SUMMARY SCIENTIFIC REPORT

of contract DN02/3 dated 13.12.2016.

on the topic:

MODELING VOLUNTARY SACCADIC MOVEMENTS OF EYES IN DECISION MAKING

Supervised by Prof. Petya Koprinkova-Hristova

Base organization:

Institute of Information and Communication Technologies - BAS

Partner organization:

Institute of Neurobiology - BAS

Summary description of the research and work package activities carried out

Types of activities	Expected results	Results obtained	Publications
Work Package 1: Creating a Neural Model of Voluntary Saccadic Movements			
Activity 1.1: Selection of specific parameters of the hierarchical on neural network related to model, age-related changes	Select on the variables model parameters	Software has been created that allows us to generate a model with a different number of neurons in each layer, different parameters of the differential simulating nerve cells in equations, each structure and different parameters and topologies of the connections within the model.	1 pc with IF: No. 2 5 pcs with SJR: No. 7-9, 12,17 3 papers referenced in Scopus: No. 18, 19, 21 1 unreferenced: No. 23 4 abstracts of international conferences: No. 24, 25, 32, 33 1 pc. presentations: No. 36
Activity 1.2: Creating a distributed simulator architecture of the model in NEST environment	Simulator in the NEST environment	A simulator has been developed in the NEST environment that mimics all stages of visual information processing, starting from the photoreceptors. cells in the eye, through the perceptual taking solution to modulated by external reward/punishment final solution for eye motor response (saccade) to visual stimulation. The model code is available on github. **Additional activities:** 1. After the literature review, the following were added to the planned structure of our model: three additional layers – photoreceptor, LGN and interneurons+TRN, as well as feedback from the output to the input levels of the model that make it make it more realistic in terms of point of the latest results from the study of the structure of the brain, published through recent years. 2. We had to write parallel version of the layer with photoreceptors using cells, mpi4py and OpenMPI. The simulation research showed that our parallel version is approximately 17 times faster than the non-parallel one, which reduced the required simulation time from nearly three days to just over three hours. 3. In addition to the planned simulation studies,	

		such simulated damage was performed in the various structures that process visual information.	
Activity 1.3: Training the neural network model with the experimental data for the different groups	Determining the parameters on the model	A methodology has been developed for setting the parameters of using the model exponential input current for the neurons to the output layer, which reaches its maximum at a time corresponding to the estimated average reaction time of the respective age group. The resulting weights were analyzed of dynamic synapses in the model typical for the different ones age groups.	
Work Package 2: Modeling the Decision-Making Process and Learning Over Time with the Theory of Plausible and Paradoxical Reasoning of Deser-Smarandache based on Belief Functions			
Activity 2.1: Defining an input interface formalizing the coordinates of the for human gaze. on	Input interface	The existing theories for analysis of data fusion in the literature have been carried out. The combination rules VPPPC and NCP have been selected as the most appropriate data pooling methods. For for comparison, the following were used The Bayesian approach Normalized Conjunctive Consensus (NCC) and the pPCR5 rule from the Deser-Smarandache theory.	1 pc. with SJR: No. 6 1 referenced in Scopus: No. 22
Activity 2.2: Merge the predicted on solution from the person with the testimony, obtained from the feedback through the Deser-Smarandache Theory.	Software for updated testimony for the correctness of on the human response	Software has been created to unify information about Forma, Movement and Color with the selected methods and comparison of the results obtained, the unification of the information obtained through them from with the data from the experiments conducted in Work Package 3.	
Activity 2.3: Evaluation on evolution on pignistic probabilities associated over time with correct human responses.	Determining the parameters on the model	The results of the application of the combination rules VPPPC and NCP in predicting the decision-making process ultimately show that for the three age groups, the main rule VPPPC chosen by the team gives more accurate and adequate estimates. from the NCP, especially in cases where the information about Form and Movement are in conflict. VPPPC	

		utilizes all available information about the stimuli, even in conditions of conflict. In this way, the VPPPC preserves the effect of the richness of the available data in the process of combination and provides information in the decision-making process. more adequate By attitude on the characterization of human decision making in the following three classification tasks: with only traffic information; with only combined traffic and color information for the color; Both the NCC and the pPCR5 rule were found to predict individual learning curves well, with a slight advantage for the pPCR5 rule, as it described all learning curves well. This finding gives evidence of the importance of proposed approach for learning curve analysis.	
Work Package 3: Creating scenarios and conducting experiments to collect data on human eye movements when processing motion information			
Activity 3.1: Selection of appropriate groups of subjects	Groups of elected officials	A series of pilot experiments were conducted to determine the experimental conditions. on the main ones Selected to participate in the psychophysical experiments suitable subjects, divided into three age groups in the experiments on perception of direction for self-motion and two in the experiments with feedback on the accuracy of the decision made with approximately equal numbers and equal gender ratio.	2 summaries with IF: No. 3, 4 5 pcs. with SJR: No. 5, 11, 13, 15, 16 8 abstracts of international conferences: No. 26-31, 34, 35
Activity 3.2: Creating on computer programs to generate appropriate on visual stimulation and to analyze the results obtained	Computer programs for visual stimulation	Programs were created to conduct psychophysical research on: 1. The adopted direction of self-motion under different requirements for temporal and spatial integration of information in the optical flow. 2. Study of probabilistic classification of sequences of point sets that are	

