1st NeuroMat Young Researchers Workshop

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Short Talk 1

A test of hypotheses for random graph distributions

Andressa Cerqueira (USP, São Paulo), Claudia Vargas (UFRJ, Rio de Janeiro), Daniel Fraiman (UDESA, Argentina) e Florencia Leonardi (USP, São Paulo)

The theory of random graphs has been successfully applied in recent years to model neural interactions in the brain. While the probabilistic properties of random graphs has been extensively studied in the literature, the development of statistical inference methods for this class of objects has received less attention. In this work we propose a non parametric test of hypotheses to decide if two samples of random graphs are originated from the same probability distribution. We show how to compute efficiently the test statistic and we study the performance of the test on simulated data. The main motivation of this work is to apply this test to analyze brain functional networks constructed from electroencephalographic (EEG) data. This work is inserted within the NeuroMat goal of the development of statistical tools required to analyze neural data.

Short Talk 2

INVESTIGATION OF TOUCH THRESHOLD AND REFERRED SENSATION IN BRACHIAL PLEXUS INJURIES AND SURGICAL REPAIRS

Bia Ramalho Lima; Paulo Leonardo Tavares; Maria Luiza Rangel; José Fernando Guedes; Ana Carolina Schmaedeke; Fátima Smith Erthal; Juliana Maia; Claudia Domingues Vargas; José Vicente Martins
UFRJ, Rio de Janeiro

Nine patients with brachial plexus injury (BPI) and submitted to different nerve surgeries were subjected to sensory evaluation using Semmes-Weinstein monofilaments to define tactile thresholds and to evaluate referred sensations. We applied the sensory test in six points of each upper limb corresponding to the territory of each brachial plexus nerve. Control subjects were matched in age and sex with the patients. In two BPI patients who underwent intercostal to musculocutaneous nerve transfer, a referred sensation map was also made in the rib cage (region of the donor nerve) ipsilateral to the BPI during the stimulation of the forearm (innervated by the musculocutaneous nerve). Within NeuroMat we expect to investigate how this referred sensation is mapped into the brain using fMRI/EEG techniques. We also intend to adapt this sensory protocol for other types of BPI surgical protocols.

Short Talk 3

Spike Sorting for Interacting Neurons

Bruno Monte de Castro
USP, São Paulo

Extracellular recordings of brain activity can contain spikes from more than one neuron. Often it's necessary to distinguish the spikes from distinct neurons, that is a spike sorting problem. In our situation, the spike sorting is based on the moment in time when the spike occur (spike times). We consider that the neuronal spikes are generated by jump processes with memory of variable length whose rate depends on the membrane potential. We want to do statistical model selection to perform spike sorting, that is one of main goals of

Neuromat project. We suppose that we know both the number of interacting neurons on the system and all model parameters. Given a sample of the spike times, we want to estimate the most likely configuration. By configuration, we mean the neuron of origin for each spike. In order to do that, we propose to use the Metropolis-Hasting algorithm.

Short Talk 4

Are there electrically coupled networks of pyramidal cells in the hippocampus and cortex? A computational study

Cesar Celis Ceballos
USP, Ribeirão Preto

Theoretical studies have proposed the existence of electrically coupled networks of pyramidal cells in the hippocampus and cortex. Experimental verification of the existence of such coupled networks and the determination of their size is difficult. However, it is possible to determine experimentally the local neuronal connectivity. I am using computational modeling to study clusters of electrically coupled pyramidal cells in the hippocampus and cortex. The models attempt to mimic experimentally found local patterns of electrical synaptic connections and allow a study of the formation and sizes of electrical syncytia in the hippocampus and cortex. This work interacts with NeuroMat in the sense that it provides a computational framework for the study of large dynamical networks of electrically coupled neurons.

