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PROJECT #1 / TEAM LEADER: ANETA LISOWSKA / A.LISOWSKA@SANOSCIENCE.ORG

/ [GITHUB ANLI66]()

PERSUASIVE TECHNOLOGY FOR DIGITAL BEHAVIOR CHANGE INTERVENTION

DIGITAL BEHAVIOUR INTERVENTION, WEARABLE, MACHINE LEARNING, M-HEALTH, PERSONALISATION

ABSTRACT:

Behavior change strategies aim to modify health risk behaviors such as physical inactivity, unhealthy eating and substance abuse to prevent the development of chronic diseases [1] and improve individuals physical and mental well-being [2]. Ubiquitous availability of mobile phones paired with wearable devices provides an opportunity for provision of digital behavior change interventions (DBCI). The effectiveness of DBCI depends on individuals adherence to the intervention. To facilitate adherence, it is important to provide the right support at the right time. The adequate support may include tailored content of notifications and personalised activity suggestions. The right time not only reflects the literal time of the day, but also takes into account the context of the individual (both internal, e.g. emotional state, and external, e.g. location). Machine learning methods can be used both to understand the patient's internal context (e.g., classify emotions based on a signal captured by the wearable device [3]) and to personalize an intervention (e.g., tailor notification timing [4]). Brain hack participants will have the opportunity to develop methods that facilitate behaviour change. This may include predicting adherence to the

activity suggestions, classifying emotional state from consumer-grade wearable1 and finding the conditions under which individuals are responsive to ’nudges’. The solutions to these problems may rely on simple statistical models or on more advance deep learning approaches. A successfully developed solution can be published and potentially even applied in real-life study!

[1] Dietz, W.H., Brownson, R.C., Douglas, C.E., Dreyzehner, J.J., Goetzel,R.Z., Gortmaker, S.L., Marks, J.S., Merrigan, K.A., Pate, R.R., Powell,L.M., et al.: Chronic disease prevention: Tobacco, physical activity, andnutrition for a healthy start: A vital direction for health and health care.NAM Perspectives (2016)
[2] Dale, H., Brassington, L., King, K.: The impact of healthy lifestyle inter-ventions on mental health and wellbeing: a systematic review. MentalHealth Review Journal (2014)
[3] Lisowska, A., Wilk, S., Peleg, M.: Catching patient’s attention at the righttime to help them undergo behavioural change: Stress classification exper-iment from blood volume pulse. In: International Conference on ArtificialIntelligence in Medicine, pp. 72–82 (2021). Springer
[4] Lisowska, A., Wilk, S., Peleg, M.: From personalized timely notificationto healthy habit formation: A feasibility study of reinforcement learn-ing approaches on synthetic data. In: Proceedings of the AIxIA 2021SMARTERCARE Workshop, CEUR-WS, pp. 7–18 (2021)
[5] Pinder, C., Vermeulen, J., Cowan, B.R., Beale, R.: Digital behaviourchange interventions t o break and form habits. ACM Transactions onComputer-Human Interaction (TOCHI)25(3), 1–66 (2018)
[6] Eyal, N.: Hooked: How to Build Habit-forming Products. Penguin, ???(2014)
[7] Kahneman, D., Sibony, O., Sunstein, C.R.: Noise: a Flaw in HumanJudgment. Little, Brown, ??? (2021)
[8] Sapolsky, R.M.: Behave: The Biology of Humans at Our Best and Worst.Penguin, ??? (2017)
[9] Fogg, B.J.: Tiny Habits: the Small Changes that Change Everything.Eamon Dolan Books, ??? (2019)
[10] Shah, R.V., Grennan, G., Zafar-Khan, M., Alim, F., Dey, S., Ramanathan,D., Mishra, J.: Personalized machine learning of depressed mood usingwearables . Translational Psychiatry11(1), 1–18 (2021)
[11] Saganowski, S., Kazienko, P., Dziezyc, M., Dutkowiak, A., Polak, A., Dzi-adek, A., Ujma, M.: Review of consumer wearables in emotion, stress,meditation, sleep, and activity detection and analysis. arXiv preprintarXiv:2005.00093 (2020)

LIST OF MATERIALS:

The reading is aimed only as an inspiration (a bit of context for a project) and of course is not obligatory pre-requisite for participation.

