

NEVRONSKE MREŽE

UČNI NAČRT PREDMETA/COURSE SYLLABUS

Predmet: NEVRONSKE MREŽE

Course title: NEURAL NETWORKS

Članica nosilka/UL Member: UL FS

Študijski programi in stopnja	Študijska smer	Letnik	Semestri	Izbirnost
Strojništvo, tretja stopnja, doktorski	Ni členitve (študijski program)	1. letnik, 2. letnik	Celoletni	izbirni

Univerzitetna koda predmeta/University course code: 0033417

Koda učne enote na članici/UL Member course code: 7009

Predavanja /Lectures	Seminar /Seminar	Vaje /Tutorials	Klinične vaje /Clinical tutorials	Druge oblike študija /Other forms of study	Samostojno delo /Individual student work	ECTS
90					160	10

Nosilec predmeta/Lecturer: Edvard Govekar, Primož Potočnik

Izvajalci predavanj: Edvard Govekar, Primož Potočnik

Izvajalci seminarjev:

Izvajalci vaj:

Izvajalci kliničnih vaj:

Izvajalci drugih oblik:

Izvajalci praktičnega usposabljanja:

Vrsta predmeta/Course type: Izbirni predmet /Elective course

Jeziki/Languages:

Predavanja/Lectures:

Angleščina, Slovenščina

Vaje/Tutorial:

Angleščina, Slovenščina

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:**Prerequisites:**

Veljajo splošni pogoji za doktorski študij.

General prerequisites for the third level studies.

Vsebina:**Content (Syllabus outline):**

(i) Splošna predstavitev

Kaj je nevronska mreža, biološke nevronske mreže, umetne nevronske mreže, prednosti nevronskih mrež, kratka zgodovina nevronskih mrež, uporaba nevronskih mrež

(ii) Model nevrona, arhitekture mrež in učenje

Model nevrona, aktivacijske funkcije, arhitekture mrež, učni algoritmi, paradigme učenja, učne naloge, predstavitev znanja, nevronske mreže napram statističnim metodam

(iii) Perceptroni in linearni filtri

Perceptron nevron, perceptronsko učno pravilo, ADALINE, LMS učno pravilo, adaptivni filtri, XOR problem

(iv) Vzratno učenje (backpropagation)

Večnivojske mreže, algoritem vzratnega učenja, uporaba vzratnega učenja, napredni algoritmi, zmogljivosti večnivojskih perceptronov

(v) Dinamične mreže

Zgodovinske dinamične mreže, nevronska mreža s fokusirano časovno zakasnitvijo, nevronska mreža s porazdeljeno časovno zakasnitvijo, NARX mreža, mreža s povratnimi plastmi, zmogljivosti dinamičnih nevronskih mrež, učni algoritmi, identifikacija sistemov, modelno referenčno adaptivno vodenje

(vi) Mreže radialnih baznih funkcij (RBFN)

(i) General Introduction

What is a neural network?, Biological neural networks, Human nervous system, Artificial neural networks, Benefits of neural networks, Brief history of neural networks, Applications of neural networks

(ii) Neuron Model, Network Architectures and Learning

Neuron model, Activation functions, Network architectures, Learning algorithms, Learning paradigms, Learning tasks, Knowledge representation, Neural networks vs. statistical methods

(iii) Perceptrons and Linear Filters

Perceptron neuron, Perceptron learning rule, Adaline, LMS learning rule, Adaptive filtering, XOR problem

(iv) Backpropagation

Multilayer feedforward networks, Backpropagation algorithm, Working with backpropagation, Advanced algorithms, Performance of multilayer perceptrons

(v) Dynamic Networks

Historical dynamic networks, Focused time-delay neural network, Distributed time-delay neural network, NARX network, Layer recurrent network, Computational power of dynamic networks, Learning algorithms, System identification, Model reference adaptive control