Short Talk 5

Analysis of reaction time during pattern learning

Estevão Vieira
USP, São Paulo

Our project is based on searching a relationship between event's previsibility and reaction time, using the Serial Reaction Time (SRT) task: a mark is shown on the screen (defining an event), and its location (one of four possibilities) determines the button to be pressed by the subject. The marks's sequence can be defined as a stochastic source, which defines the next mark's location probabilistically from its previous ones. In earlier studies, our team found a strong relation between a source's entropy and the mean response time (after some training and stabilization of the mean time) to its events. Knowing that reaction time differs significantly throughout same source's distinct events, we now aim to find some feature specific to a single event (i.e. Amount of information) that relates to its specific response time, now including earlier trials, when response time decays over subsequent events, due to learning (the subject's updating its model of the source). We therefore aim towards a learning model for a simple implicit learning task, and its related neural activity-which is fully related to NeuroMat.

Short Talk 6

Large-scale patterns of neural activity

Hjalmar Turesson
Instituto do Cérebro, UFRN

Neural activity occurs at multiple temporal and spatial scales. The relationships between sub-cellular neural morphology, receptor distributions, ion channels and trans-membrane potentials are relatively well understood. Nevertheless, at greater scales the correlation between behavior and neural activity have been described only through averaging activity over multiple repetitions of the same behavior. I propose that the reason for this limitation is that current data sets are not sampled at the appropriate spatio-temporal scale. My goal is to to identify the scale at which the neural activity is predictive of behavior without averaging over multiple repetitions. I will discuss why the signal obtained by sub-durally located ECoG arrays might be the appropriate scale at which to relate behavior with neural activity. Such recordings would provide data for the first two year of algorithm and data handling development within NeuroMat.

Short Talk 7

Study of neuronal morphology by computational modeling

Julian Tejada
Universidade Federal de Sergipe

The neuronal morphology could be affected by countless processes, from normal neuronal activity, such as learning or memory, up to injuries provoked by diseases, such as dementia or epilepsy. In the context of the latter, several days after the injury, new cells arise with different morphological alterations in both branching patterns and axonal targets. The way in which these new cells are integrated into the hippocampus is still unknown, but computational models may provide insights about how these morphological alterations could affect the behavior not only of an individual neuron but also the activity in the network.

To achieve this objective, we worked with Spiking Neural Networks which are models able to incorporate detailed morphological information that comes from animal tissue and we use them to build large-scale network models incorporating different morphological alterations observed in animal models of epilepsy. Our results show that there are some specific morphological alterations present in the hippocampus granule cells, specifically the mossy fiber sprouting - MFS (axon sprouting making recurrent excitatory synapses) and the spine loss – SL (significant reduction in the number of dendritic spines), may be responsible for increasing (MFS) or decreasing (SL) the dentate gyrus activity.

Short Talk 8

Digital Database: Experience from the Institute of Neurology Deolindo Couto at UFRJ

Cristiane Patroclo, Juliana Maia, Bia Ramalho, Maria Luiza Rangel, Evandro Santos Rocha, Kelly Braghetto, Claudia Vargas
INDC/UFRJ

Since July 2014, the Laboratory of Neuroscience and Rehabilitation of the Federal University of Rio de Janeiro in association with NeuroMat develops a digital database with clinical and experimental information from patients suffering from traumatic brachial plexus injury. Its objective is to contribute, to the comprehension of the mechanisms of cortical organization after brachial plexus injury and surgical repair. The main characteristics of the base are its multidisciplinarity and the concern on data security and patients' anonymity. In the current feeding stage the challenges are: review of the first version of the NES (Neuroscience Experiments System) program, acquisition of different sorts of information (anatomical, clinical, surgical, image, electrographic) and standardization of the data collected prior to the project's start. In the near future the collected data will be available to the community.

Short Talk 9

A study on the correlation between resting-state functional connectivity and intrinsic neuronal activity of stochastic neural network models

Karina Yuriko Yaginuma
USP, São Paulo

The brain is the most complex organ in a vertebrate's body, understand its operation is one of the great challenges of modern science. The first model of a spiking neuron was proposed by Hodgkin and Huxley in 1952. Most recent, Galves and Löcherbach (2014) introduced a new class of infinite systems for neural nets. An extension of this model was introduced by me in my PhD dissertation (2014). With the emergence of new stochastic models for biological neuron nets, also comes the need to check whether the proposed models are in same sense "good models" to described the dynamics of this biological neural nets. In this work, we will analyze the correlation between regions of the brain to verify if the model is a "good model". For this, we implemented a simulation algorithm of the models. Finally, we compare the correlation matrices of the collected data and the simulated sample. The main challenge of this work is to create a methodology to compare two matrices of correlations.