• People after biology or psychology degree might like: Paper: [5], Books: [6–9] , Podcast: HubermanLab Podcast (episode ”Build strong habits”)

• People after electrical engineering or computer science degree could have a look at: Papers [10, 11], Presentation: Reinforcement Learning in Production

LIST OF REQUIREMENTS FOR TAKING PART IN THE PROJECT:

1-3 people with bio-med background (including psychology, cognitive science) and knowledge of statistics (Regression, Tests of Significance, ANOVA etc.), 1-3 people with math or computer science background and knowledge of machine learning (SVM, Random Forest, Convolutions Neural Networks, Q-Learning), 1-3 people with physics or engineering background and knowledge of signal denoising approaches. Programming language of choice: Python.

MAXIMAL ALLOWED NUMBER OF TEAM MEMBERS: 9

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PROJECT #2 / TEAM LEADERS: ALESSANDRO CRIMI, JOAN FALCO ROGET
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/ GITHUB ALECRIMI

MULTIMODAL RESERVOIR CAUSALITY FOR EFFECTIVE BRAIN CONNECTIVITY

ABSTRACT:

The relationship between structure and function is of interest in many research fields involving the study of complex biological processes. In neuroscience in particular, the fusion of structural and functional data can help to understand the underlying principles of the operational networks in the brain. Dynamical causal model and Granger causality have been used in this context to define effective connectivity. Despite the success, those tools have received criticisms as being just predictors of temporal correlation (and not really perturbation based). More recently, new models are emerging from chaos theory and attractors representations. Among those causal representations convergent cross mapping (CCM) is the one receiving a lot of interest in biology

and zoology. However, CCM is so far limited to couples of signals/behaviors. In this project we want to investigate this approach for multivariate relationships using recurrent neural networks.

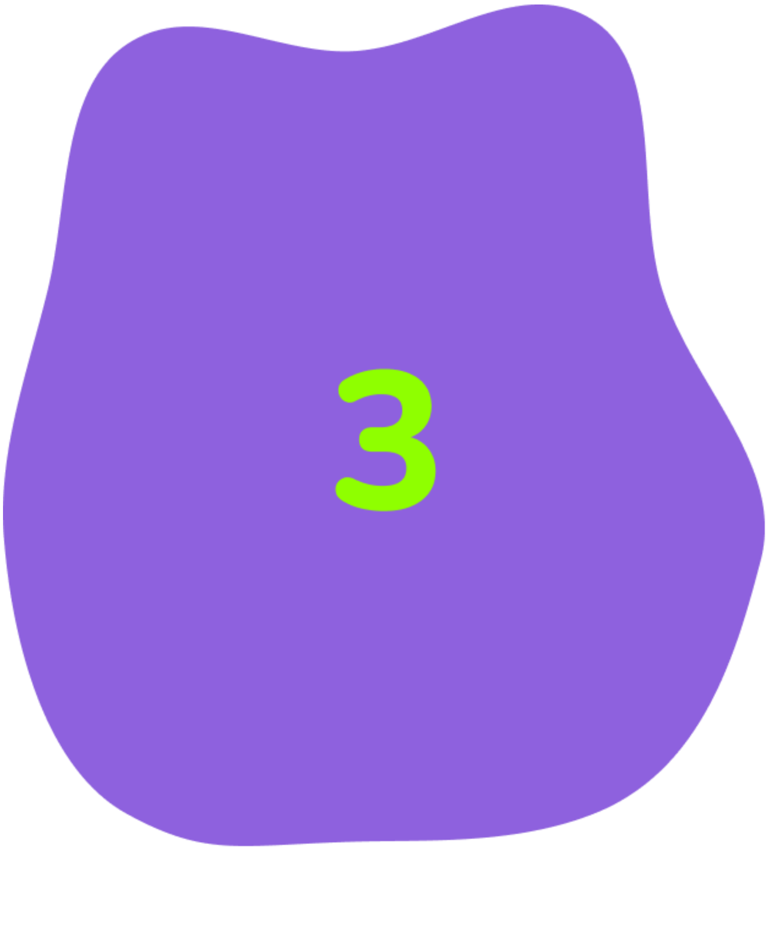
LIST OF MATERIALS:

