RIDC NeuroMat

Fifth Report of Activities

Jun 30, 2017 - Dec 30, 2018

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1 RIDC NeuroMat Identification

RIDC: Research, Innovation and Dissemination Center for Neuromathematics (NeuroMat)

Grant number: 2013/07699-0

Host institution: Instituto de Matemática e Estatística da Universidade de São Paulo

Associated institutions: CNRS; École Normale Supérieure de Paris; Gran Sasso Science Institute (GSSI); IBM Thomas J. Watson Research Center; Institute of Neuroscience and Medicine; Instituto de Matemática Pura e Aplicada (IMPA); National Institute of Neurological Disorders and Stroke (NIH); New York University Shanghai; Purdue University; Universidad de Buenos Aires, Argentina; Universidad de la Republica, Uruguay; Universidad de San Andrés, Argentina; Universidade Estadual de Campinas (UNICAMP); Univeridade Federal do ABC (UFABC); Universidade Federal da Bahia (UFBA); Universidade Federal de Minas Gerais (UFMG); Universidade Federal de Ouro Preto (UFOP); Universidade Federal de Pernambuco (UFPE); Universidade Federal do Rio de Janeiro (UFRJ); Universidade Federal do Rio Grande do Norte (UFRN); Universidade Federal do Rio Grande do Sul (UFRGS); Universidade Federal de São Carlos (UFSCar); Università di Roma "La Sapienza"; Université de Cergy-Pontoise; Université Paris Descartes; University of Carlifornia; University of Memphis; Princeton University; Universiteit Utrecht.

Webpage: http://neuromat.numec.prp.usp.br

Principal Investigator/Center Director: Jefferson Antonio Galves

Vice Director: Pablo Augusto Ferrari

Co-Principal Investigators: Antonio Carlos Roque da Silva Filho; Claudia D. Vargas; Ernst Hamburger (*in memoriam*); Fernando da Paixão; Jorge Stolfi; Oswaldo Baffa Filho; Pablo Augusto Ferrari

Education and Knowledge Dissemination Coordinator: Fernando Jorge da Paixão Filho

Technology Transfer Coordinator: Antonio Carlos Roque da Silva Filho

RIDC Executive Manager:

System analyst: Carlos Eduardo Ribas - IME/USP (Procontes)

Administrative assistant: Lourdes Vaz da Silva Netto - IME/USP; Vera Lúcia Ribeiro - IME/USP

Manager of Education and Dissemination of Knowledge:

Manager of Technology Transfer:

The Research, Innovation and Dissemination Center for Neuromathematics (RIDC NeuroMat) is a center of mathematics whose mission is to develop the new mathematics needed to construct a Theory of the Brain accounting for the experimental data gathered by neuroscience research. Mathematician Antonio Galves coordinates this center. Hosted by the University of São Paulo, the RIDC NeuroMat was established in 2013, with support from the São Paulo Research Foundation (FAPESP), grant 2013/07699-

0, and in November was renewed for a six-year term, from 2018 to 2024.

The RIDC NeuroMat has an interdisciplinary team, bringing together researchers in mathematics, computer science, statistics, neuroscience, biology, physiotherapy, medicine, physics and communication, among other disciplines. RIDC NeuroMat leads a worldwide university network, with ramifications that sprawl to several high-level research institutions in Brazil, Latin America, the United States and Europe (Annex 1). Most research output has had co-authors from more than one country, thus contributing to put NeuroMat at the center of a blossoming international scientific cooperation around Neuromathematics.

Alongside a research team that focuses on the scientific challenges pertaining to Neuromathematics, NeuroMat has active technology-transfer and dissemination teams. The technology-transfer effort is concentrated on devising renewed tools for diagnosing and clinical guidelines for neurological conditions, and on developing free, open-source computational tools to manage and compile experimental and clinical data. This development team is part of a joint effort to create an international open database for neuroscientific data. The dissemination-team effort includes a nonstatic web portal (Creative Commons license), open multimedia productions and training projects with public-school teachers. A distinctive feature of this effort is that it relies on web-2.0 media tools as a means of communicating on-the-go scientific endeavors as well as involving a scientific and broad community around bridging the high-level science that this RIDC develops and general audiences.