Short Talk 10

Families of database schemas for neuroscience experiments

Larissa Moraes
USP, São Paulo

In neuroscience context we use several kinds of experiments to investigate the brain functioning. In order to be able to reuse experimental data out of the scope where they were collected, neuroscientists need to have access to data provenance information, i.e., a description of the experiment protocol and other information about its execution. Neuroscientists normally store experimental data as common files in a computer. This approach makes it difficult for the maintenance, recovery, sharing and reuse of data. One of the biggest challenges of creating patterns to represent and store these data is the great variability that exists in the experimental protocols in neuroscience. This project proposes a method to deal with data variability using the Software Product Lines paradigm. Considering Neuromat's objective of creating tools for technology transfer, we will create a tool that generates databases to store experimental data customized for the needs of a particular laboratory or research group.

Short Talk 11

Hippocampal-prefrontal plasticity seems to reverberate in a thalamic-prefrontal loop: what else neuromathematics could tell us?

Lézio Soares Bueno-Júnior, João Pereira Leite
USP, Ribeirão Preto

Hebbian theory (1949) inspired the sentence "cells that fire together, wire together". Since then, evidences supporting the "fire together" (i.e., electrical stimulation of presynaptic cells) and the "wire together" (i.e., long-term alteration of postsynaptic voltage responses) have accumulated. My current effort is to give these ideas a systems neuroscience approach, through which excitatory reverberation in a circuit loop (between prefrontal cortex and limbic thalamus) is manipulated by electrical recruitment of a connected pathway (from hippocampus to prefrontal cortex) in conscious rats. According to electrophysiological data in this presentation, collaboration with NeuroMat could yield denser information other than descriptive statistics.

Short Talk 12

FUNCTIONAL CONNECTIVITY OF PATIENTS WITH BRACHIAL PLEXUS INJURY: A RESTING-STATE FMRI STUDY

Souza, L.[1,2], Fraiman, D.[5,6], Erthal, F.[1,2], Miranda, M.[3], Rombouts, S.A.R.B.[4], Galves, A.[3], Malessy, M.[4], Vargas, C.D[1,2]

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Resting-state functional connectivity magnetic resonance image (FMRI) is a useful technique to study the brain's functional reorganization in subjects suffering from peripheral nervous system lesions such as the brachial plexus injury (BPI). In this study we aimed at the effects of BPI on local functional connectivity by exploring the decay of functional correlations between neighboring voxels within the Primary Motor Cortex (M1). We found evidence that these correlations decay faster as a function of distance in BPI patients submitted to ICN-MC nerve transfer, as compared to the control group in the M1 region corresponding to the arm but not to the face area. Structural imaging analysis showed no difference in gray matter density between groups. We intend now to explore the effects of BPI over functional connectivity with high density electroencephalography.

Short Talk 13

Retrieving stimulus hidden structure from spike data through context tree modeling

Ludmila Brochini Rodrigues
USP, São Paulo

In modern Neurobiology, one of the main limiting factors to the understanding of neural systems can be attributed to lack of tailored mathematical tools adequate to neural data analysis. This project proposes to apply model selection in the class of stochastic chains of variable length also called context trees, that are well suited for neural data analysis for taking into account structural dependencies in the data and at the same time being computationally relatively inexpensive. By modelling a spike train through context trees it is possible to have a better understanding of the signal structure produced by a neural system spontaneous activity that cannot be achieved by other means. Furthermore this project proposes the experimental investigation of how the neural signal structure is influenced by an external source, in other words, if the structure of the stimulus generated by a context tree can be retrieved in the neural response context tree model. This way, the project aims to reach a framework that will help to unveil hidden properties of spike trains with physiological relevance and design stimulation protocols for electrophysiological experimentation.

