

FRAMEWORK PROGRAMME OF EARLY STAGE RESEARCHER TRAINING¹

1. BASIC DATA

Mentor's name and surname	Božidar Potočnik	Mentor's register number at ARIS (SICRIS) :	15801
Mentor's e-mail:	bozidar.potocnik@um.si	Mentor's tel. no.:	+38622207484
Research programme (RP) leader's name and surname:	Domen Mongus	RP leader's register number at ARIS (SICRIS) :	29243
Title of research programme:	Computer Systems, Methodologies, and Intelligent Services	RP's Register number at ARIS (SICRIS) :	P2-0041
Research organisation (RO) of University of Maribor, where training shall be conducted:	Faculty of Electrical Engineering and Computer Science	RO Register number at ARIS (SICRIS) :	0796
Research field according to ARIS classification :	2.07 Computer Science and Informatics	Research field according to Ortelius classification (EURAXESS)	9.10 Programming

2. DEFINITION OF RESEARCH PROBLEM AND GOALS OF DOCTORAL RESEARCH²

Starting point of research task of the early stage researcher and its position in the research programme, where the mentor is included, work hypothesis, research goals and foreseen result with emphasis on an original contribution to science:

a. Starting point of research task

The candidate's research work will complement the research of the Programme group and research projects of the Systems Software Laboratory at the Institute of Computer Science, UM FERl. It will be focused on the field of computer processing of multidimensional signals (images, volumes), computer vision and deep computational models (deep neural networks). The emphasis will be on

¹ Term early stage researcher (ESR) is written in male form and used as neutral for women and men.

² Research and study programme of training have to harmonise with contents of the research programme, where the mentor is a member.

the development of new algorithms for processing multidimensional medical data, especially those where deep computational models have not proven to be very successful so far. In the Systems Software Laboratory, we have been successfully engaged in the analysis of multi-channel electromyograms (EMG) for many years, so one demonstrator will probably also be focused on this area.

Deep neural networks have been routinely used for the processing of multidimensional signals (e.g., images, volumes, image sequences) in the last few years. In recent years, methods based on attention models have proved to be the most successful, e.g. the Transformer architecture. The latter is used by all successful Large Language Models (LLM). The planned research will therefore focus on attention-based models.

In recent years, a wide variety of deep neural networks for processing multidimensional data have been found in the literature. They often prove successful for a certain selected set of data, but less successful or even unsuccessful for other types of data. We can clearly see the problem of the so-called NFL theorem (No Free Lunch Theorem), which states that there is no universal optimisation algorithm that is better than all others for all possible problems. The NFL theorem suggests that the effectiveness of algorithms varies depending on the specific problem being solved, and emphasises the need to choose the most appropriate computational method for a given task. Today's development of deep neural networks is typically based on trial-and-error methodology.

With this research, we want to take a step towards a more systematic design of deep neural networks. On the one hand, we want to address i) the problem of designing deep neural network architectures based on data characteristics, while ii) understanding and trusting the results returned by such neural networks (the subfield of Explainable Artificial Intelligence - XAI).

b. Work hypothesis and methods

The young researcher will develop new computational methods for the systematic design of attention-based deep neural network architectures. He/she will introduce a procedure for quantitative analysing of the latent data space, trying to evaluate and understand the changes introduced into the deep neural network architecture. The area of application of the research will be the segmentation and classification of diverse multidimensional data (presumably biomedical data).

The scientific methodology is expected to include, but not be limited to, selected chapters from the fields of digital image processing, computer vision, machine learning, deep neural networks, data mining, big data analysis, and artificial intelligence.

In his/her research work, the young researcher will attempt to prove the following work hypothesis:

Computer-aided attention-based deep neural networks, designed using latent data space analysis, are more successful than existing deep neural networks on the previously less successfully solved problems of segmentation and classification of multidimensional data.

c. Research goals and foreseen results

The candidate's training and research program will be based on the long-standing experience and knowledge of our Programme group in the field of computer processing of biomedical images and signals, machine learning, artificial intelligence and will be directed towards the following original scientific research goals and contributions:

- 1.) Design and implementation of new or analysis and improvement of existing computational algorithms for quantitative analysis of latent data space;
- 2.) Design and implementation of a methodology for designing deep attention-based neural networks using the results of latent data space analysis;
- 3.) Quantitatively supported analysis of the effectiveness of introducing changes to the architecture of a deep neural network, with an emphasis on explainability;
- 4.) Testing the accuracy and robustness of the developed methods for designing attention-based deep neural networks on the problems of segmentation and/or classification of selected multidimensional (biomedical) data, which have been less successfully solved so far;
- 5.) Transfer of scientific research results into practice and analysis of the socio-economic potential of the research.

