLIFIERS AND ANALOG-TO-DIGITAL CONVERTERS

An electronic amplifier is an electronic system that increase voltages. The system's power supply provides the energy required for amplification. A perfect amplifier does not interfere with the input signal. The output is an exact reproduction of the input signal but of increased pitch. It is a live quadripole based on active component(s), for example, transistor and operational amplifier.

> Electronic amplifiers are implemented in most electronic circuits. They are able to give rise to electrical signals, in the case of a sensor’s output, to a level of voltage that can be used by the rest of a given system. They can also improve the maximum power that a system has available and can provide to power to a charge such as a speaker and radio antenna.

The Application of Laplace and Fourier Transform

Laplace and Fourier Transform are used in conjunction with each other to mitigate against the Nyquist Effect and bring sinusoidal (and other types of) waves to its pure form. Signals are amplified using Laplace Transform and hence exceeding the threshold to overcome noise/attenuation on a channel(s). Fourier Transform is then used to sub-divide sinusoidal waves (and also other types of waves) into periods of time. Here signals are looked at introspectively to remove any other electromagnetic interference and extract data for

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digitization and hence conveying an accurate representation of analog data in binary form.

The processing of the analog waves occurs 100 picohertz. The Microprocessor Implantation accepts 80, 000 samples per second (80 milliseconds or 80 Megabits per second) and process them using 16 Core Computers. This Operation overall happens so fast that the brain will not recognize.

The Nyquist Theorem is a principle in the digitization of analog signals. For analog-to-digital conversion (ADC) to result in a faithful reproduction of the signal, the analog waveform must be taken frequently. The Nyquist Effect is when signals become halved when they exceed a threshold (that a system is unable to keep up with).

Any analog signal has several frequency elements. An example, the sine wave where all energy is concentrated at one frequency. Analog signals have complex wave forms with varied frequency elements. The highest frequency measurement dictates the bandwidth for that analog signal. Frequency is proportional to bandwidth, if all other considerations remain the same.

The Nyquist Theorem for a given analog signal f_{max} is at least $2f_{max}$. The sampling converter from continuous to non-continuous signal is actuated by a clock (or pulse generating device). If the sampling rate is less than $2f_{max}$, the highest frequency components are not guaranteed be correctly represented in the digitized output. When such a digital signal is converted back to analog form by a digital-to-analog converter, it does not return to its original analog signal or even near so. This undesirable condition is an aliasing/distortion.

The Nyquist–Shannon sampling theorem serves as a fundamental bridge between continuous-time signals and discrete-time signals. It establishes an appropriate situation for a sample rate that permits a discrete sequence of samples to capture all the information from a continuous-time signal of bounded/limited bandwidth.

The theorem is applicable to a class of mathematical functions having a Fourier transform that is zero outside of a certain region of frequencies. It is anticipated that when a continuous function reduces to a discrete sequence, it returns to a continuous function, the fidelity of the result depends on the sample rate of the original signals.

The theorem for experimentation (or sampling) is designed so that no information is lost and that the actual fidelity for the class' hierarchy to certain bandwidth is band-limited.It shows the sampling as an expression of the bandwidth for specific hierarchy of function(s). The theorem is effectively a formula for the reconstruction of the original continuous-time or analog function from collected waveforms.

Perfect reconstruction is probable even when the sample-rate criterion is not satisfied, given other limitations on the signal are established. In some situations, where the sample-rate criterion is not met, using additional constraints allows for estimated reconstitution. The fidelity of these reconstitutions can be verified and quantified with Bochner's theorem.

RADIO FREQUENCY (RF) TRANSCEIVER:

With carrier aggregation (CA) and advanced-MIMO techniques, the New Radio (NR) devices can attain up to several Gb/s peak data-rate. The demand of high bandwidth has created a need for exploring high-frequency spectrum over 3GHz, while sustaining legacy Long Term Evolution (LTE) bands for LTE-NR dual connectivity (EN-DC). Since User Equipment (UE) requires small form-factor and low power consumption, a single-chip RF transceiver is essential to cover both NR and legacy protocols, simultaneously. This integrated CMOS (complementary metal-oxide-semiconductor) Radio Frequency Integrated Card (RFIC) that supports multimode and multiband applications including all the legacy 2G, 3G, 4G and stand-alone/non-stand-alone sub-6GHz 5G NR features.