Short Talk 14

Neurophysiologic Predictors of Motor Function in Stroke

Marcel Simis
USP, São Paulo

Stroke is the leading cause of long-term disability. Functional recovery following stroke depends on multiple factors including the initial impact of the lesion and subsequent adaptive and maladaptive plastic changes. Understanding neural mechanism involved in stroke recovery is important to develop novel therapies as well as surrogate outcomes. In this context we assessed several TMS and EEG variables and their associations with motor recovery as indexed by Fugl-Meyer Assessment (FM). Thirty five subjects with chronic stroke were recruited. Neurophysiologic assessments included motor threshold (MT), intracortical inhibition (ICI), intracortical facilitation (ICF) as measured by transcranial magnetic stimulation (TMS); and intra and interhemispheric coherence as indexed by quantitative electroencephalography (qEEG). Motor function was assessed by FM. Multiple univariate and multivariate linear regression analyses were performed to assess the predictors for FM. Our results from univariate analyses showed significant main effect of MT in the lesioned hemisphere indicating higher MT is associated with worse FM. In the multivariate analyses, we found significant interaction effect of MT in the lesioned hemisphere and high-beta coherence in the unlesioned hemisphere. This interaction suggest that the higher beta activity (in EEG) in the unlesioned hemisphere strengthens the association between MT and FM. In conclusion, our results support the notion that MT is one of the strongest factors in predicting motor recovery after stroke where as qEEG changes appear to provide additional information as it helps to make the association between TMS findings and MT more specific. Combining EEG and TMS data provide a better model involving both lesioned and unlesioned hemispheres that supports the importance of bi-hemispheric activity in recovery. This study is inserted within NeuroMat main goals, since it helps to understand and explain plasticity mechanisms underlying neurorecovery and adapted rewiring.

Short Talk 15

Predicting upcoming events occurring in the space surrounding the body

Maria Luiza Rangel[1], Lidiane Souza[1], Lucas Frota[1], Erika de Carvalho Rodrigues[2] e Claudia D. Vargas[1]
1 Universidade Federal do Rio de Janeiro, 2 Centro Universitário Augusto Motta (UNISUAM)

Predicting an upcoming event is an intrinsic property of the motor system. Predicting means choosing the next state of the upcoming movement given the knowledge of the past steps and of the inferred context. This mechanism could enable the creation not only of forward state estimates of impending movements, but also of upcoming events occurring in the space surrounding the body. We applied an action observation paradigm coupled to high density electroencephalography to investigate whether the prior

knowledge of upcoming events occurring in the space surrounding the body could elicit a negative slope (NS) associated with prediction. Our results show that a NS precedes both the observation of an upcoming action and the observation of the contact of a moving object towards the hand. This protocol is now being applied to study brain plasticity after Brachial Plexus Lesion, with promising preliminary results.

Insertion within NeuroMat main goals: Development of a new class of stochastic processes.

Short Talk 16

Tensor partition regression model with applications in imaging biomarker detection

Michelle F. Miranda
USP, São Paulo

Many neuroimaging studies have collected ultra-high-dimensional imaging data in order to identify imaging biomarkers that are related to normal biological processes, diseases, and the response to treatment, among many others. These imaging data can be of various modalities (e.g. MRI, DTI, fMRI, and EEG) and are often represented in the form of a multi-dimensional array, called tensor. Existing statistical methods are insufficient for analysing these tensor data due to their ultra-high dimensionality as well as complex structure. Within the NeuroMat goals, we take into account the aforementioned high-dimensional aspects of neural systems to develop a new statistical framework to establish an association between low-dimensional clinical outcomes and ultra-high dimensional tensor covariates. Under the proposed framework, ultra-high dimensionality is not only reduced to a manageable level, resulting in efficient estimation, but also prediction accuracy is optimized to search for informative sub-tensors. We apply our tensor partition regression model to predict diagnostic status from the structural magnetic resonance imaging data of individuals with either Alzheimer's disease or healthy controls.

Short Talk 17
Can dynamical synapses produce true self-organized criticality?