Pablo Augusto Ferrari (UBA and USP), Antonio Carlos Roque da Silva Filho (USP), Fernando Jorge da Paixão Filho (UNICAMP), Ernst Wolfgang Hamburger (USP, *in memoriam*), Jorge Stolfi (UNICAMP), Claudia Domingues Vargas (UFRJ), and Oswaldo Baffa Filho (USP) remain co-principal investigators, along with PI Antonio Galves (USP). David Brillinger (UCBerkeley), Francesco Guerra (Universita di Roma "La Sapienza"), Leonard Cohen (National Institute of Neurological Disorders and Stroke), Markus Diesmann (Jülich Institute of Neuroscience and Medicine), and Wojciech Szpankowski (Purdue and NSF Center for Science of Information) take part in NeuroMat's International Advisory Board. NeuroMat's main laboratory and offices are located on a three-story building, with approximately 1,000 square meters, at 1171 Prof. Luciano Gualberto Avenue, at USP's central campus, in São Paulo. NeuroMat's main building has recently gone through an extension (+175 square meters) and renovation to support new laboratory facilities; the construction cost was BRL R$ 1,603,339 and was fully covered by USP, MaCLinC grant (recipient: Antonio Galves). NeuroMat has set up a Simulation Laboratory at the USP's Ribeirão Preto campus. NeuroMat's administrative staff team is composed of two administrative assistants and an IT professional. These positions are supported by USP.

2 Scientific report

2.1 Mission

The mission of NeuroMat is to develop the new mathematics which is deemed necessary to account for a Theory of the Brain, accounting for the full experimental data gathered by neuroscience research. The long-term objective is to understand and explain complex neuroscientific phenomena, with focus on plasticity mechanisms underlying learning and memory neurorehabilitation and rewiring. This Neuromathematics is envisioned, at this time, as conjoining probability theory, combinatorics, statistics, and neuroscience. This requires the definition of a full new class of mathematical models to describe and explain in a parsimonious way the different scales of neural activity and the relationship between them. The construction of these models should occur together with the development of suitable statistical and computational methods, including model selection principles and results.

2.2 Executive summary

The main goal of NeuroMat is to build the new mathematical, statistical and computational framework which is necessary to address the challenges of neurobiology. Activities presented in this report strictly relate to the goals announced in the document submitted to FAPESP in November 2012, in the third and final step of the selection process. The general goals of this research project are the following:

- Development of new classes of stochastic processes which are necessary to model brain functioning;
- Development of the statistical tools required by this new class of stochastic processes.

Detailed progresses on these two goals were exhaustively reported in the documents "First Report of Activities 2013-2014", "Second Report of Activities 2014-2015", "Complementary Form 2013-2015", the Evaluation by FAPESP International Committee in November 2015, "Third Report of Activities 2015-2016," the "Complementary Form 2015-2017," "Fourth Report of Activities 2016-2017," the presentation "NeuroMat: first 5 next 6" to FAPESP's International Assessment Committee, and the 2018 Statement of Impact. These documents were carefully reviewed by FAPESP. The latter, the SoI, is a summary of main activities and highlights our main achievements. This statement is still up-to-date and informs substantially this report, along with relevant parts of the document for the renewal of the RIDC NeuroMat by FAPESP, the "Project for the period 2018-2024."

The progresses achieved in the first term of the RIDC have opened up the path for a new stage of development. In the last year, the object of this report, NeuroMat started the construction of innovative applications of the new stochastic models and statistical tools developed in the previous years,

aiming at concrete questions of Neuromathematics and computational modeling in neurobiology, electroencephalographic recordings analysis, and neurorehabilitative therapy. Research highlights and corresponding published works are listed below, in the appropriate section. Since the "Fourth Report of Activities 2016-2017", the NeuroMat research team has:

- published 44 papers;
- submitted or uploaded to arXiv 28 papers;
- had 8 communications in meetings with referee

NeuroMat scientific publications in the period being assessed in this report are listed on Annex 2. A full list of publications since the inception of NeuroMat can be viewed at NeuroMat's Google Scholar (https://goo.gl/LvZV4f). Citations to these publications across the years are available on Annex 3.