		move in 8 different directions when providing feedback on the correctness of the decision made. 3. Study of the classification of multidimensional stimuli into two categories when providing feedback on the correctness of the decision made.	
Activity 3.3: Conducting pilot psychophysical experiments, selecting an appropriate interval and the parameters of the visual stimulation for	Choosing the appropriate interval and parameters for visual stimulation on	Based on the pilot experiments, the following were selected: suitable experimental conditions for determining the effect of age.	
Activity 3.4: Conducting planned experiments and collecting information about eye movements the subjects studied with an eye tracker on	Experimental data base	The planned experiments were conducted with and without feedback on the correctness of the decision made to the test subjects. A database was created with all experimental data from all experiments conducted, which allowed for analyses. on the characteristics of eye movements and their relationship with the age of the test subjects. on **Additional activities:** A hierarchical drift separation of the individual model for characteristics of individuals in the decision-making process has been created: the threshold for accumulating information for decision-making, the speed of accumulating information for decision-making, and the time for encoding information and preparing the motor response. on	
Work Package 4: Experimental Data Processing			
Activity 4.1: Choosing a methodology for processing experimental data on	Methodology and software for processing experimental data	An analysis of the monitoring sensors used was carried out of the eyes and reporting of the movement of the head the person participating in the experiment. Software has been developed for verifying incentives. on test An approach has been developed to jointly use eye-tracking sensors with inertial sensors that detect head movement and rotation in order to	1 pc with IF: No. 1 2 pcs. with SJR: No. 10, 14 1 referenced in Scopus: No. 20 1 pc. presentations: No. 37

		increasing the accuracy of the registration of the position of the view on the stage	
Activity 4.2: Validation and filtration of scenario data	Filtered validated and data	Scenario data was filtered and validated software. developed using The experimental data was processed to remove records that for some reason differed drastically from the average behavior for all test faces and the trend was removed.	
Activity 4.3: Extracting on specific features from filtered data and on clustering	Data separation in clusters	A study was conducted on the significance of some parameters of saccadic movements, by which to group people depending on their visual reactions. Through cluster analysis using three methods proven in practice – K-means, FCM and GK clustering, the informativeness of different spaces combining the data of the specified parameters was made. On this basis, a methodology was developed for research for studying the relationship of statistical parameters of eye from data, movements in response to a visual from task for groups separated by age and gender. A new approach for classification of dynamic time series using an echo state network (ESN) is proposed. A methodology for clustering according to eye movements with an ESN neural network has been developed. The processed experimental data were divided into clusters by gender, age, and according to the observed visual stimulus.	

The following proposals were made during the period:

1. Proposal pursuant to Art. 74(1) of the Regulations of the National Science Foundation for the inclusion of Senior Asst. Velin Kralev in the project team with entry No. 94PP/8 of 16.05.2017. The proposal was adopted by minutes No. 71 of the meeting of the National Science Foundation Executive Board on 01.08.2017, item 6.4.2.
2. Proposal with entry No. 94PP/5 of 28.04.2017 for changes to the planned FTAs for purchase by the partner organization INB-BAS. The proposal was adopted by minutes No. 71 of the meeting of the Executive Board of the National Science Foundation on 01.08.2017, item 6.4.1.
3. Report with entry No. 0901/13/17.02.2020 regarding the extension of the second stage by three months, until September 17, 2020. The proposal was adopted by minutes No. 7/24.02.2020 from the PNEK in Mathematical Sciences and Informatics, item I of the agenda.
4. In connection with the decision of the National Science Foundation of 16.03.2020 to extend the deadline for the implementation of current projects by 2 months due to the pandemic, the project is extended by another two months, until 17.11.2020 (I attach correspondence with the secretary of the PNEC for Mathematical Sciences and Informatics).
5. Report with entry No. 0901/29/16.06.2020 in connection with the suspension of the employment relations with the base organization of Senior Assistant Professor Dr. Yancho Todorov and his expressed desire to leave the project team with a request in accordance with Art. 2 (6) of the contract to be replaced by assistant Simona Nedelcheva. The proposal was accepted by protocol No. 11/31.07.2020 by the PNEK in Mathematical Sciences and Informatics, item I of the agenda.

6. Report with entry No. 0901/92/19.10.2020 regarding a change in the financial plan of the project for the second stage according to Art. 7 (2) of the contract. The proposal was adopted by minutes No. 12/22.10.2020 by the PNEK in Mathematical Sciences and Informatics, item I of the agenda.