Osame Kinouchi
USP, Ribeirão Preto

Neuronal networks can present activity described by power-law distributed avalanches presumed to be a signature of a critical state. Here we study a random-neighbor network of excitable cellular automata coupled by dynamical synapses. The model exhibits a behavior very similar to conservative self-organized criticality (SOC) models even with dissipative bulk dynamics. This occurs because in the stationary regime the model is conservative on average, and, in the thermodynamic limit, the probability distribution for the global branching ratio converges to a delta-function centered at its critical value. So, this non-conservative model pertains to the same universality class of conservative SOC models and contrasts with other dynamical synapses models that present only self-organized quasi-criticality (SOqC). Analytical results show very good agreement with simulations of the model and enable us to study the emergence of SOC as a function of the parametric derivatives of the stationary branching ratio.
This work fits within the NeuroMat proposal because it models neuronal networks with the use of stochastic processes and describes neural systems as networks of large numbers of components linked by interactions that evolve in time and depend on the history of the system.
Collaborative work with Ariadne de Andrade Costa (Departamento de Física, FFCLRP, USP, Ribeirão Preto, SP) and Mauro Copelli (Departamento de Física, Universidade Federal de Pernambuco, Recife, PE). The paper was submitted (and is practically accepted) to *Journal of Statistical Mechanics*

Short Talk 18

Exploring Cerebellar Inhibition of the Motor Cortex in Stroke Patients

Rebeca Boltes Cecatto
USP, São Paulo

Transcranial magnetic stimulation (TMS) can be used to monitor brain plasticity. Beside this recent researches suggest that cerebellar plasticity could be related to functional motor recovery and motor learning after stroke. This study aims determine if cerebellar TMS parameters (as measure of motor threshold (MT), intracortical inhibition and cerebellar cerebral inhibition (CBI)) could be correlated with functional motor recovery after stroke. Methods: observational study with clinical motor functional and TMS evaluation of 8 to 19 patients who have suffered a unilateral ischemic motor cortical stroke up to 2 years before and after a motor rehabilitation program to perform a statistically dependence of clinical and cerebellar TMS parameters. This study is inserted within NeuroMat main goals, since it helps to understand and explain plasticity mechanisms underlying neurorecovery and adapted rewiring.

Short Talk 19

Effect of spike-timing dependent plasticity on functional connectivity and global activity of neocortical network models

Renan Shimoura
USP, Ribeirão Preto

Important open questions in neuroscience are how the dynamics of cortical activity patterns and the functional connectivity of the cortical network are affected by long-term synaptic plasticity. The objective of this work is to study the effect of spike-timing dependent plasticity (STDP) rules on the behavior of neural activity patterns in cortical network models. The idea is to measure changes in neural spiking patterns due to changes in synaptic connection strengths and to relate these to changes in the functional connectivity of the network as disclosed by graph-theoretic measures. Results of current studies will be presented, which include cases where STDP (i) causes an increase in the mean frequency of network activity, and (ii) facilitates emergence of a synchronous network state. This work interacts with NeuroMat because synaptic plasticity is thought to be the underlying mechanism behind learning and memory as well as neurorecovery after stroke and other brain damage or disease, which are among the main research foci of NeuroMat.

Short Talk 20

A cortical microcircuit model to study structure-activity relationships

Rodrigo F. O. Pena
USP, Ribeirão Preto

Most theoretical studies of cortical activity are based on networks of randomly connected units. In spite of the usefulness of these models, it is important to have models that try to accurately represent cortical network architecture. These models would allow a better understanding of the relationship between structure and activity in the cortex. Here, a recently proposed connectivity map of local cortical microcircuitry was used to construct a cortical model with 4000 neurons. The model contains eight neural populations distributed over four cortical layers. Parameter space investigation was used to tune the model to display activity patterns that are in agreement with experimental recordings. The model is being used to study structure-activity relationships and may be used by NeuroMat members as a toy model for the study of new neural and synaptic models.

Short Talk 21

Electroencephalographic changes in patients with incomplete spinal cord injury, who underwent treatment with robot-assisted gait training.