According to the Third Generation Party Project (3GPP) (release 15) standards, 5G NR (New Radio) is able to operate in two frequency bands, that is, FR1 and FR2. A transceiver (TRx) operating in Time Division Duplex (TDD) mode at 3.5 GHz (FR1 band) is chosen for analysis. A band pass filter is a very essential component in wireless transceiver (TRx) systems. The system specification and Radio standards requirement are stated in detail by the Filter's specification. Filters play a major role in making the system more immune to unwanted radio signals, improving the selectivity of the receiver and rejecting spurious harmonic noise generated within the system.

The Tx chain contains a cascade of driver amplifier that conditions the input signal, a Band Pass Filter (BPF) operating at the desired frequency band, and a power amplifier (PA) to improve the pitch of signals to a required level for the antenna to transmit. The Rx chain consists of a low-noise amplifier (LNA) to increase the signal power to an appropriate level for detection withthe Band Pass Filter as a digital attenuator for adjusting the gain of the systemand also an amplifier (AMP) for processing the signals. The antenna is joined to the Tx and the Rx chain through a single pole double throw (SPDT) RF switch. In

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conjunction, a directional coupler (DC) can be placed after the antenna for supervision and standardization purposes.

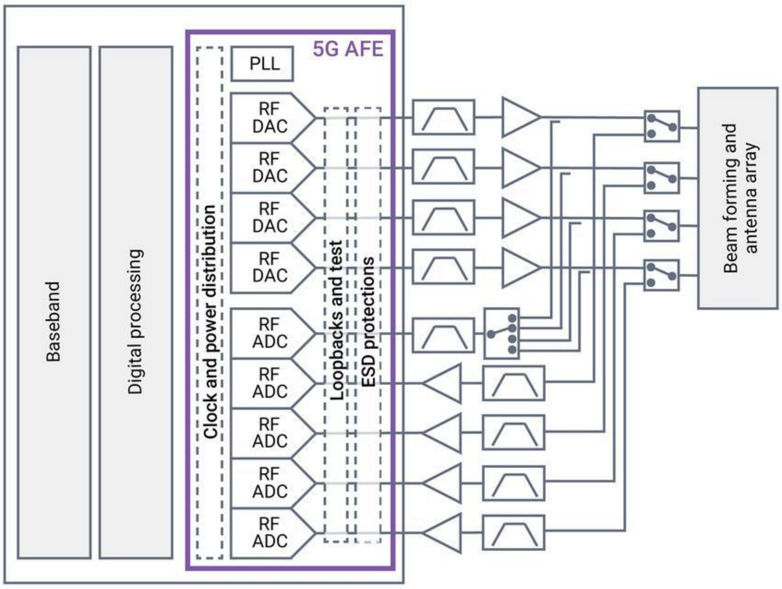

Fig. 4: 5G Radio Frequency (RF) Transceiver Configuration

ELECTRODE DIAGNOSTIC:

The medical electrode passes ionic current's energy to the (human) body as electrical current that can bemade higher pitched, researched and used for medical purposes.

Medical electrodes allow for fundamental verification of internal ionic current. This yields a radical test for varied nervous, muscular, ocular, cardiac, and other illnesses that would have otherwise required surgery to establish. Muscular examinations may disclose evidence of diminished muscle fiber(s) and reveal muscle disorders and neurologically-based illnesses along with discovering whether or not muscles are weak. The electrodes are inexpensive, easy to control, can be disposable or sterilizable and very unique in the task they perform. The main purpose of the electrode is to create proper electrical communication between the patient and the apparatus used to measure and/or record activity.

PROCESSING LOGIC:

This coordinates all the activities of the Microprocessor Implant Device. Processing Logic is a ruggedized computer used for industrial automation. These controllers provide automation of a specific function/process and as well a complete manufacturing operation.

The Processing Logic receives information from connected sensors or input devices, processes the data, and triggers outputs based on pre-programmed parameters. Depending on the inputs and outputs, a Processing Logic can monitor and record run-time data such as machine productivity or operating temperature, automatically start and stop processes, generate alarms if a machine malfunctions, and more. Processing Logics are a flexible and robust control solution and are adaptable to any application.

POWER MANAGEMENT:

The Power Management System is designed according to Advanced Configuration and Power Interface (ACPI). ACPI is open standard that Operating Systems use to discover and configure hardware components to perform power management operations such as putting unused components to sleep and perform status monitoring.