Presentation of scientific results

1. Scientific publications on the project (published or accepted for publication):

Publications with impact factor

1. Koprinkova-Hristova, P., Stefanova, M., Genova, B., Bocheva, N., Kraleva, R., Kralev, V., Features extraction from human eye movements via echo state network (2020) Neural Computing and Applications, 32 (9), pp. 4213-4226. ISSN: 09410643; DOI: 10.1007/s00521-019-04329-z; IF 2019 4.774 (Q1)

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85068870985&doi=10.1007%2fs00521-019-04329-z&partnerID=40&md5=1149ac79b15e1b7fcdd0806f60b0c581

2. Koprinkova-Hristova, PD, Bocheva, N., Nedelcheva, S., Stefanova, M., Spike timing neural model of motion perception and decision making (2019) Frontiers in Computational Neuroscience, 13, art. no. 20. ISSN: 16625188; DOI: 10.3389/fncom.2019.00020; IF 2019 2.535 (Q2)

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85064228639&doi=10.3389%2ffncom.2019.00020&partnerID=40&md5=f84e8556eac34ca71912eeeeed61c2de7

Abstracts in journals with impact factor

3. Genova, B., Stefanov, S., Stefanova, M., Bocheva, N., Effects of probabilistic stimulus–response associations on motion direction categorization tasks, In: 42nd European Conference on Visual Perception (ECVP) 2019 Leuven, Perception, vol. 48(2_suppl), p. 215; ISSN: 0301-0066, eISSN: 1468-4233; Accession Number: WOS: 000486182000659; DOI: 10.1177/0301006619863862; IF 2019 1.217 (Q4)

https://journals.sagepub.com/doi/10.1177/0301006619863862
http://apps.webofknowledge.com/Search.do?product=WOS&SID=E5IGTmWa4YQ1NW5Q1R4&search_mode=GeneralSearch&prID=c5becb2a-9547-42af-9c58-fd5c2d783d6a

4. Stefanova, M., Bocheva N., Genova B., Stefanov S., Age effects on task-related saccadic eye movements, In: Martinez-Conde, S., Martinez-Otero, L., Compte, A., Groner, R. (Eds.), Abstracts of the 20th European Conference on Eye Movements, 18-22 August 2019, in Alicante (Spain), Journal of Eye Movement Research, vol. 12(7), p. 369; ISSN: 1995-8692; Accession Number: WOS: 000580628900001; DOI: 10.16910/jemr.12.7.1; IF 2019 1.404 (Q3)

https://bop.unibe.ch/JEMR/article/view/JEMR.12.7.1
http://apps.webofknowledge.com/Search.do?product=WOS&SID=E5IGTmWa4YQ1NW5Q1R4&search_mode=GeneralSearch&prID=f3e013a4-c953-49c7-b8a9-946d01186261

Posts with SJR rank

5. Kralev, V., Kraleva, Koprinkova-Hristova, P., Data modeling and data processing generated by human eye movements, International Journal of Electrical and Computer Engineering (IJECE), ISSN 2088-8708 (accepted paper); SJR 2019 0.322

https://www.scopus.com/sourceid/21100373959

6. Tchamova, A., Dezert, J., Bocheva, N., Konstantinova, P., Genova, B., Stefanova, M., A Study on Human Learning ability during Classification of Motion and Color Visual Cues and Their Combination (2020) Cybernetics and Information Technologies (accepted paper); Print ISSN: 1311-9702; Online ISSN: 1314-4081; SJR 2019 0.31

https://www.scopus.com/sourceid/21100199814

7. Koprinkova-Hristova, P., Nedelcheva, S., Bocheva, N., Kraleva, R., Kralev, V., Stefanova, M., Genova, B., STDP Training of Hierarchical Spike Timing Model of Visual Information Processing (2020) Proceedings of the International Joint

Conference on Neural Networks, art. no. 9207598. ISBN: 9781728169262; DOI: 10.1109/IJCNN48605.2020.9207598; SJR 2019 0.366

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85093851876&doi=10.1109%2fIJCNN48605.2020.9207598&partnerID=40&md5=dc3895e6be5a239413da22d281292b8e

8. Koprinkova-Hristova, P., Bocheva, N., Nedelcheva, S., Stefanova, M., Genova, B., Kraleva, R., Kralev, V., STDP plasticity in TRN within hierarchical spike timing model of visual information processing (2020) IFIP Advances in Information and Communication Technology, 583 IFIP, pp. 279-290. ISSN: 18684238; ISBN: 9783030491604; DOI: 10.1007/978-3-030-49161-1_24; SJR 2019 0.209

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85086269234&doi=10.1007%2f978-3-030-49161-1_24&partnerID=40&md5=6e730116236dd32a9a137ee50d070c65

9. Koprinkova-Hristova, P., Bocheva, N., Brain-inspired spike timing model of dynamic visual information perception and decision making with STDP and reinforcement learning (2020) Machine Learning, Optimization, and Data Science, 6th International Conference, LOD 2020, Siena, Italy, July 19–23, 2020, Revised Selected Papers, Part II, Lecture Notes in Computer Science, 12566, pp.1-15 (to appear). ISBN: 978-3-030-64579-3; eISBN: 978-3-030-64580-9; DOI: 10.1007/978-3-030-64580-9_35; SJR 2019 0.427

https://doi.org/10.1007/978-3-030-64580-9_35

https://www.springer.com/gp/book/9783030645793

10. Alexiev, K., Toshkov, T., Dojnow, P., Enhancing accuracy and precision of eye tracker by head movement compensation and calibration (2019) ACM International Conference Proceeding Series, pp. 226-233. ISBN: 978-145037149-0; DOI: 10.1145/3345252.3345278; SJR 2019 0.200