3. STUDY PROGRAMME

Foreseen study programme, to which early stage researcher shall be enrolled in academic year 2025/2026:

Computer Science and Informatics (3rd Cycle, doctoral)

4. DESCRIPTION OF WORK AND TASKS

During the postgraduate studies, the young researcher will acquire advanced knowledge in the fields of digital image processing, computer vision, machine learning, deep neural networks, data mining, big data analysis and artificial intelligence. He/she will also gain experience and knowledge for research work and meet national and international partners in the aforementioned professional and scientific fields. He/she will present the results of his/her studies at established international scientific conferences in the field of multidimensional data processing and biomedical engineering and in journals with an impact factor that are in the first or second quarter of the selected field. He/she will also participate in trade fair presentations, workshops and scientific meetings that we (co-)organise within the framework of the Programme group. In this way, he/she will learn to address the target audience appropriately and to present complex scientific results clearly and concisely. He/she will also participate in the application of international and national projects, thus gaining experience for an independent academic career. Through practical experience, he/she will also gain knowledge about intellectual property protection and about concluding scientific-research or industrial contracts. In accordance with the contract, he/she will also enable participation in the pedagogical process at the Faculty of Electrical Engineering and Computer Science, thereby gaining experience in public speaking, promoting science and teaching.

The study programme will be divided into four parts

1st Year:

- Introduction to the research, scientific and professional work of the Programme group;
- Reviewing the professional literature in the field of digital processing of multidimensional signals and machine learning;
- Acquiring the advanced knowledge in the field of digital processing of multidimensional signals, machine learning, deep neural networks, data mining, big data analysis and artificial intelligence;
- Beginning of the development of methods for assessing and analysing latent data space;
- Beginning of the development of methods for designing deep neural networks based on attention, using the results of latent data space analysis;
- Preparing articles for international scientific conferences;
- Establishing of international and national scientific and professional contacts;
- Fulfilling the obligations of the 1st year of doctoral studies and the conditions for enrolling in the 2nd year of doctoral studies.

2nd Year:

- Intensive research work on the topic of the thesis;
- Developing, implementing and testing of computer algorithms for the latent data space estimation;
- Developing, implementing and testing of computer algorithms for designing deep neural networks based on attention;
- Continuously following the progress of professional literature and state of the art in the field of deep neural networks, digital multidimensional signal processing, machine learning, high-performance computing systems;
- Acquiring advanced knowledge in the field of digital multidimensional signal processing, deep neural networks, machine learning, data mining, big data analysis, artificial intelligence and high-performance and distributed computing;
- Preparing articles for international scientific conferences and journals with an impact factor;
- To further establishing and strengthening the international and national scientific and professional contacts;
- Fulfilling the obligations of the 2nd year of doctoral studies and the conditions for enrolling in the 3rd year of doctoral studies.

3rd Year:

- Intensive research, scientific and professional work on the doctoral thesis;
- Iterative developing, implementing and testing of computer algorithms for the latent data space estimation;
- Iterative developing, implementing and testing of computer algorithms for designing attention-based deep neural networks;
- Preparation and submission of an application for obtaining a dissertability of the doctoral topic;
- Continuous monitoring of the progress of professional literature and the state of the art in the field of the doctoral thesis;
- Preparing articles for international scientific conferences and journals with an impact factor;
- To further establishing and strengthening the international and national scientific and professional contacts;
- Implementing the measures for the protection of intellectual property and possible preparation of a patent application;
- Participating in the preparation of project applications;
- Fulfilling the obligations of the 3rd year of doctoral studies.

4th Year:

- Intensive research, scientific and professional work on the doctoral thesis;
- Continuous monitoring of the progress of professional literature and the state of the art in the field of the doctoral dissertation;
- To further establishing and strengthening the international and national scientific and professional contacts;

- Preparation, submission and defence of the doctoral thesis;
- Preparing articles for international scientific conferences and journals with an impact factor;
- Participating in the preparation of project applications;
- Implementing the measures for the protection of intellectual property and possible preparation of a patent application.

5. REQUESTED LEVEL OF EDUCATION

A completed undergraduate programme or a Master's (2nd-cycle) programme

6. REQUESTED FIELD OF EDUCATION

A completed undergraduate programme or a Master's (2nd-cycle Bologna) programme in the fields of Computer Science or Informatics

7. KLASIUS SRV

17 Seventh level: Second-cycle higher education and similar education/Second-cycle higher education and similar education

8. KLASIUS P

481 – Computer Science

9. REQUESTED KNOWLEDGE

Computer skills: MS Windows, Word, Excel, Internet, e-mail

10. REQUESTED SPECIAL REQUIREMENTS

Kliknite ali tapnite tukaj, če želite vnesti besedilo.

11. REQUESTED LANGUAGES

Knowledge of Slovenian and English language

12. REQUESTED WORK EXPERIENCE

Kliknite ali tapnite tukaj, če želite vnesti besedilo.

13. FORESEEN POSTDOCTORAL TRAINING

Kliknite ali tapnite tukaj, če želite vnesti besedilo.

Mentor's signature:

Research programme leader's signature:

Name and surname of Dean or
authorised person³:
Gorazd Štumberger

Signature of dean or authorised person:

Place and date:

Maribor

5. 02. 2025

Stamp:

³ The training program is signed by the dean of the member where the ESR's employment and training will take place.