The Power Management System is used to: reduce overall energy consumption, prolong battery life for portable and embedded systems, reduce cooling requirements, reduce noise and reduce operating costs for energy and cooling.

Lower power use means lower heat dissipation (leading systems stability) and less energy use and that reduce costs and reduce negative impacts on people and the environment.

SENSOR FEEDBACK:

Sensor is a device, module, machine, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor.[12]

The Sensor(s) relating to the Microprocessor Implantations are used for interfacing with the Electrodes causing the External Device to speak with the Microprocessor Implantations and vice versa. This is different from the Bio-Sensors in the External Device which are used to interface with the computer terminal.

Table: Specifications Of Microprocessor Implants

Channels	24, 000 to 48, 000
Root Mean Square Noise	7.2 microvolts
Amplifier/Analog-Digital-Converter Power	3.3 microwatts
Spike Detection	2,000 nanoseconds
Stimulation Resolution	0.2 microamperes and 3.0455 microseconds
Die Size	4 x 5 mm

V. COMPUTER TERMINAL

This specialized terminal will facilitate all the needs of the user. This terminal will relate with the servers responsible for the Guidance, Navigation and Control (GN and C) Sub-System, the Electrical Power Sub-System (responsible for providing and storing electrical energy, user can use it to adjust lighting in the space vehicle) andthe Thermal Control Sub-System (responsible for regulating temperature throughout the space vehicle).

The user can connect with the computer terminal via an USB cable or wirelessly. The terminal will consist of soft controls placed on the screen. All controls for the space vehicle will be on the screen of this terminal. The user will have the luxury of utilizing soft buttons, textboxes, etc. to enter and commit commands. The screen will have options to which server the user wants to switch to or login to (may incorporate a special window that pops up with the information and GUI for that server).

There will be an option for the user to change controls, for example from input via textboxes to a soft toggle or lever control on the screen, that is, when maneuvering the vehicle. The user will be able to log into the Electrical Power Sub-system to adjust lighting and any authorized electrical needs. The user will be able to log into the Thermal Control Sub-system to adjust the temperature throughout the vehicle. The terminal will have camera footages displaying every aspect of the space vehicle.

