FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

Modulbezeichnung:	**Machine Learning in Signal Processing (MLISP)** (Machine Learning in Signal Processing)	**5 ECTS**
Modulverantwortliche/r:	André Kaup	
Lehrende:	André Kaup	

Startsemester: WS 2020/2021	Dauer: 1 Semester	Turnus: jährlich (WS)
Präsenzzeit: 60 Std.	Eigenstudium: 90 Std.	Sprache: Englisch

Lehrveranstaltungen:

Machine Learning in Signal Processing (WS 2020/2021, Vorlesung, 3 SWS, Veniamin Morgenshtern)
Supplements for Machine Learning in Signal Processing (WS 2020/2021, Übung, 1 SWS, Veniamin Morgenshtern)

Inhalt:

This course is an introduction into statistical machine learning and artificial intelligence. The special emphasis is on applications to modern signal processing problems. The course is focused on design principles of machine learning algorithms.

First we will study basic methods for regression and classification: linear regression, logistic regression, the nearest neighbors algorithm. Based on these examples, we will discuss the fundamental trade-off between the flexibility of the model and the ability to fit the model based on the moderate amount of training data. We will contrast learning in high-dimensional spaces vs. learning in low dimensional spaces.

Next, we will study methods that help make linear models flexible: polynomial features and splines. When these tools are used, regularization is crucial. We will discuss structured signal representations: short-time Fourier transform and wavelets. We will focus on the importance of sparsity in signal representations. This will lead us to compressed sensing and to other modern convex-optimization-based methods for signal denoising, reconstruction, and compression. We will review key concepts in convex optimization, study the LASSO, support vector machines, the idea of kernels. The last part of the course will focus on the breakthrough new technology for computer vision: the deep learning.

The course contains exercises: 30 percent mathematical and 70 percent programming in Python. You will be asked to implement basic machine learning and signal processing algorithms yourself. For more advanced algorithms, you will practice using powerful numerical and optimization libraries (numpy, cvxpy, scikit-learn, pywavelets, pytorch).

Lernziele und Kompetenzen:

Students are able to:

- Apply standard machine learning and signal processing algorithms to design solutions to practical problems in new domains.
- Use standard packages for machine learning in Python: numpy, cvxpy, scikit-learn, pywavelets, pytorch.
- Choose appropriate algorithms and signal representations for the problem at hand.
- Debug and calibrate machine learning algorithms. Develop simple modification to the standard algorithms as appropriate to the problem at hand.
- Rapidly discover, understand, and apply advanced algorithms and signal representations that were not covered in class.
- Explain the theoretical aspects that underpin the design of new algorithms.
- Explain the importance of statistics and optimization in machine learning.

Literatur:

Literature:

- T. Hastie, R. Tibshirani, J. Friedman: The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Second

Edition, Chapters 1 - 7.

- Ng: Lecture notes and materials for Stanford CS229 class. Lecture Notes and Exercises.
- M. Kon: Lecture notes on basics of wavelets.

- M. Nielsen: Neural networks and deep learning.

Verwendbarkeit des Moduls / Einpassung in den Musterstudienplan:

Das Modul ist im Kontext der folgenden Studienfächer/Vertiefungsrichtungen verwendbar:

[1] **Advanced Signal Processing & Communications Engineering (Master of Science)**
(Po-Vers. 2016w | TechFak | Advanced Signal Processing & Communications Engineering (Master of Science) | Gesamtkonto | Pflichtmodule | Machine Learning in Signal Processing)

[2] **Advanced Signal Processing & Communications Engineering (Master of Science)**
(Po-Vers. 2020w | TechFak | Advanced Signal Processing & Communications Engineering (Master of Science) | Gesamtkonto | Machine Learning in Signal Processing)

[3] **Communications and Multimedia Engineering (Master of Science)**
(Po-Vers. 2011 | TechFak | Communications and Multimedia Engineering (Master of Science) | Gesamtkonto | Wahlpflichtmodule | Technische Wahlpflichtmodule | Machine Learning in Signal Processing)

[4] **Communications and Multimedia Engineering (Master of Science)**
(Po-Vers. 2011 | TechFak | Communications and Multimedia Engineering (Master of Science) | Gesamtkonto | Wahlmodule | Technische Wahlmodule | Machine Learning in Signal Processing)

[5] **Computational Engineering (Master of Science)**
(Po-Vers. 2016w | Gesamtkonto | Wahlpflichtbereich Technisches Anwendungsfach | Information Technology - DSP | Machine Learning in Signal Processing)

[6] **Computational Engineering (Rechnergestütztes Ingenieurwesen) (Master of Science)**
(Po-Vers. 2013 | TechFak | Computational Engineering (Rechnergestütztes Ingenieurwesen) (Master of Science) | Gesamtkonto | Wahlpflichtbereich Technisches Anwendungsfach | Information Technology - DSP | Machine Learning in Signal Processing)

[7] **Elektrotechnik, Elektronik und Informationstechnik (Bachelor of Science)**
(Po-Vers. 2009 | TechFak | Elektrotechnik, Elektronik und Informationstechnik (Bachelor of Science) | Wahlfächer | Technische Wahlfächer (aus dem Angebot der Technischen Fakultät frei wählbar) | Machine Learning in Signal Processing)