In parallel to the mathematical and theoretical biological developments which are necessary to foster the scientific project of NeuroMat, the RIDC has also sustained two laboratories. In April 2016, NeuroMat launched a new research facility: the NeuroMat Simulation Laboratory. The simulation of large-scale network models remains a key activity to test analytical results, and the NeuroMat SimLab allows for such tests, providing the NeuroMat team with a new experimental tool to test and construct large-scale computational implementations of NeuroMat newly developed models (over 100,000 neurons). The NeuroMat SimLab is installed at the Laboratory of Neural Systems (SisNe) of the Department of Physics of USP Ribeirão Preto, under the direction of NeuroMat PI and Technology transfer coordinator A.C. R. da Silva Filho (USP-Ribeirão Preto). In July 2017, NeuroMat launched an Electroencephalography Laboratory, with an EEG DC actiCHamp 128CH System. The creation of NeuroMat's EEG lab was made possible by the expansion of the building, through a grant from the University of São Paulo (value of support: BRL R$ 1,603,339).

2.3 Research results highlights

The most general challenge the NeuroMat team faces is the development of new classes of probabilistic models to study different aspects of brain functioning. As presented on the 2018 Statement of Impact:

"A main scientific achievement was the introduction by the NeuroMat team of a new class of stochastic processes aimed at a realistic description of nets of spiking neurons. These processes are systems with infinitely many interacting chains with memory of variable length. Since their introduction, these stochastic processes have become part of the research agenda of several centers in the world.

Our contributions to the investigation of this new class of stochastic processes include:

- the identification of mathematical conditions assuring the existence of the processes together with the design of a perfect simulation algorithm for their numerical implementation;

- results on the hydrodynamical limit of processes belonging to the class. This is an important step to relate different scales of description of the system, from the microscopic level, modelling systems of spiking neurons, to the mesoscopic and macroscopic levels, describing EEG and fMRI data;

- existence of phase transition for a specific instantiation of these models with leakage, setting a new framework for the rigorous investigation of spontaneous transitions of brain activity states, e.g. healthy to seizure-like activity. This is the first phase transition result rigorously proved for a mathematical model describing a system of interacting spiking neurons;

- introduction of a novel estimator of the interaction graph for models in this class and the proof of its strong consistency, not requiring the usual assumptions of stationarity and uniqueness of the invariant measure. This contribution addresses an important issue in contemporary neurobiology, namely the question of how to infer neural interactions from the activity of an ensemble of neurons.

A second major achievement is the introduction of a new mathematical approach to address the classical conjecture that the brain retrieves statistical regularities from sequences of stimuli. This approach is based on a new class of stochastic processes, namely sequences of random objects driven by chains with memory of variable length. These processes appear as good candidates to model the relationship between sequences of stimuli and sequences of suitably parsed brain signals and behavioral states registered while exposed to stimuli.

This framework offers a new way to model structural learning and memory in the brain, including the following promising directions of research:

- It provides an effective way to identify brain sensitivity and reaction to sequences of stimuli which goes much beyond the possibilities offered by current averaging-based methods;

- As a consequence, it allows the introduction of a entire new class of experimental protocols in which physiological or behavioral data are recorded while a volunteer is exposed to sequences of stimuli generated by a stochastic chain with memory of variable length;

- This approach offers promising perspectives in clinical neuroscience by identifying different signatures in response to structured sequences of stimuli in neurological disorders;

From a purely statistical point of view, sequences of random objects driven by chains with memory of variable length constitute an innovative tool in functional data analysis and high dimension statistics."

An ongoing list of project along the lines presented above include:

- Hebbian time evolution for the interaction graph of a network of spiking neurons

- Statistical analysis of stochastic processes

- Simulation laboratory scientific project
- Phase transitions, criticality and oscillations in stochastic neuronal networks
- Structural learning and decision making
- Modeling the plasticity in the brain after a traumatic brachial plexus injury in adults
- Instrumentation issues to address brain plasticity: the state of the art
- Stochastic modeling of spatio-temporal patterns of epileptic seizures
- Random networks for the brain
- Random graphs and computational psychiatry

These research directions are elements within the general challenge the NeuroMat team faces: the development of new classes of probabilistic models to study different aspects of brain functioning. This general challenge has been associated to: developing a new class of stochastic processes describing nets of spiking; making steps towards a mathematical and statistical framework to formulate the phenomenon of brain plasticity; and developing stochastic models, statistical procedures and neurobiological experimental protocols to address the classical conjecture of the Statistician Brain. Specific summaries of the research directions within the NeuroMat agenda may be found at the NeuroMat website.

2.4 Scientific meetings organized by NeuroMat in the period

An important aspect of the work NeuroMat produces depends on fostering a tight relationship among members of the NeuroMat worldwide. As emphasized in our interaction with FAPESP International Committee, we are especially aware of this challenge, and we have sustained partnerships among scientists from different parts of the world —of which the high rate of papers with co-authors from different countries is an evidence. The fostering of a tight community around Neuromathematics strongly meets the expectations of FAPESP's Committee.