<p>struktura RBFN mrež, natančna interpolacija, radialne bazne funkcije, mreža radialnih baznih funkcij, RBFN učenje, RBFN za razpoznavanje vzorcev, primerjava z večnivojskim perceptronom, verjetnostne nevronske mreže (PNN), posplošene regresijske mreže (GRNN)</p> <p>(vii) Samo-organizirajoče se mreže</p> <p>Samo-organizacija, samo-organizirajoče se preslikave (SOM), SOM algoritem, lastnosti SOM mreže, učenje z vektorsko kvantizacijo (LVQ)</p> <p>(viii) Praktični napotki</p> <p>Priprava podatkov, izbira vhodov, kodiranje podatkov, metoda glavnih osi (PCA), invariance in predhodno znanje, posploševanje, splošna načela za izgradnjo nevronske mreže</p> <p>(ix) Napredne vsebine</p> <p>Optimalna zgradba mreže, evolucija nevronske mreže, mreže podpornih vektorjev (SVM), committee stroji, naključnostni stroji, mreže glavnih osi</p>	<p>(vi) Radial Basis Function Networks</p> <p>RBFN structure, Exact interpolation, Radial basis functions, Radial basis function networks, RBFN training, RBFN for pattern recognition, Comparison with multilayer perceptron, Probabilistic networks, Generalized regression networks</p> <p>(vii) Self-organizing maps</p> <p>Self-organization, Self-organizing maps, SOM algorithm, Properties of the feature map, Learning vector quantization</p> <p>(viii) Practical Considerations</p> <p>Preparing data, Selection of inputs, Data encoding, Principal component analysis, Invariances and prior knowledge, Generalization, General guidelines</p>
----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Temeljna literatura in viri/Readings:

- [1] S. Haykin: Neural Networks: A Comprehensive Foundation, 2/E, Prentice Hall, 1999, [COBISS.SI-ID 1223764].
- [2] C.M. Bishop: Neural Networks for Pattern Recognition, Oxford University Press, 1995, [COBISS.SI-ID 1599515].
- [3] I. Grabec, W. Sachse: Synergetics of measurement, prediction and control, Berlin; Heidelberg; New York: Springer, 1997, [COBISS.SI-ID 63089].
- [4] P. Potočnik: Fundamentals of neural networks, 2023.
<https://github.com/ppotoc/Fundamentals-of-Neural-Networks>, [COBISS.SI-ID 142219779]. e-knjiga

Cilji in kompetence:

Cilji:

- (i) predstaviti principe in metode nevronske mreže,
- (ii) predstaviti poglobljene modele nevronske mreže,
- (iii) prikazati postopek uporabe nevronske mreže v praksi.

Objectives and competences:

Goals:

- The objectives of the course are:
- (i) to introduce the principles and methods of neural networks,
 - (ii) to present the principal neural network models,
 - (iii) to demonstrate the process of

<p>Kompetence:</p> <p>Študent bo:</p> <ul style="list-style-type: none"> (i) pridobil razumevanje koncepta neparametričnega modeliranja z nevronskimi mrežami, (ii) znal razložiti poglobitve arhitekture nevronskih mrež (večnivojski perceptron, dinamične nevronske mreže, mreže radialnih baznih funkcij, samo-organizirajoče se mreže), (iii) razvil sposobnost izgradnje nevronskih mrež za reševanje realnih problemov, (iv) zmožen zasnovati ustrezno arhitekturo nevronske mreže, doseči dobre učne in posplošitvene rezultate, ter izdelati rešitev z nevronskimi mrežami. 	<p>applying neural networks in practice.</p> <p>Competences:</p> <p>The student will:</p> <ul style="list-style-type: none"> (i) understand the concept of nonparametric modelling by neural networks, (ii) explain the most common NN architectures (multilayer perceptrons, dynamic networks, radial basis function networks, self-organized networks), (iii) develop the ability to construct neural networks for solving real-world problems, (iv) be able to design proper NN architecture, achieve good training and generalization performance, and finally, implement a neural network solution.
---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

