Scientist develops an open-source algorithm for selecting a dictionary of a neurointerface
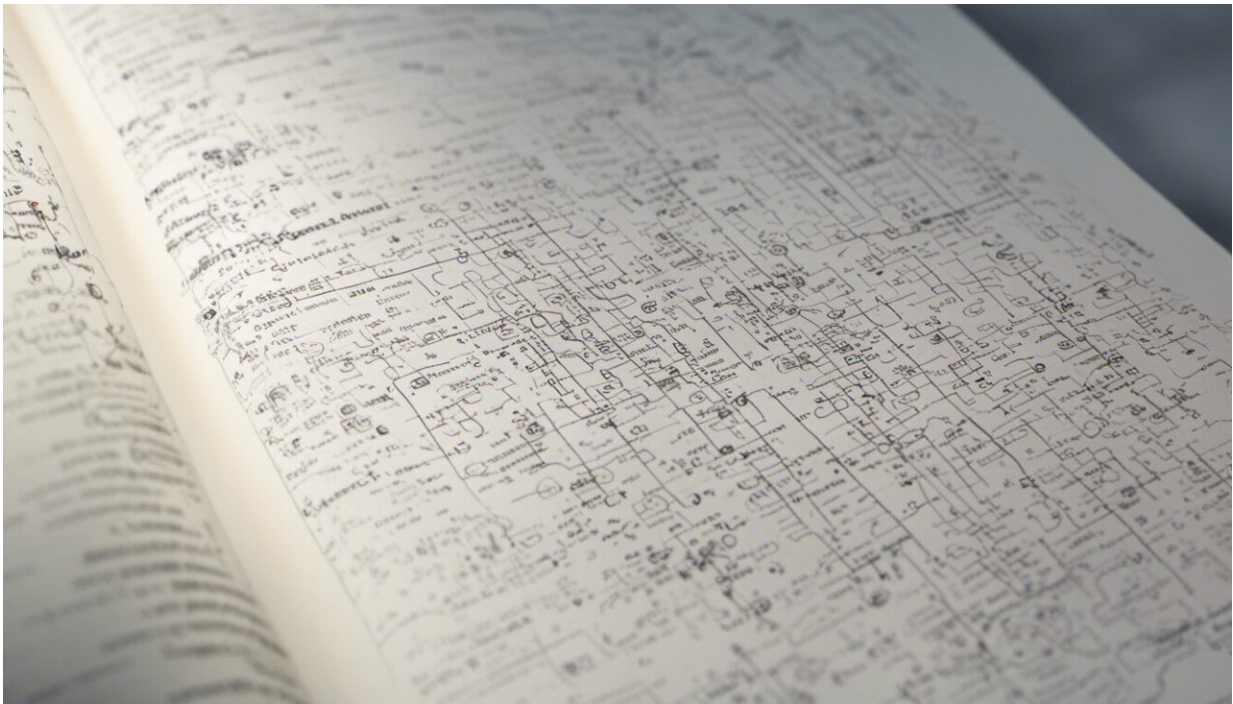
October 28 2022

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Associate Professor of the Department of Information Technologies and Computer Sciences at MISIS University, Ph.D., mathematician and doctor Alexandra Bernadotte has developed algorithms that significantly increase the accuracy of recognition of mental commands by robotic devices. The result is achieved by optimizing the selection of a

dictionary. Algorithms implemented in robotic devices can be used to transmit information through noisy communication channels. The results have been published in the peer-reviewed international scientific journal *Mathematics*.

The task of improving the object (audio, video or electromagnetic signals) classification accuracy, when compiling so-called "dictionaries" of devices is faced by developers of different systems aimed to improve the quality of human life.

The simplest example is a voice assistant. Audio or video transmission devices for remote control of an object in the line-of-sight zone use a limited set of commands. At the same time, it is important that the commands classifier based on the neural network accurately understands and does not confuse the commands included in the device dictionary. It also means that the recognition accuracy should not fall below a certain value in the presence of extraneous noise.

Choosing a limited command dictionary is also very relevant for the brain–computer interface (BCI) that is used to remotely control a robotic arm by people with movement disorders. The device perceives and recognizes patterns of the brain electrical activity when a person thinks about a particular command.

The difficulty is that these patterns are similar for words with similar meanings or sounds. In this regard, the classification of mental or other commands from a specific dictionary for the design of the input devices using an audible or electromagnetic signal is a serious problem. However, 16–20 commands are enough to control most robotic devices, and priority is given not to the variety of objects in the dictionary, but to the quality of recognition.

The Maximin and Maximal algorithms proposed by Alexandra

Bernadotte in her work allow to select a set of dictionary objects to maximize the accuracy of classification while reducing the time for selecting a dictionary of commands by five orders of magnitude compared to the brute-force algorithm.

"Existing algorithms, usually help increasing the accuracy of the classification of the already created dictionary. My aim was to optimize the process of selecting dictionary commands itself. The Maximin algorithm is effective when the dictionary is large enough and you want words to be recognized equally well. The Maximal algorithm is used if we need to increase the accuracy of recognition, and there are significantly more resources for selecting a dictionary.

"The idea of solving the problem is to represent a set of objects (encoded as a sequence of symbols or visual sequences) in the form of a k-partite graph, where each partite of the graph corresponds to a group of objects with a certain common feature (equivalence class). The edges of the graph have weights corresponding to the value of the Kolmogorov-Smirnov criterion obtained on the distributions of n-dimensional signals of mental commands belonging to different classes of equivalence—to different partites.

"Finding a clique with the Maximal or Maximin total weight in this graph gives the desired dictionary of commands which are classified with an accuracy not lower than the specified one. This algorithm can be used for different tasks in the field of information transmission," explained Alexandra Bernadotte, Ph.D., mathematician and doctor, associate professor of the Department of Information Technologies and Computer Sciences at MISIS University, employee of the Faculty of Mechanics and Mathematics at Lomonosov Moscow State University.

The results of the proposed algorithms on simulated data can be repeated using the open-source project on GitHub

(github.com/aibern/maximin_k_cl … sification_algorithm)

The next stage of research will be the algorithm application to real (not simulated) data and the theoretical justification of a more general task.

More information: Alexandra Bernadotte, The Algorithm That Maximizes the Accuracy of k-Classification on the Set of Representatives of the k Equivalence Classes, *Mathematics* (2022). DOI: 10.3390/math10152810

Provided by The National University of Science and Technology MISIS