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85073077878&doi=10.1145%2f3345252.3345278&partnerID=40&md5=8357bb44ec61d5f951cf6e02999c1617

11. Kralev, VS, Kraleva, RS, Visual analysis of actions performed with big graphs (2019) International Journal of Innovative Technology and Exploring Engineering, 9 (1), pp. 2740-2744; ISSN: 2278-3075; DOI: 10.35940/ijitee.A4978.119119; SJR 2019 0.102

https://www.scopus.com/inward/record.uri?eid=2-s2.0-85075175864&doi=10.35940%2fijitee.A4978.119119&partnerID=40&md5=c1645da0e494d67e6f2b10dd8569f1a2

12. Koprinkova-Hristova, P., Bocheva, N., Spike timing neural model of eye movement motor response with reinforcement learning, 13th Annual Meeting of the Bulgarian Section of SIAM, December 18-20, 2018, Sofia, Studies in Computational Intelligence (accepted, to appear); SJR 2019 0.215

https://www.scopus.com/sourceid/4900152708

http://www.math.bas.bg/bgsiam/docs/bgsiam_2018_abstracts-v2.pdf#page=76

13. Bocheva, N., Genova, B., Stefanova, M., Drift Diffusion Modeling of Response Time in Heading Estimation Based on Motion and Form Cues, International Journal of Biology and Biomedical Engineering, vol.12, 2018, pp.75-83, ISSN: 1998-4510, SJR 2017: 0.118

http://www.naun.org/main/NAUN/bio/2018/a222010-024.pdf

https://www.scimagojr.com/journalsearch.php?q=21100381259&tip=sid&clean=0

14. Koprinkova-Hristova, P., Stefanova, M., Genova, B., Bocheva, N., Echo State Network for Classification of Human Eye Movements During Decision Making, In: Iliadis L., Maglogiannis I., Plagianakos V. (eds) Artificial Intelligence Applications

and Innovations. AIAI 2018. IFIP Advances in Information and Communication Technology, vol 519, pp.337-348; SJR 2017: 0.178
https://link.springer.com/chapter/10.1007/978-3-319-92007-8_29

15. Kraleva, R., Kralev, V., Sinyagina, N., Koprinkova-Hristova, P., Bocheva, N.. Design and analysis of a relational database for behavioral experiments data processing. International Journal of Online Engineering, vol. 14, issue 2, 2018, pp. 117-132; ISSN: 1861-2121; SJR 2017: 0.150
https://www.scopus.com/record/display.uri?eid=2-s2.0-85042659008&origin=resultslist
16. Kralev, V., Kraleva, R., Sinyagina, N., Koprinkova-Hristova, P., Bocheva, N., An analysis of a web service based approach for experimental data sharing, International Journal of Online Engineering, vol. 14, issue 9, 2018, pp. 19-34; ISSN: 1861-2121; SJR 2017: 0.150

https://www.scopus.com/record/display.uri?eid=2-s2.0-85054127598&origin=resultslist
17. Nedelcheva, S., Koprinkova-Hristova, P., Orientation selectivity tuning of a spike timing neural network model of the first layer of the human visual cortex. 12th Annual Meeting of the Bulgarian Section of SIAM BGSIAM'17, December 20-22, 2017, Sofia, Bulgaria (Abstract); accepted for publication in: Advanced Computing in Industrial Mathematics, K. Georgiev, M. Todorov, I. Georgiev (Eds.), Studies in Computational Intelligence, ISSN:1860-949X, E-ISSN:1860-9503; SJR 2017: 0.184
https://www.scopus.com/sourceid/4900152708

Publications referenced in Scopus and DBLP

18. Koprinkova-Hristova, P., Bocheva, N., Age-related Spike Timing Dependent Plasticity of Brain-inspired Model of Visual Information Processing with Reinforcement Learning (2020) Proceedings of the 2020 Federated Conference on Computer Science and Information Systems, FedCSIS 2020, art. no. 9222902, pp. 93-100. ISBN: 9788395541674; DOI: 10.15439/2020F141 (Scopus)
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85095727187&doi=10.15439%2f2020F141&partnerID=40&md5=477026515c2be8626761940198560d64
19. Nedelcheva, S., Georgieva, K., Koprinkova-Hristova, P., Parallel Implementation of the Model of Retina Ganglion Cells Layer (2020) INISTA 2020 - 2020 International Conference on INnovations in Intelligent SysTems and Applications, Proceedings, art. no. 9194616. ISBN: 9781728167992; DOI: 10.1109/INISTA49547.2020.9194616 (Scopus)
https://www.scopus.com/inward/record.uri?eid=2-s2.0-85091985123&doi=10.1109%2fINISTA49547.2020.9194616&partnerID=40&md5=db8d4869fab1466f5dee5ce83aad581f
20. Georgieva, O., Bocheva, N., Genova, B., Stefanova, M. (2020) Eye Movement Data Analysis, In: Iliadis L., Angelov P., Jayne C., Pimenidis E. (eds) Proceedings of the 21st EANN (Engineering Applications of Neural Networks) 2020 Conference. EANN 2020. Proceedings of the International Neural Networks Society, vol. 2. Springer, Cham. DOI: 10.1007/978-3-030-48791-1_36 (DBLP)
https://link.springer.com/chapter/10.1007%2F978-3-030-48791-1_36
21. Koprinkova-Hristova, P., Nedelcheva, S., Bocheva, N., Investigation of Feedback Connections Effect of a Spike Timing Neural Network Model of Early Visual, IEEE (SMC) International Conference on INnovations in Intelligent SysTems and Applications INISTA 2018, July 3-5, 2018, Thessaloniki, Greece. ISIBN: 978-153865150-6, DOI: 10.1109/INISTA.2018.8466292 (Scopus)
https://www.scopus.com/record/display.uri?eid=2-s2.0-85055507324&origin=resultslist