A key part of the community-building entrepreneurship NeuroMat has sustained relates to organizing frequent conferences and meetings on topics pertaining to Neuromathematics. In October 2017, NeuroMat held the workshop "Random Structures in the Brain". The workshop was organized as a setting for a general discussion on NeuroMat's achievements and prospective activities and as an opportunity for sparking new directions for the RIDC working groups in research, technology transfer and scientific dissemination. A main goal was to provide a sense of scientific challenges the NeuroMat team faces ahead. Link for this event is neuromat.numec.prp.usp.br/rsbrain. In October 2018, NeuroMat held the workshop "Mathematical and Simulation Modeling in Neuroscience". This event was an opportunity to

discuss the research projects and to present the achievements and current results of the NeuroMat Simulation Laboratory (SimLab). In particular, two challenging scientific questions were debated: (1) how the analytical results obtained by NeuroMat researchers can be validated by simulations of large-scale neuronal networks? and (2) how the theoretical and simulation work conducted by NeuroMat can help to deepen the understanding of the relative influences of intrinsically and network-generated stochasticity on single neuron activity in the brain? Link for this event is neuromat.numec.prp.usp.br/matsim.

2.4.1 Research events & seminars

During the period of activities being reported in this document, the NeuroMat team has also taken part in smaller-scale research events and seminars. An illustration is the I Working Meeting of the NeuroMat SimLab, held in December, 2018 and the Workshop in Bioinformatics and Algorithms, held in June, 2018. NeuroMat's seminars compilation is attached to this report as Annex 9.

3 Technology transfer report

The development of two neuro-rehabilitation and diagnosis initiatives, directed to Parkinson's Disease (AMPARO) and Brachial Plexus Injuries (ABRAÇO), has been a main focus area of activity. Both initiatives took advantage of a computational tool NeuroMat had previously developed, namely the Neuroscience Experiments System (NES). Recent developments of NES and the NeuroMat Open Database have been oriented towards the needs of AMPARO and ABRAÇO.

During the period assessed in this report, NeuroMat has continued the development of a new tool for neuro-rehabilitation and diagnosis, the Goalkeeper Game. This tool is a direct result of the theoretical and experimental research developed by NeuroMat around brain functioning. By doing this NeuroMat reaches one of its main goals, which is to produce new technology based on new scientific results.

3.1 Neuro-rehabilitation and diagnosis

3.1.1 AMPARO Initiative

The NeuroMat focus area towards Parkinson's Disease is called AMPARO Initiative, or Rede de Apoio NeuroMat a Amigos e Pessoas com Doença de Parkinson. Link for the website is amparo.numec.prp.usp.br.

3.1.1.1 A tool for early Parkinson's Disease diagnosis The team led by NeuroMat researcher Maria Elisa Pimentel Piemonte (FM-USP) is using the Goalkeeper Game (see Section 3.2.1) to study putative novel relationships between the main cardinal Parkinson's Disease symptom, bradykinesia, and implicit probabilistic learning and lack of ability in automatic motor control. The study aims at developing a new measure and typology to establish the limits between normal decline associated to aging process and abnormal alterations associated the onset of the pathological process of Parkinson's Disease. The clinical implication of this work is to offer a free and friendly test to early diagnosis of Parkinson's Disease by e.g. cell phones using the Goalkeeper Game. A pilot with 48 patients was conducted in 2016-2017. A first paper on results associated to this work is currently under review.

3.1.1.2 Collaborative network for Parkinson's Disease clinical guideline AMPARO Initiative organizes monthly meetings with NeuroMat members, professionals, patients and caregivers. The goal is to share knowledge towards the collaborative building of guidelines for Parkinson's Disease in Brazil, especially for the public health system. Comments are also gathered through online interactions and web surveys, as meetings are video streamed. Relevant early findings suggest the need to build instructions for clinical professionals, such as easing diagnosis and collaborating with an interprofessional team, and caregivers, especially around motricity, sleep and emotional support. Summaries of meetings are being produced as educational resources.