5.1 Guidance, Navigation and Control (GN and C) Sub-system

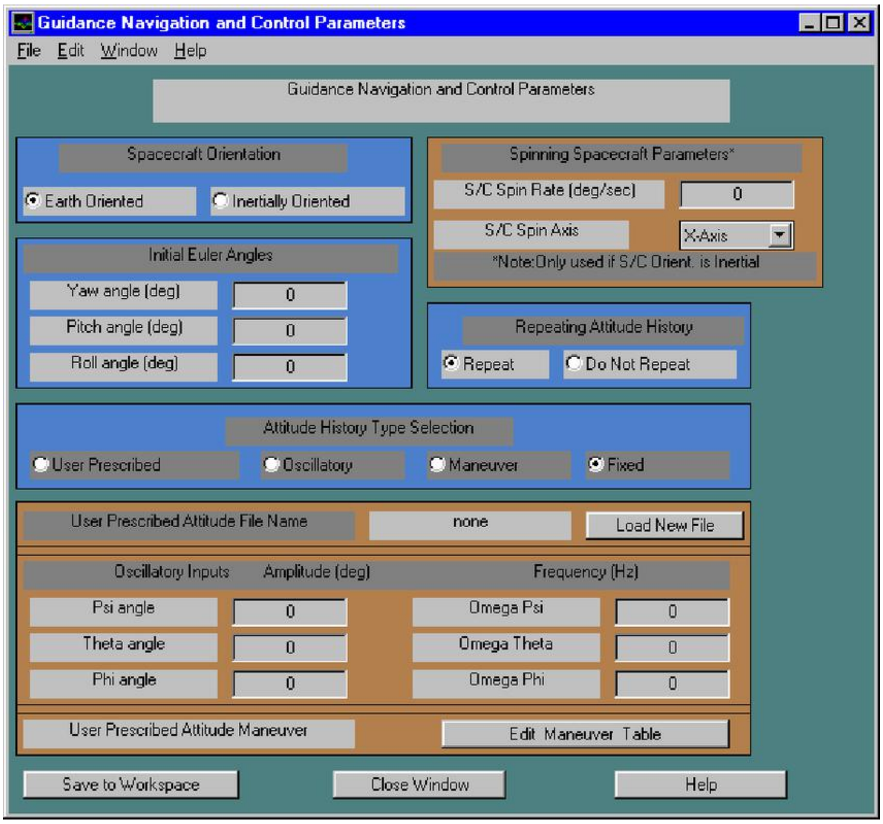

Fig. 5: GN and C Sub-system

When the user attempts to change the speed and orientation of the space vehicle, a window displaying the effect of the proposed move will appear. The user will see how the vehicle would appear once the command has been committed and a possible warning the user should brace for.

Then the user has the option to commit the command or to make changes. For continuous motion controls, for example, a steering, in place of such, the user can enter (double) floating point numbers, (if not using soft controls (eg. Toggle Control)) to input data.

The user will have control over the engines of the vehicle collectively or individually. This becomes important in cases where spacecraft needs to perform Soyuz Rendezvous and docking to facilitate proper docking and to avoid collisions and possible errors when attempting to dock. This is also important when disengaging from dock to allow for smooth transition and movement away from the International Space Station (ISS) or any docking facility.

The GN and C also known as AOCS (Attitude Orbit Control System) is responsible for the orientation, position, velocity and angular velocity (navigation) of the space vehicle. It is responsible for force and torque (control) along a trajectory as defined in the Guidance Function. It measures the current state of the space vehicle and inspects the data from the sensors and it interfaces with the actuator hardware and applies the required forces and torques.

Sensor measurements are usually corrupted with sensor noise, drift and biases, the Navigation Function has a filter to correct the attenuation present in the measurements. In the absence of sensors to measure all the dynamical states, the navigation tool reconstructs some states to measure the hardware. This is done through Sensor Fusion and Robotic Applications and Stochastic Filtering Techniques (such as variations of Kalman Filters – regular, extended and unscented).

The Kalman filter uses a system's dynamic model…known control inputs to that system, and multiple sequential measurements…to form an estimate of the system's varying quantities.[13]

The predicted and update functions in the extended Kalman filter (EKF) could be either linear or non-linear functions. In the case, they are non-linear, these functions are very distinguishable.

$$x_k = f\,(x_{k-1}, u_k) + w_k \qquad (3)$$

$$z_k = h\,(x_k) + v_k$$

The function f is usually used to calculate the state transition of previous estimate and the function h to calculate the observational model. However, the Jacobian matrix (of partial derivatives) is used to compute the covariance directly.

In each period of time, the Jacobian is evaluated with current forecasted conditions. These matrices are possible in the Kalman filter equations. This procedure fixes a nonlinear function around the present approximated value.

When the predicted and update functions f and h are very non-uniform and the extended Kalman filter gives a poor judgement. In lieu of the state transition and observation models propagating output(s) non-linear. The unscented Kalman filter (UKF) uses unscented transformation (UT) to select minimal sigma points around the average, considered a very deterministic sampling technique. Those set of sampling points are spread throughout non-linear functions from which new average and covariance estimates are then produced.

The resulting filter depends on the set of sigma points used and the way in which the transformed statistics of the UT are calculated. It should be remarked that it is always possible to construct new UKFs in a consistent way. In certain cases, the resulting UKF more accurately approximates the true mean and covariance.

This can be verified with Monte Carlo sampling or Taylor series expansion of the posterior statistics. Thistechnique typically removes the requirement to explicitly calculate Jacobians, which for complex functions can be a complicated task in itself or may not even be impossible (especially when those functions are not differentiable).

The Guidance Function specifies the desired dynamical states either in a waypoint as a function of time or Trajectory Generator that will smooth out the transition between the waypoints. It also calculates the error between the desired states and estimated states to compute the trajectory tracking error between these states and feed the signal to the onboard Controller. This is to ensure the required torque be applied to the different actuators onboard the space vehicle and that the vehicle follows the desired trajectory.

The GN and C Sub-system also facilitates reconfiguration while the spacecraft is in orbit.

VI. CONCLUSION

Artificial Intelligence (AI) is intelligence demonstrated by machines as it relates to the natural intelligence displayed by humans beings. AI Machines are any device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals. AI is often used to describe machines (or computers) that emulate cognitive functions that humans associate with the human mind, that is, problem solving and learning.

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