22. Tchamova, A., Dezert, J., Konstantinova, P., Bocheva, N., Genova, B., Stefanova, M., Human Heading Perception Based on Form and Motion Combination, IEEE (SMC) International Conference on INnovations in Intelligent SysTems and Applications INISTA 2018, July 3-5, 2018, Thessaloniki, Greece. ISIBN: 978-153865150-6, DOI: 10.1109/INISTA.2018.8466324 (Scopus)

https://www.scopus.com/record/display.uri?eid=2-s2.0-85055580288&origin=resultslist

Other non-refereed publications

23. Grigorov, M., Nedelcheva, S., Koprinkova-Hristova, P., Neural model of the first layer of the visual cortex, XV National Youth Scientific and Practical Conference, Federation of Scientific and Technical Unions in Bulgaria, 2017, ISSN: 1314-8931, pp.70-75. Award-winning presentation

Abstracts and reports of international scientific forums

24. Koprinkova-Hristova, P., Nedelcheva, S., Bocheva, N., (2020), BioInfoMed 2020, Book of abstracts, pp.69-70; to be published in full text in Springer series, under review SJR. Award-winning presentation

http://bioinfomed.org/wp-content/uploads/2020/10/BioInfoMed_2020_Book_of_Abstracts.pdf
http://bioinfomed.org/awards/

25. Koprinkova-Hristova, P., Bocheva, N., An integrated model of visual perception and reinforcement learning in NEST, NEST Conference 2020.

https://indico-jsc.fz-juelich.de/event/115/material/0/7.pdf

26. Bocheva, N., Stefanova, M., Genova, B., Hristov, A., Age-related differences in eye movements' behavior during decision making in classification tasks, The Virtual Congress on Brain Health Innovation & Technologies, 12-13 October 2020, Book of abstracts, EPoster 3, p.7

https://brain-hit.com/wp-content/uploads/sites/46/2020/10/BrainHIT-Abstract-Book.pdf

27. Genova, B., Bocheva, N., Stefanova, M., Effect of probabilistic stimulus-response associations on learning of unstructured categories with motion direction stimuli, The 12th International Conference on Biomedical - Life Sciences and Health Care, Amsterdam, The Netherlands, October 22-24, 2020, under review in Symmetry, SI "Simulation and Modeling in Natural Sciences, Economics, Biomedicine and Engineering", ISSN: 2073-8994; IF 2019 2.645 (Q2)
28. Stefanova, M., Bocheva, N., Genova, B., Hristov, A., Kraleva, R., Kralev. V., Age-related changes in eye movements' characteristics in decision-making and classification tasks, Scientific Conference "Neurosciences - from theory to experiment and practice", 23-25 October 2020, Bachinovo, Bulgaria, p. 45.
29. Genova, B., Bocheva, N., Stefanova, M., Hristov, A., Effect of age in single- and multi-cue classification tasks, Scientific Conference "Neurosciences - from theory to experiment and practice", 23-25 October 2020, Bachinovo, Bulgaria, p.47
30. Genova, B., Bocheva, N., Decision making in motion direction classification with probabilistic rules, International Scientific Conference "Neuroscience, Bioinformatics, Microbiome, and Beyond", 17-18 September 2019, Bachinovo, Bulgaria, pp.84-85.
31. Stefanova, M., Bocheva N., Genova B., Stefanov S., Age-effects on task-related eye movements, International Scientific Conference "Neuroscience, Bioinformatics, Microbiome, and Beyond", 17-18 September 2019, Bachinovo, Bulgaria, pp.83-84.

https://youtu.be/GM-VDTGp9os

32. Koprinkova-Hristova, P., Bocheva, N., Spike timing model of visual motion perception and decision making with reinforcement learning in NEST, NEST Conference 2019.

https://indico-jsc.fz-juelich.de/event/92/material/0/0.pdf#page=10

33. Koprinkova-Hristova, P., Bocheva, N., Nedelcheva, S., Stefanova, M., A model of self-motion perception developed in NEST, NEST Conference 2018: A Forum for Users and Developers, 25-26 June 2018, NMBU, Ås, Norway

https://indico-jsc.fz-juelich.de/event/71/material/3/2.pdf

34. Bocheva, N., Genova, B., Stefanova, M., Stefanov, S., Drift diffusion modeling of reaction time: effects of information reliability and age on decision making, SCIENTIFIC CONFERENCE WITH INTERNATIONAL PARTICIPATION, Dedicated to the 70th Anniversary of the Institute of Neurobiology, Bulgarian Academy of Sciences, 30 November – 01 December, 2017, Sofia, Bulgaria.