[1] Structurally constrained effective brain connectivity, Crimi et al. Neuroimage 2021
https://www.sciencedirect.com/science/article/pii/S10538119210 05644
[2] Detecting Causality in Complex Ecosystems Sugihara et al. Science 2012.
https://cdanfort.w3.uvm.edu/csc-reading- group/sugihara-causality-science-2012.pdf
[3] Systematic identification of causal relations in high- dimensional chaotic systems: application to stratosphere- troposphere coupling. Huang et al. Climate Dynamics. 2020 Nov;55(9):2469-81.

LIST OF REQUIREMENTS FOR TAKING PART IN THE PROJECT:

Participants should be knowledgeable on Python programming. Signal theory, dynamical system is an asset Neuro anatomy and physiology is welcome.

MAXIMAL ALLOWED NUMBER OF TEAM MEMBERS: 8



/ GITHUB JOANSANO

NETWORK SIMILARITIES ACROSS BRAIN FOCAL LESIONS

ABSTRACT:

With adequate mathematical and computational methods brain networks can be reconstructed from Magnetic Resonance Images (MRIs) opening the gates for meaningful statistical studies about several brain deseases (e.g. stroke, tumor, alzheimer, ...) In this project we will focus on finding structural similarities between brain networks suffering from stroke and tumors. Possible approaches include network statistics, statistical connectomics and topological data analysis. Next steps would include inferences on common cognitive impairments between the groups.

LIST OF MATERIALS:

[1] - Jeurissen, B., Descoteaux, M., Mori, S., & Leemans, A. (2019). Diffusion MRI fiber tractography of the brain. NMR in Biomedicine, 32(4), e3785.
[2] - Faskowitz, Joshua, Richard F. Betzel, and Olaf Sporns. "Edges in brain networks: Contributions to models of structure and function." Network Neuroscience 6.1 (2022): 1-28.
[3] - Rubinov, Mikail, and Olaf Sporns. "Complex network measures of brain connectivity: uses and interpretations." Neuroimage 52.3 (2010): 1059-1069.
[4] - Chung, Jaewon, et al. "Statistical connectomics." Annual Review of Statistics and Its Application 8 (2021): 463-492.
[5] - Centeno, Eduarda Gervini Zampieri, et al. "A hands-on tutorial on network and topological neuroscience." Brain Structure and Function (2022): 1-22.

LIST OF REQUIREMENTS FOR TAKING PART IN THE PROJECT:

Python
Mathematics
Complex Systems (optional)

MAXIMAL ALLOWED NUMBER OF TEAM MEMBERS: 5

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PROJECT #4 / TEAM LEADERS: ADAM SOBIESZEK, HUBERT PLISIECKI
/ AW.SOBIESZEK@STUDENT.UW.EDU.PL

/ GITHUB ADAMSOBIESZEK

SIGNAL SPACE GENERATIVE ADVERSARIAL NETWORKS FOR MODELLING EEG BRAIN ACTIVITY AND PREDICTING EMOTIONAL DECISIONS

ABSTRACT:

We recently proposed an architecture for generating EEG signals called a Signal Space Generative Adversarial Network (SigS-GAN), that learns a latent space representation of the signals it was trained on. We impose a regularization on these latent representations of signals, which makes them useful for understanding and predicting the processes that were visible in the EEG activity.

The regularization (which is an extension of Path-Length Regularization to the frequency domain) encourages the learning of a latent space where a distance between two points approximately corresponds to a measure of distance between the two signals that would be generated if we were to put these points into the generator. This is useful as it (a) adds smoothness to the representation, such that signals that are similar correspond to points that are near each other, (b) directions in latent space start to correspond to useful features of the signals, which makes it easier to describe and perform classification, (c) you can use such a latent space in order to perform a new kind of EEG analysis, where you analyze, in the latent space, the differences between point corresponding to signals that, for example, lead to two different decisions.