<p>Predvideni študijski rezultati:</p> <p>Študent bo:</p> <ul style="list-style-type: none"> (i) pridobil razumevanje koncepta neparametričnega modeliranja z nevronskimi mrežami, (ii) znal razložiti poglobitve arhitekture nevronskih mrež (večnivojski perceptron, dinamične nevronske mreže, mreže radialnih baznih funkcij, samo-organizirajoče se mreže), (iii) razvil sposobnost izgradnje nevronskih mrež za reševanje realnih problemov, (iv) zmožen zasnovati ustrezno arhitekturo nevronske mreže, doseči dobre učne in posplošitvene rezultate, ter izdelati rešitev z nevronskimi mrežami. 	<p>Intended learning outcomes:</p> <p>The student will:</p> <ul style="list-style-type: none"> (i) understand the concept of nonparametric modelling by neural networks, (ii) explain the most common NN architectures (multilayer perceptrons, dynamic networks, radial basis function networks, self-organized networks), (iii) develop the ability to construct neural networks for solving real-world problems, (iv) be able to design proper NN architecture, achieve good training and generalization performance, and finally, implement a neural network solution.
-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

<p>Metode poučevanja in učenja:</p> <p>Predavanja, laboratorijske vaje, seminarsko delo, e-izobraževanje, konzultacije. Seminarsko delo v čim večji meri navezuje se na področje</p>	<p>Learning and teaching methods:</p> <p>Lectures, laboratory practice & seminar work, e-education, consulting. The seminar work is related, as much as possible, to the student's doctoral</p>
---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------	------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

doktorskega raziskovanja. Študij z uporabo priporočene literature.	research field. Study on a recommended literature basis.
--------------------------------------------------------------------	----------------------------------------------------------

Načini ocenjevanja:	Delež/Weight	Assessment:
Ocena je sestavljena iz seminarja (100%). Ocena seminarja je sestavljena iz pisnega dela (40%) in predstavitve ter ustnega zagovora (60%).		The grade is determined from the seminar (100%). The seminar grade consists of the written part (40%), presentation and oral defence (60%).

Ocenjevalna lestvica:	Grading system:
5 - 10, pri čemer velja, da je pozitivna ocena od 6 - 10	5 - 10, a student passes the exam if he is graded from 6 to 10

Reference nosilca/Lecturer's references:

prof. dr. Edvard GOVEKAR

POTOČNIK, Primož, OLMOS LOPEZ-ROSO, Borja, VODOPIVEC, Lučka, SUSIČ, Egon, GOVEKAR, Edvard. Condition classification of heating systems valves based on acoustic features and machine learning. Applied acoustics. [Print ed.]. Mar. 2021, vol. 174, str. 1-9, ilustr. ISSN 0003-682X.

<https://www.sciencedirect.com/science/article/pii/S0003682X20308409?via%3Dihub>, DOI: 10.1016/j.apacoust.2020.107736. [COBISS.SI-ID 35370243], [JCR, SNIP, WoS do 7. 10. 2022: št. citatov (TC): 6, čistih citatov (CI): 6, čistih citatov na avtorja (CIAu): 1,20, Scopus do 25. 5. 2022: št. citatov (TC): 7, čistih citatov (CI): 7, čistih citatov na avtorja (CIAu): 1,40]

POTOČNIK, Primož, ŠKERL, Primož, GOVEKAR, Edvard. Machine-learning-based multi-step heat demand forecasting in a district heating system. Energy and buildings. [Print ed.]. Feb. 2021, vol. 233, str. 1-14, ilustr. ISSN 0378-7788. <https://www.sciencedirect.com/science/article/pii/S0378778820334599?via%3Dihub>, DOI: 10.1016/j.enbuild.2020.110673. [COBISS.SI-ID 45195779], [JCR, SNIP, WoS do 31. 3. 2023: št. citatov (TC): 11, čistih citatov (CI): 11, čistih citatov na avtorja (CIAu): 3,67, Scopus do 3. 4. 2023: št. citatov (TC): 13, čistih citatov (CI): 13, čistih citatov na avtorja (CIAu): 4,33]