3.1.2 ABRAÇO Initiative

NeuroMat's Brachial Plexus Injuries focus area is called ABRAÇO Initiative, or Ação NeuroMat para a Lesão do Plexo Braquial. A reference website may be found at: abraco.numec.prp.usp.br. This website is the first worldwide platform devoted to this health condition and is aimed at being both a source of help and support for patients, caregivers, students and professionals, and a powerful scientific knowledge sharing platform.

3.1.2.1 Assessing plasticity associated to Brachial Plexus Injuries The team led by NeuroMat CO-PI Claudia Domingues Vargas (INDC/UFRJ) is using the Goalkeeper Game (Section 3.2.1) to study mechanisms of plasticity in the brain after a brachial plexus injury aiming at developing new tools to assess plastic changes in the brain induced by this traumatic injury. In the motor context, prediction can be seen as an automatic process of choosing and implementing a next step in a sequence of events. Tests are being conducted with human subjects playing the Goalkeeper Game to determine which parameters of the context tree generating stochastic sequences of events in the Goalkeeper Game are best associated with the optimal processing of sequences of motor events. The objective is to check the possibility of using the Goalkeeper Game as a tool for rehabilitation of brachial plexus injury patients. Data of these patients have fed NeuroMat's database.

A major progress was the expansion of the core team of this initiative, which has expanded its work frame. ABRAÇO was joined by:

- Clarice Tanaka, Full Professor of the Department of Physical Therapy, Speech Therapy and Occupational Therapy, Faculty of Medicine, University of São Paulo, and Service Director in the Physical Therapy Division of the Central Institute of the Hospital das Clínicas of the Faculty of Medicine, University of São Paulo;

- Abrahão Fontes Baptista, Associate Professor I of the Center of Mathematics, Computing and Cognition at the Federal University of ABC.

3.2 Computational tools

3.2.1 Goalkeeper Game

NeuroMat researchers devised experimental protocols to test the performance of human subjects in identifying sequences of stimuli represented by context trees. An innovation spin-off from NeuroMat's research project is the "Goalkeeper Game". It is an online game with desktop and mobile device versions in which the player, taking the role of a goalkeeper in a penalty shootout, guesses the position in the goal where the ball will hit (left side, right side or center) after being kicked by the opponent. The game consists in a sequence of penalty kicks in which the ball positions are generated by a context tree model. As

the player (the goalkeeper) succeeds in guessing the right sequence, the complexity of context tree model increases and the game becomes more difficult. The goalkeeper game has potential to be used as diagnosis and rehabilitation tool in neurology, and the NeuroMat technology transfer team is currently testing its applicability in its two main clinical development fronts: Parkinson's Disease and Brachial Plexus Injuries (see Sections 3.1.1.1 and 3.1.2.1). The game is openly, freely available at: game.numec.prp.usp.br and also at Apple Store and Google Play. The development team of the Goalkeeper Game is led by Marcos Dimas Gubitoso (IME/USP).

3.2.2 Neuroscience Experiments System

The Neuroscience Experiments System (NES) is a free software to manage data and metadata from neuroscience experiments. It integrates data records from different types such as clinical, electrophysiological, and behavioral. NES is currently being used by the teams involved in both ABRAÇO (Section 3.1.2) and AMPARO (Section 3.1.1) initiatives. NES is integrated to the Goalkeeper Game (Section 3.2.1) and to the NeuroMat Open Database (Section 3.2.3). The main functionalities, which include Electrophysiology and Export modules, were improved since August, 2017, and modules that deal with the data using machine learning are being developed. The development team of the Neuroscience Experiments System is led by Kelly Rosa Braghetto (IME/USP).

3.2.3 NeuroMat open database

The NeuroMat open database provides an open-access platform for sharing and searching data and metadata from neuroscience experiments. The platform is constituted by a web portal and a REST (Representational State Transfer) API (Application Programming Interface). The web portal was designed to have a user-friendly interface. The REST API is used to feed the open database with experimental data generated by NeuroMat's researchers. Currently, the API intermediates the receiving and retrieving of data from research laboratories which use NES (Section 3.2.2). It can be can easily adapted to receive (or transfer) data from (for) other client systems. The development team of the NeuroMat open database is led by Kelly Rosa Braghetto (IME/USP).

Link to the NeuroMat Open Database webpage: neuromatdb.numec.prp.usp.br.

4 Dissemination report

NeuroMat's dissemination activities have as guideline to work as a collaborative web-2.0 hub, developing web-2.0 media tools as a means of communicating on-the-go scientific endeavors as well as involving a scientific and broad community around the high-level science that this RIDC develops. As stated on the 2018 Statement of Impact: "NeuroMat's activities in science dissemination use innovative means to transform scientific culture, overcoming artificial field boundaries and contributing to foment an integrated and genuinely multidisciplinary approach to the study of the brain."