The goal of this project is to develop the architecture, and create the analysis methods and tool needed to pursue this last opportunity (c) for a new way of EEG analysis. We will brainstorm what modification to the present architecture would make a latent space analysis of EEG signals easier and more fruitful. Implement them, and train the networks on several different datasets of ERP studies, where participants made different types of decisions based on a processing of emotional words. Next we will apply the developed methods in order to explain what differences in electrical activity correlated with different decisions and try to predict them on data unseen by the model. The techniques developed as a part of this project could lead to a scientific publication.

LIST OF MATERIALS:

[1] Path-Length Regularization:
https://paperswithcode.com/method/path-length-regularization
https://arxiv.org/pdf/1912.04958.pdf

[2] EEG and GANs:
https://arxiv.org/abs/1806.01875
https://www.sciencedirect.com/science/article/abs/pii/S0208521621001273?via%3Dihub

LIST OF REQUIREMENTS FOR TAKING PART IN THE PROJECT:

- Either knowledge of python (we'll use PyTorch for the neural net) or mathematics (linear algebra, multi-variate calculus), as we'll spend some time working out Fourier-analysis-based regularization terms and statistical approaches to the analysis of a trained latent space.

- It is not required to be proficient in the topics discussed in the abstract (GANs, path-length regularization, latent space representations), as we will spend some time at the beginning of the project acquainting ourselves with them.

MAXIMAL ALLOWED NUMBER OF TEAM MEMBERS: 10

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PROJECT #5 / TEAM LEADERS: MONIKA PYTLARZ, SYLWIA MALEC
/ M.PYTLARZ@SANOSCIENCE.ORG

/ GITHUB OCTPSMON

RENAISSANCE OF DIFFUSION MODELS – DO THEY REALLY BEAT GANS? STAIN STYLE TRANSFER AND DATA AUGMENTATION FOR BRAIN HISTOLOGY IMAGES.

ABSTRACT:

Assessment of brain tissue can be more precise by combining different histology stainings. Generating digital fluorescence histology would be beneficial, because of fewer artifacts and easier diagnostic recognition than on grayscale images. Staining style transfer is also widely used for the normalization task compensating for variability occurring during the sample preparation. The goal is to implement a transfer style (or data augmentation and transfer style) for generating histology images of different staining. Recent studies describing the renaissance of diffusion probabilistic models suggest that they can prove to be superior to variations of GANs within the transfer style and data augmentation. In the case of researching brain pathologies, we are facing the challenge of lacking publicly available big histology datasets and benchmarks. Data augmentation helps overcome the challenge of small sample size settings, improves the model prediction accuracy, and reduces data overfitting. The aim of the project is to compare these two competitive neural networks – the diffusion model vs GAN – and to determine the winner in the scope of the specified domain.

LIST OF MATERIALS:

Diffusion models:

1. Hiroshi Sasaki, Chris G. Willcocks, Toby P. Breckon. „UNIT-DDPM: Unpaired Image Translation with Denoising Diffusion Probabilistic Models", 2021.
2. Yang Song, Stefano Ermon. „Generative Modeling by Estimating Gradients of the Data Distribution", 2019.
3. Prafulla Dhariwal, Alex Nichol. „Diffusion Models Beat GANs on Image Synthesis", 2021.

Cycle-GAN:

1. Jun-Yan Zhu, Taesung Park, Phillip Isola Alexei A. Efros. „Unpaired Image-to-Image Translation using Cycle-Consistent Adversarial Networks", 2020.

Stain style transfer:

1. M. T. Shaban, C. Baur, N. Navab and S. Albarqouni, "Staingan: Stain Style Transfer for Digital Histological Images," 2019 IEEE 16th International Symposium on Biomedical Imaging (ISBI 2019), 2019, pp. 953-956, doi: 10.1109/ISBI.2019.8759152.
2. Tanishq Abraham, Andrew Shaw, Daniel O'Connor, Austin Todd, Richard Levenson. „Slide-free MUSE Microscopy to H&E Histology Modality Conversion via Unpaired Image-to-Image Translation GAN Models". 2020.
3. Lee J-S, Ma Y-X. Stain Style Transfer for Histological Images Using S3CGAN. Sensors. 2022; 22(3):1044. https://doi.org/10.3390/s22031044.
4. Izadyyazdanabadi M, Belykh E, Zhao X, et al. „Fluorescence Image Histology Pattern Transformation Using Image Style Transfer". Front Oncol. 2019;9:519. Published 2019 Jun 25. doi:10.3389/fonc.2019.00519.

