This course deals with the foundations and advances of online learning and online convex optimization. The main theme of the course is the design and theoretical understanding of algorithms that make sequential decisions in adversarial environments, striving to perform as close as possible to a fixed strategy that knows the future in advance. Special attention will be paid to parameter-free, efficient, and practical algorithms. The focus will be on theorems and proofs for the analysis of online learning algorithms. The class will also cover applications of online learning to stochastic optimization, boosting, portfolio selection, and statistical machine learning topics.

Prerequisites
A strong level of mathematical maturity is required. In particular, Linear Algebra, e.g., EK102 or MA142, Multivariate Calculus, e.g., MA225 are required. Prior knowledge of convex optimization, e.g. EC524 or ES524, is also suggested.

Textbooks
- Online Learning and Online Convex Optimization by Shai Shalev-Shwartz
- Prediction, Learning, and Games by Nicolo Cesa-Bianchi and Gabor Lugosi
- Bandit Algorithms by Tor Lattimore and Csaba Szepesvari

Tentative Syllabus
1. Introduction to online learning and examples
2. Notes on convex analysis
3. Learning with experts and lower bound
4. Online convex optimization, OGD, and lower bound
5. Online Mirror descent and Exponentiated Gradient
6. FTRL and Vovk-Azoury-Warmuth forecaster
7. \( L^{\infty} \) bounds
8. Adaptivity to gradients: AdaGrad
9. Connection to stochastic optimization: online-to-batch, noise, and smoothness
10. Connection to statistical learning theory and boosting
11. Adaptation to competitor norm and KL bounds with reduction to coin-betting
12. Exp-concave losses and Online Newton Step
13. Online learning and concentration inequalities
14. Universal portfolio selection
15. Multi-armed Bandits (MAB), Exp3 algorithm, lower bounds
16. Optimal MAB algorithms, FTRL/OMD with Tsallis entropy
17. Stochastic MAB and UCB
18. Stochastic linear bandits and LinUCB
19. Contextual bandits and Exp4