Thais Filippo
USP, São Paulo

PURPOSE: Robot-assisted gait training (RAGT) is a therapeutic intervention that can improve walking ability in patients with spinal cord injury (SCI), however the prognosis biomarker and the neuronal plasticity involved in this process needs to be better understand. Therefore, purpose of this study was to assess gait function and electroencephalography in SCI patients that underwent treatment with RAGT.
METHODS: Fifteen SCI subjects participated in 30-minute sessions 5 times weekly for 6 weeks. Patients underwent training with gradual increase in load and speed, according to the tolerance of each patient. The body support started at 50 % of the patient body weight, with progressive load increase of 10% of the patient body weight every 2 weeks. The progression of speed was accompanied during the training period. Walking capacity was assessed by the Walking Index for Spinal Cord Injury II (WISCI II), 10 Meter Walking Test (10MWT), Six-Minute Walk Test (6MWT), Berg Balance Scale (BBS) and Time Up and Go (TUG), and a major clinical evaluation of SCI rehabilitation-two times (before and after training). A 128 channels electroencephalogram (EEG) was used to record the rest state activity before and after intervention.
RESULTS: At the end of rehabilitation, the group showed a significant improvement in the score WISCI II, 6 MWT, BBS and TUG ($P<0.01$).
The ratio of the spectral potentials of the alpha and theta bands measure at the baseline was correlated with the improvement of motor function. Besides, changes in alpha theta ratio was correlated with motor function improvement.
CONCLUSION: Index of alpha theta ratio measure by EEG, may be a prognostic biomarker for SCI patients., however further studies are necessary. This study is inserted within NeuroMat main goals, since it helps to understand and explain plasticity mechanisms underlying neurorecovery and adapted rewiring.

Short Talk 22

Dependency between clinical assessment and kinematic variables assessed with robotic device

Thais Terranova

USP, São Paulo

There are several stroke rehabilitation trials discussing evaluation methods and these results of therapies aiming to improve motor function in upper limb. Consequently, it is important to have a reliable evaluation of the treatments in order to give an objective numerical value for abstract concept of disability and to determine the efficacy of the interventions to better understand the benefits of new approaches for clinical practice. Robotic devices recently have been used as systems for the evaluation since they record the kinematic and kinetic variables of upper limb movements. Our goal is to test the independency between clinical variables and the variables of the robotic device to propose a new method for evaluating the upper limb function. Among 41 stroke patients, robot measures predicts well the clinical measures favoring use of the robotic device for evaluation the recovery of upper limb function. This study is inserted within NeuroMat since here is demonstrated the use of new statistical approach to better understand the clinical data. Besides, an objective measure of motor function is essential to explain plasticity mechanisms related to clinical recovery.

Short Talk 23

EPILEPSY AND SLEEP : THE EFFECTS OF BRAIN NETWORKS.

Lucas Stolerman (IMPA, Rio de Janeiro), Roberto Imbuzeiro (IMPA, Rio de Janeiro) and Cláudio Queiroz (ICe-UFRN)

Recent works ([1]) have shown that rapid eye movement (REM) sleep and theta band oscillations are a strongly correlated to Temporal Lobe epileptic (TLE) seizures in experimental models with rats. Moreover, C. Queiroz and colleagues have recently found gamma distributions (not exponential) for the periods between REM sleep and TLE seizures. The mechanisms behind these experimental results are still unknown. In this work (in progress) we propose a modelling approach using Stochastic Dyamical Systems theory, and we suggest that functional and physiological Brain Networks plays a major role in explaining the susceptibility to seizures for some Epileptic Brains.

Short Talk 24

A continuous time stochastic model for biological neural nets

Leonardo Nagami Coregliano (USP, São Paulo)

We propose a new stochastic model for biological neural nets which is a continuous time version of the model proposed by Galves and Löcherbach in [A. Galves and E. Löcherbach, "Infinite systems of interacting chains with memory of variable length - a stochastic model for biological neural nets", J. Stat. Phys. 151 (2013), no. 5, 896-921.]. We also show how to computationally simulate such model for easy neuron potential decays and probability functions and characterize when the model has a finite time of death almost surely.