35. Bocheva, N., Stefanova, M., Stefanov, S., Contribution of spatial and temporal integration in heading perception, 15th International Congress Vision Science and Eye, London, 10-11.08.2017, International Journal of Ophthalmic Pathology, vol.6, Issue 4 (Proceedings of 15th International Congress on Vision Science and Eye), 2017, p.34; ISSN: 2324-8599, DOI: 10.4172/2324-8599-C1-002

https://www.scitechnol.com/proceedings/contribution-of-spatial-and-temporal-integration-in- heading-perception-4657.html

Other presentations

36. Koprinkova-Hristova, P., Brain-inspired Spike Timing Model with STDP and Dopamine Synapses, Invited presentation at Workshop “Design, Implementation and Applications of Spiking Neural Networks and Neuromorphic Systems”, IEEE World Congress on Computational Intelligence (WCCI) 2020, 19 – 24th July, 2020, Glasgow, UK

https://wcci2020.org/workshops/#workshop-6

https://kedri.aut.ac.nz/snn-and-nms-workshop-wcci2020

37. Dimov, D., On more a specific application of Hough/Radon transforms in image processing, Seminar lecture in University of Pavia, Oct. 25, 2018

https://vision.unipv.it/events/DDimov-Pavia-Oct2018.pdf

2. Presentation of project results at universities and other scientific institutions organizations or companies in the country or abroad.

• Seminar of the Bio-Mathematics Society on 21.02.2018 on the topic "Mathematical Foundations of Neurobiology", reported by the project manager Assoc. Prof. P. Koprinkova-Hristova

• Seminar on Mathematical Modeling (MM) at the Faculty of Mathematics and Physics, mandatory for masters in the specialty "Computational Mathematics and Mathematical Modeling", held on 28.02.2018 on the topic "Mathematical Foundations of Neurobiology", reported the project manager Assoc. Prof. P. Koprinkova-Hristova

• The results were also reported at the intra-institutional seminar of the Institute of Biomedical Sciences-BAS.

• Participation in a poster session of the “European Night of Scientists” organized under the project “Scientists in the Knowledge Triangle”, September 27, 2019, Sofia (I enclose a certificate of participation)

• Participation with a poster in the Open Days at IICT-BAS on October 3 and 4, 2019. The program is published here: http://www.iict.bas.bg/3-4-Oct-2019.html

- Invited presentation at Workshop "Design, Implementation and Applications of Spiking Neural Networks and Neuromorphic Systems", IEEE World Congress on Computational Intelligence (WCCI) 2020, 19 – 24th July, 2020, Glasgow, UK
- Seminar lecture in University of Pavia, Oct. 25, 2018

3. Popularization of project results among the public

The project is promoted in:

https://www.researchgate.net/project/Modelling-of-voluntary-saccadic-eye-movements- during-decision-making

Information about the project is also available on the website of the IMIC section at IICT-BAS:

http://mmsip.bas.bg/Project_fni_2016.html

4. Description of created software products related to the implementation of the scientific project.

When completing the tasks of the first stage of the project, the following were created: software products:

1. Model of visual perception and the basal ganglia involved in reward/punishment decision making in the human brain. The software product is implemented with the NEST simulator libraries of python.
2. A program implementing the Probabilistic Proportional Rule (PPPR) number 5 for Redistribution of Conflicts in the Deser-Smarandache Theory and the Normalized Consensus Rule. The program product is implemented in the MATLAB environment.
3. Programs for simulating the direction of self-motion of an observer in space. The programs are written in Visual C++ with the inclusion of OpenGl. To conduct experiments with these programs, stimuli with fixed parameters were generated using MATLAB.
4. Software product for simulating the movement of an observer in a three-dimensional environment along a predefined Python trajectory.
5. Software for verification of test stimuli. It was created in a programming environment MATLAB.

In addition to these software products, various programs have been created and implemented within the project to obtain various statistics from measurements, trend removal, probability distributions, classification and clustering. These programs do not have an independent purpose and are designed to extract specific information from the obtained experimental data. Most of them are implemented in MATLAB.

Other project results

1. Report on the implementation of the Plan for the exploitation of scientific results from the implementation of the project.

The plan for the exploitation of the scientific results of the project includes:

A. Dissemination of scientific and applied scientific results:

1. Direct use of the results obtained by providing
the software developed for research purposes by colleagues with similar scientific interests;

The developed model is open source and available on github.

2. Dissemination of scientific results through popularization through:

- Organizing seminars and lectures for doctoral students and researchers,
working in the area.