[8] **Elektrotechnik, Elektronik und Informationstechnik (Bachelor of Science)**
(Po-Vers. 2017w | TechFak | Elektrotechnik, Elektronik und Informationstechnik (Bachelor of Science) | Technische Wahlfächer (aus dem Angebot der Technischen Fakultät frei wählbar) | Machine Learning in Signal Processing)

[9] **Elektrotechnik, Elektronik und Informationstechnik (Bachelor of Science)**
(Po-Vers. 2019w | TechFak | Elektrotechnik, Elektronik und Informationstechnik (Bachelor of Science) | Gesamtkonto | Wahlfächer | Technische Wahlfächer (aus dem Angebot der Technischen Fakultät frei wählbar) | Machine Learning in Signal Processing)

[10] **Information and Communication Technology (Master of Science)**
(Po-Vers. 2019s | TechFak | Information and Communication Technology (Master of Science) | Gesamtkonto | Pflicht- und Wahlpflichtmodule der Studienschwerpunkte | Schwerpunkt Embedded Systems | Wahlpflichtmodul aus EEI im Schwerpunkt Embedded Systems | Machine Learning in Signal Processing)

[11] **Information and Communication Technology (Master of Science)**
(Po-Vers. 2019s | TechFak | Information and Communication Technology (Master of Science) | Gesamtkonto | Pflicht- und Wahlpflichtmodule der Studienschwerpunkte | Schwerpunkt Networks and Digital Communication | Wahlpflichtmodul aus EEI im Schwerpunkt Networks and Digital Communication | Machine Learning in Signal Processing)

[12] **Information and Communication Technology (Master of Science)**
(Po-Vers. 2019s | TechFak | Information and Communication Technology (Master of Science) | Gesamtkonto | Pflicht- und Wahlpflichtmodule der Studienschwerpunkte | Schwerpunkt Media Processing Systems | Wahlpflichtmodul aus EEI im Schwerpunkt Media Processing Systems | Machine Learning in Signal Processing)

[13] **Informations- und Kommunikationstechnik (Master of Science)**
(Po-Vers. 2016s | TechFak | Informations- und Kommunikationstechnik (Master of Science) | Gesamtkonto | Schwerpunkte im Masterstudium | Schwerpunkt Eingebettete Systeme | Wahlpflichtmodule | Wahlpflichtmodul aus EEI im Schwerpunkt Eingebettete Systeme | Machine Learning in Signal Processing)

[14] **Informations- und Kommunikationstechnik (Master of Science)**
(Po-Vers. 2016s | TechFak | Informations- und Kommunikationstechnik (Master of Science) | Gesamtkonto | Schwerpunkte im Masterstudium | Schwerpunkt Kommunikationsnetze und Übertragungstechnik | Wahlpflichtmodule |

Wahlpflichtmodul aus EEI im Schwerpunkt Kommunikationsnetze | Machine Learning in Signal Processing)

[15] **Informations- und Kommunikationstechnik (Master of Science)**
(Po-Vers. 2016s | TechFak | Informations- und Kommunikationstechnik (Master of Science) | Gesamtkonto | Schwerpunkte im Masterstudium | Schwerpunkt Multimediasysteme | Wahlpflichtmodule | Wahlpflichtmodul aus EEI im Schwerpunkt Multimediasysteme | Machine Learning in Signal Processing)

[16] **Mechatronik (Master of Science)**
(Po-Vers. 2012 | TechFak | Mechatronik (Master of Science) | Mechatronik (Studienbeginn bis 30.09.2020) | Gesamtkonto | M3 Technische Wahlmodule | Machine Learning in Signal Processing)

[17] **Wirtschaftsingenieurwesen (Master of Science)**
(Po-Vers. 2009 | TechFak | Wirtschaftsingenieurwesen (Master of Science) | Masterstudiengang Wirtschaftsingenieurwesen (bis 30.09.2018) | Gesamtkonto | Ingenieurwissenschaftliche Studienrichtungen | Technische Wahlmodule | Technische Wahlmodule | Machine Learning in Signal Processing)

[18] **Wirtschaftsingenieurwesen (Master of Science)**
(Po-Vers. 2018w | TechFak | Wirtschaftsingenieurwesen (Master of Science) | Masterstudiengang Wirtschaftsingenieurwesen (Studienbeginn ab 01.10.2018) | Gesamtkonto | Studienrichtung Maschinenbau | Technische Wahlmodule und Hochschulpraktikum | Technische Wahlmodule | Machine Learning in Signal Processing)

[19] **Wirtschaftsingenieurwesen (Master of Science)**
(Po-Vers. 2018w | TechFak | Wirtschaftsingenieurwesen (Master of Science) | Masterstudiengang Wirtschaftsingenieurwesen (Studienbeginn ab 01.10.2018) | Gesamtkonto | Studienrichtung Elektrotechnik | Technische Wahlmodule und Hochschulpraktikum | Technische Wahlmodule | Machine Learning in Signal Processing)

Studien-/Prüfungsleistungen:

Machine Learning in Signal Processing (Prüfungsnummer: 84401)
Prüfungsleistung, Klausur, Dauer (in Minuten): 90
Anteil an der Berechnung der Modulnote: 100% Prüfungssprache: Englisch

Erstablegung: WS 2020/2021, 1. Wdh.: SS 2021
1. Prüfer: André Kaup