LIST OF REQUIREMENTS FOR TAKING PART IN THE PROJECT:

python programming, machine learning, deep learning skills; familiarity with generative adversarial networks, basic knowledge about above mentioned medical imaging modalities may be also useful

MAXIMAL ALLOWED NUMBER OF TEAM MEMBERS: 9

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PROJECT #6 / TEAM LEADER: BARTEK KRÓL-JÓZAGA / KROLJOZA@AGH.EDU.PL

/ [GITHUB BARTEKKROL96]()

ANALYSIS OF LC ACTIVITY DURING THE DECISION-MAKING PROCESS BASED ON CHANGES IN PUPIL SIZE

ABSTRACT:

A high-level cognitive process of decision making (DM) among desirable alternatives requires coordination of distinct cortical and subcortical areas. Computational models can be used to understand these processes, but many of the existing ones focus on simulating only one of the many parallel operations. The existing holistic spiking neural model (https://doi.org/10.5281/zenodo.4280963), which addresses the problem of simulation DM will be our starting point to examine emotional arousal on DM.

The aim of this project will be first to extend the existing model with a population representing the neuromodulatory locus coerelus (LC) functions and then to validate the correlation of its activity with the actual data of changes in pupil size collected using the eyetracker during behavioral test.

Participants will have the opportunity to work in a multidisciplinary team focused on several parallel areas: cloud computing, digital medical signal processing, building a spiking neural network model, and validating cognitive theories regarding decision-making and emotional impact. Our

model will land on a supercomputer and we will find out if AI can have emotions!

LIST OF MATERIALS:

The list of materials is intended to provide inspiration, but learning about these items will help you visualize the topic and get into the project faster.

- People after biology or psychology degree:
Aston-Jones G, Cohen JD: An integrative theory of locus coeruleus-norepinephrine function: Adaptive gain and optimal performance Annual Review of Neuroscience (2005). DOI:10.1146/annurev.neuro.28.061604.135709

- People with a technical background:
Nengo documentation - https://www.nengo.ai/nengo/,
Mariska E. Kret & Elio E. Sjak-Shie: Preprocessing pupil size data: Guidelines and code. Behavior Research Methods (2019). DOI: 10.3758/s13428-018-1075-y

- Both groups:
Duggins Peter, Krzemiński Dominik, Eliasmith Chris, Wichary Szymon: A spiking neuron model of inferential decision making : urgency, uncertainty, and the speed-accuracy tradeoff. Proceedings of the 42nd Annual Conference of the Cognitive Science Society : developing a mind: learning in humans, animals, and machines (2020).
https://ruj.uj.edu.pl/xmlui/bitstream/handle/item/266895/wichary_et-al_a_spiking_neuron_model_of_inferential_decision_making_2020.pdf?sequence=1&isAllowed=y
Siddhartha Joshi, Yin Li, Rishi M. Kalwani, Joshua I. Gold: Relationships between Pupil Diameter and Neuronal Activity in the Locus Coeruleus, Colliculi, and Cingulate Cortex. Neuron (2016). DOI: https://doi.org/10.1016/j.neuron.2015.11.028

LIST OF REQUIREMENTS FOR TAKING PART IN THE PROJECT:

Researcher role: (1-3) people with bio-med background (you will be a substantive support for technicians; your task will be to be able to define the functions of specific areas of the brain in the decision-making process). Knowledge in the field of statistics will also be appreciated.

DSP Engineer: (1-3) your role will be to digitally process the eye tracker signal. Get ready for a task in the field of filtration or implementation of the blink detection algorithm.

Python Dev: (1-3) your task will be to run the existing model on the cloud, implement the spiking neural network populations and give them functions defined by Researchers. Knowledge of the basics of nengo Python library is required.

Programming language of choice: Python!

MAXIMAL ALLOWED NUMBER OF TEAM MEMBERS: 9