The results of the project were presented at the seminars described above in the report. In the process of work, three students were trained under the Student Internship program. Two of the students presented their work at the Youth Conference, for which they received the 3rd prize.

The seminar at the FMI was attended by master's and bachelor's students.

The results of the project were presented at the "European Scientists' Night" in 2019, which was attended by many schoolchildren and students.

The presentation during the Open Days at IICT-BAS was also
visited by schoolchildren and students and was accessible to any interested citizen.

- Presentation of the developed software products and methodologies on a website with Demo versions.

The developed model is open source and available on github.

- Participation of team members in conferences and workshops with the aim of exchanging results with teams working abroad.

Prof. P. Koprinkova-Hristova presented the project results at the IEEE World Congress on Computational Intelligence (WCCI) 2020, 19 – 24th July, 2020, Glasgow, UK, participating with an invited presentation in a workshop on “Design, Implementation and Applications of Spiking Neural Networks and Neuromorphic Systems”

Assoc. Prof. D. Dimov presented results of his work on the project at a seminar and
lecture to students at the University of Pavia, Italy on October 25, 2018

Prof. Koprinkova-Hristova regularly participates in the annual NEST Conference of
the developers and users of NEST simulator in 2018, 2019 and 2020.

- Publication of scientific results in journals and papers at international and national conferences.

The majority of the results obtained were published in journals with an impact factor (two in full text and two in abstract), 13 in publications with an SJR rank and 5 in collections with
papers at international conferences, referenced in Scopus and other world-renowned databases of scientific publications. 12 abstracts of papers presented at international scientific conferences have also been published, with two of these materials being peer-reviewed and expected to be published in one journal with an impact factor and in one series with an SJR rank.

B. Dissemination of project results through teaching and learning
activity.

1. It is envisaged that the members of the staff leading lecture courses will:
familiarize students with the topic of the project and the results obtained.

During the work at IICT-BAS, three students were trained under the Student Internship program.

Prof. P. Koprinkova-Hristova has offered a course on "Mathematical Foundations of Neurobiology" at the Center for Doctoral Training at the Bulgarian Academy of Sciences. The same course is also offered in English in the Erasmus+ training program of the Bulgarian Academy of Sciences.

2. Use and reference of project results in doctoral dissertations, master's and bachelor's theses, and projects of students trained at both institutes
participating in the project.

The project team includes four doctoral students who actively participated in the project work, as follows:

PhD student Krasimira Georgieva-Alexandrova took an active part in the installation and preparation of the server for simulating the developed NEST simulator model. She is currently enrolled with the right to defend.

Doctoral student Anton Nedyalkov developed the software to generate incentives for
the experiments for the second of the project.

PhD student Vesselina Dalgacheva is working on the creation of the experimental data base in the first stage of the project. She defended her thesis in 2016 and is now a senior assistant professor at SWU-Blagoevgrad. Due to personal reasons, she was unable to participate in the work on the second stage of the project.

Doctoral student Margarita Dikova was dismissed with the right to defend her thesis and was unable to actively participate in the work on the project due to family reasons.

Assistant Simona Nedelcheva, who was initially appointed as a programmer at IICT on a part-time basis, and later completed her master's degree and was appointed as an assistant, actively participated in the development of the simulator in the NEST environment and is a co-author on a number of publications on the project.

3. Increasing scientific capacities and training of young scientists.

The project leader, then Associate Professor Petya Koprinkova-Hristova, and Associate Professor O. Georgieva, became professors at the end of 2019.

We have three young scientists and post-doctoral students in the team (Senior Assistant Professor Radoslava Kraleva, Senior Assistant Professor Miroslava Stefanova and Assistant Professor Simona Nedelcheva), who actively participated in the publication activity and the work on the project.

As a result of their scientific growth, Senior Assistant Professor Velin Kralev and Senior Assistant Professor Radoslava Kraleva have completed their habilitation and are now associate professors.

Assistant Simona Nedelcheva developed and defended her master's thesis at the Institute of Information and Communication Technology, which was related to the 3-dimensional visualization of part of the model simulation.

4. Developing scientific cooperation.

As a result of our participation in the NEST conference, we received an offer to publish in a thematic issue of a renowned journal, which resulted in a publication with an impact factor in Q2, referenced in the Web of Science. In early 2020, we submitted a project to the call for expressions of interest for

participation in the European flagship project Human Brain Project, which reached the second stage of evaluation, but was not among those who received funding.

During our participation in conferences and seminars, where we presented our model in the NEST environment, interest was also expressed in future collaboration with colleagues working on similar topics.