POTOČNIK, Primož, SOLDI, Božidar, ŠIMUNOVIĆ, Goran, ŠARIĆ, Tomislav, JEROMEN, Andrej, GOVEKAR, Edvard. Comparison of static and adaptive models for short-term residential natural gas forecasting in Croatia. Applied energy. Sep. 2014, vol. 129, str. 94-103, ilustr. ISSN 0306-2619. [COBISS.SI-ID 13478939], [JCR, SNIP, WoS do 6. 4. 2023: št. citatov (TC): 49, čistih citatov (CI): 46, čistih citatov na avtorja (CIAu): 7,67, Scopus do 29. 3. 2023: št. citatov (TC): 51, čistih citatov (CI): 48, čistih citatov na avtorja (CIAu): 8,00]

BERLEC, Tomaž, POTOČNIK, Primož, GOVEKAR, Edvard, STARBEK, Marko. A method of production fine layout planning based on self-organising neural network clustering. International Journal of Production Research. 2014, vol. 52, iss. 24, str. 7209-7222, ilustr. ISSN 0020-7543. DOI: 10.1080/00207543.2014.910619. [COBISS.SI-ID 13421083], [JCR, SNIP, WoS do 10. 3. 2021: št. citatov (TC): 5,

čistih citatov (CI): 4, čistih citatov na avtorja (CIAu): 1,00, Scopus do 24. 10. 2022: št. citatov (TC): 6, čistih citatov (CI): 5, čistih citatov na avtorja (CIAu): 1,25]

doc. dr. Primož Potočnik

POTOČNIK, Primož, ŠKERL, Primož, GOVEKAR, Edvard. Machine-learning-based multi-step heat demand forecasting in a district heating system. *Energy and buildings*. [Print ed.]. Feb. 2021, vol. 233, str. 1-14, ilustr. ISSN 0378-7788. <https://www.sciencedirect.com/science/article/pii/S0378778820334599?via%3Dihub>, DOI: [10.1016/j.enbuild.2020.110673](https://doi.org/10.1016/j.enbuild.2020.110673). [COBISS.SI-ID [45195779](#)]

POTOČNIK, Primož, OLMOS LOPEZ-ROSO, Borja, VODOPIVEC, Lučka, SUSIČ, Egon, GOVEKAR, Edvard. Condition classification of heating systems valves based on acoustic features and machine learning. *Applied acoustics*. [Print ed.]. Mar. 2021, vol. 174, str. 1-9, ilustr. ISSN 0003-682X. <https://www.sciencedirect.com/science/article/pii/S0003682X20308409?via%3Dihub>, DOI: [10.1016/j.apacoust.2020.107736](https://doi.org/10.1016/j.apacoust.2020.107736). [COBISS.SI-ID [35370243](#)]

POTOČNIK, Primož, GOVEKAR, Edvard. Semi-supervised vibration-based classification and condition monitoring of compressors. *Mechanical systems and signal processing*. Sep. 2017, vol. 93, str. 51-65, ilustr. ISSN 0888-3270. <http://www.sciencedirect.com/science/article/pii/S088832701730047X>, DOI: [10.1016/j.ymssp.2017.01.048](https://doi.org/10.1016/j.ymssp.2017.01.048). [COBISS.SI-ID [15296539](#)]

POTOČNIK, Primož, SOLDI, Božidar, ŠIMUNOVIĆ, Goran, ŠARIĆ, Tomislav, JEROMEN, Andrej, GOVEKAR, Edvard. Comparison of static and adaptive models for short-term residential natural gas forecasting in Croatia. *Applied energy*. Sep. 2014, vol. 129, str. 94-103, ilustr. ISSN 0306-2619. [COBISS.SI-ID [13478939](#)]