The dissemination team is committed on the development of a new language for NeuroMat's communication and education efforts, so as to bring the scientific frontier to general audiences. As part of this effort, the dissemination team creates its own media, like the Web Portal and the newsletter, promotes educational activities in schools and invests in the use of collaborative electronic platforms, like Wikipedia, to improve science contents available to the public. NeuroMat's dissemination activities are:

- the Wikipedia Initiative
- the Wikimedia Commons Initiative
- Training course for teachers
- Media Exposure and Newsletter
- Web resources: portal, Facebook page, dissemination blog
- NeuroCineMat

4.1 Wikipedia Initiative

NeuroMat's Wikipedia Initiative has become a strategic activity at the interface of communication and education. It has been recognized in Brazilian and foreign outlets as "success case" of the use of Wikipedia and other collaborative projects as a means of scientific dissemination.

Main achievements are:

- 26.4 million content viewers in Portuguese Wikipedia;
- 33.2 million words added to Portuguese Wikipedia;
- 25 thousand entries created on Wikimedia projects; and
- 45 thousand entries improved on Wikimedia projects.

The control panel of the NeuroMat Wikipedia Initiative is available at: campaigns/neuromat/programs.

4.2 Wikimedia Commons Initiative

NeuroMat has been engaged in uploading media files to the open repository Wikimedia Commons. As of December 2018, 27.6 thousand files had been uploaded by the NeuroMat team in this repository.

Files NeuroMat added to Wikimedia Commons were viewed 7,687,538 times in November 2018. This figure is obtained from the web visualization control tool GLAMorgan (https://goo.gl/U6V7e4).

4.3 Media Exposure and Newsletter

Activities from FAPESP'S RIDC NeuroMat were featured in seventy six external media outlets since its inception, in 2013. Since July 2017, there have been ten media publications. Coverage from FAPESP and USP media outlets have been continuous.

NeuroMat's media clipping for this year is attached to this report as Annex 4. NeuroMat's newsletter has had 58 issues since it was first released in February 2014. It runs monthly, generally being sent to subscribers at the end of each month. It is distributed to around 703 people, always in English. NeuroMat's newsletter compilation is attached to this report as Annex 5.

4.4 Web resources: portal, Facebook page, dissemination blog

NeuroMat's web portal was launched in early February 2014, and is thought of as the main official reference of the RIDC. It provides robust updates on research, technology transfer and dissemination activities. Publications are in English and Portuguese. 26,572 different users —53,64% of whom were identified as non-Brazilian users– have visited NeuroMat's webpage since its inception, with 137,608 page views, as of December, 2018. Average session duration was 3 minutes and 11 seconds, with a bounce rate of 51,65%. A website analytics report is attached as Annex 6.

NeuroMat's Facebook page was launched in September 2014 to serve as a reference space for the diverse community that is involved with and interested in Neuromathematics. Since its creation (9/20/2014), the page has reached 1,175 followers, as of December 10, 2018, with steady progress. The community growth has been organic.

Since April 2016, the NeuroMat dissemination team has sustained a blog on scientific challenges and activities pertaining to science communication, especially relying on web-2.0 platforms. The blog is called "Traço de Ciência." The blog has been viewed 17,333, since its inception as of September, 2016. 370 posts were published on this platform in the period of activities that is reported in this document; this figure is illustrated on Annex 7.

References are:

- web portal: neuromat.numec.prp.usp.br
- Facebook page: www.facebook.com/neuromathematics
- blog: difusaoneuromat.wordpress.com

4.5 NeuroCineMat

The NeuroMat dissemination team has fully produced five movies—on the exhibition "Inside the Brain", NeuroMat's Network on Brachial Plexus Injuries, Ernst Hamburger, Open Science, and on Tycho Brahe, Johannes Kepler and the Open Science video. A full list is available on: neuromat.numec.prp.usp.br/streaming

4.6 Research on Communication Science

The NeuroMat dissemination team has presented nine conference papers, included in the annals of the Congresso Brasileiro de Ciências da Comunicação, COMPÓS and ABCiber. Research output is presented on the general documentation on publications.

5 Annexes

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Annex 2 - NeuroMat Scientific Publications

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