5. Other results

The publications describing our project results are already being noticed by the global scientific community, with 11 citations of 5 of them noted so far:

1. Koprinkova-Hristova, P., Stefanova, M., Genova, B., Bocheva, N.. Echo State Network for Classification of Human Eye Movements During Decision Making. IFIP Advances in Information and Communication Technology, 519, Springer, 2018, ISBN:978-3-319-92007-8, ISSN:18684238, DOI:10.1007/978-3-319-92007-8_29, 337-348. SJR (Scopus):0.178

Cited in:

1. Sun, C., Song, M., Hong, S., Li, H., A Review of Designs and Applications of Echo State Networks, 2020, arXiv:2012.02974, Link

2. Kralev, V., Kraleva, R., Sinyagina, N., Koprinkova-Hristova, P., Bocheva, N.. An analysis of a web service based approach for experimental data sharing. International Journal of Online Engineering, 14, 9, Kassel University Press, 2018, ISSN:18681646, DOI:10.3991/ijoe.v14i09.8740, 19-34. SJR (Scopus):0.15 *Cited in:*

2. Halim, M., Adadi, N., Chenouni, D., Berrada, M., Web services composition in E-Learning platform (2020) International Journal of Emerging Trends in Engineering Research, 8 (2), art. no. 41, pp. 525-532. ISSN: 23473983; DOI: 10.30534/ijeter/2020/41822020, Link

3. Kraleva, R., Kralev, V., Sinyagina, N., Koprinkova-Hristova, P., Bocheva, N.. Design and analysis of a relational database for behavioral experiments data processing. International Journal of Online Engineering, 14, 2, Kassel University Press, 2018, ISSN:18681646, DOI:10.3991/ijoe.v14i02.7988, 117-132. SJR (Scopus): 0.15

Quoted in:

3. Kiswanto, NP, Paturusi, SD, & Tulenan, V. (2020). Aplikasi E-Log Book Penangkapan Ikan Menggunakan Progressive Web App. Jurnal Teknik Informatika, 15(2), 93-100., Link
4. Sutanto, Nur Hamid, et al. "Analisis Aspek-Aspek Kualitas Skema Basis Data (Studi Kasus: Analisis Jabatan Bagian Organisasi Kabupaten Balangan)." Jurnal Syntax Admiration, Vol. 1 No. 7 (2020), pp. 890-901. DOI: 10.46799/jsa.v1i7.134, Link
5. Gaynazarov, SM, Yarashov, IK, ALGORITHM OF MOBILE APPLICATION FOR MEDICINE RESEARCH, Science and Education, 2020, vol. 1(8), pp. 600 - 605, ISSN: 2181-0842, Link
6. El Moukhi, N., et al., X-ETL: A Data-Driven Approach for Designing Star Schemas, International Journal of Recent Contributions from Engineering, Science & IT (iJES) vol. 7.1 (2019), pp. 4-21. eISSN: 2197-8581, Link
7. Esbai, R., Elotmani, F., Belkadi, FZ, Toward automatic generation of column-oriented NoSQL databases in Big Data context (2019) International journal of online and biomedical engineering, 15 (9), pp. 4-16. DOI: 10.3991/ijoe.v15i09.10433, Link
8. Wongsakthawom, R., Limpiyakorn, Y. Development of IT Helpdesk with Microservices (2018) Proceedings of 2018 IEEE 8th International Conference on Electronics Information and Emergency Communication, ICEIEC 2018, art. no. 8473557, pp. 31-34. DOI: 10.1109/ICEIEC.2018.8473557, Link

4. Tchamova, A., Dezert, J., Konstantinova, P., Bocheva, N., Genova, B., Stefanova, M., Human heading perception based on form and motion combination, 2018 Innovations in Intelligent Systems and Applications (INISTA), Thessaloniki, 2018, pp. 1-8, doi: 10.1109/INISTA.2018.8466324.

Quoted in:

9. Karapetyan, K. Process Mining of Automation Services with Long Short-Term Memory Neural Networks. (2019), MS thesis, Link

5. Koprinkova-Hristova, P., Bocheva, N., Nedelcheva, S., Stefanova, M.. Spike timing neural model of motion perception and decision making. Frontiers in Computational Neuroscience, 13, 2019, ISSN:16625188, DOI:10.3389/fncom.2019.00020, 1-20. JCR-IF (Web of Science):2.323 *Cited in:*

10. Shevinsky, Carly A., Reinagel, P., The interaction between elapsed time and decision accuracy differs between humans and rats, Frontiers in Neuroscience, November 2019, Volume 13, Article 1211 doi: 10.3389/fnins.2019.01211, Link

6. Koprinkova-Hristova, P., Stefanova, M., Genova, B., Bocheva, N., Kraleva, R., Kralev, V.. Features extraction from human eye movements via echo state network. Neural Computing and Applications, 32, 9, Springer London, 2020, ISSN:09410643, DOI:10.1007/s00521-019-04329-z, 4213-4226. JCR-IF (Web of Science):4.774 *Cited in:*

11. Salas-Morera, L., García-Hernández, L., Antolí-Cabrera, A. et al. Using eye-tracking into decision makers evaluation in evolutionary interactive UA-FLP algorithms. Neural Comput & Appl 32, 13747–13757 (2020). https://doi.org/10.1007/s00521-020-04781-2, Link

General information about the project:

Number of PhD students in the project	4
Number of young scientists	3
Number of scientific publications	23
Of them with impact factor	2 articles + 2 abstracts
Of them with impact rank	13
Number of patents, incl. registered patent applications	
Number of citations of all publications under the project	11