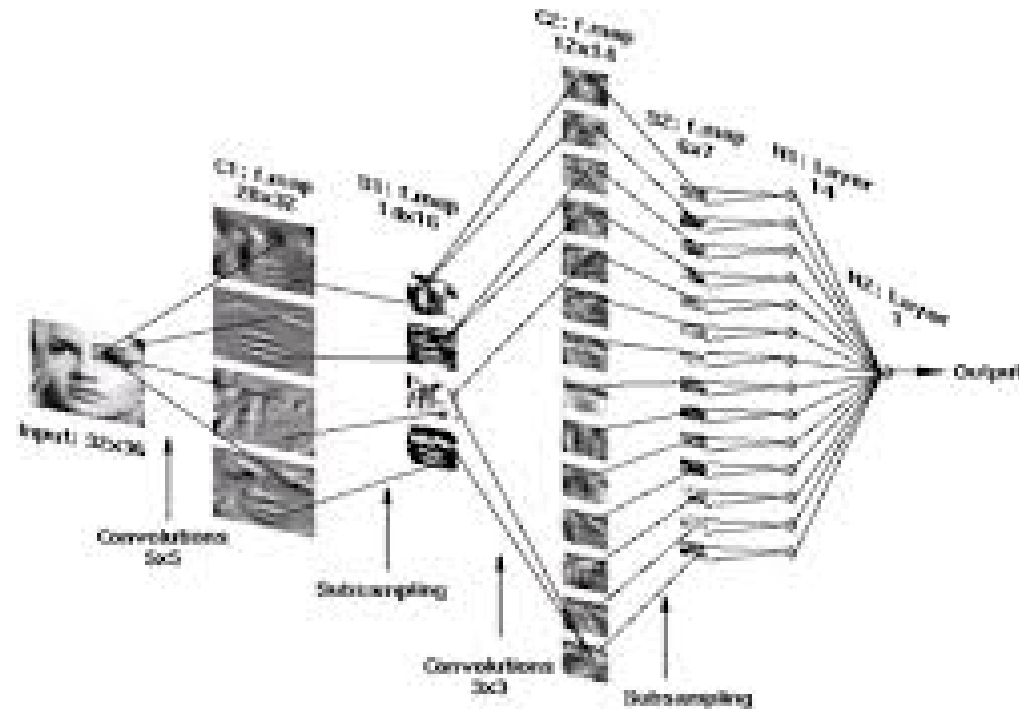# Advanced Machine Learning

Course Outline

Course Details and Topics

Course Structure

- Lectures

    ★ 11:00-11:45 Tuesday, Building 35 room 1005
    ★ 16:00-16:45 Tuesday, Building 44 room 1041 (L/T A)
    ★ 15:00-15:45 Thursday, Building 44 room 1041 (L/T A)

- Assessment

    ★ 80% Exam
    ★ 20% Problem Sheet

Problem Sheets

- I am going to provide many problem sheets

- One problem sheets will be marked and worth 20% (you will know which one this is)

- The other problem sheets are optional, but some small proportion of the questions will be on the exam

- I will go through the problem sheets, but if you have not attempted the questions you won't learn that much

What's in the Course

- This course is going to cover the core principles and mathematics behind machine learning

- It is not going to explicitly teach different machine learning algorithms, although some will be covered

- We are not looking at advanced algorithms but cover the principles: fish

- There are very good implementation available (e.g. scikit-learn)

- Along the way though we will meet (often many times) particular algorithms

Cracking the Code

- Mathematics is the language of machine learning

- You can do machine learning without mathematics, but if you want to develop and understand advanced algorithms then you have no choice

- This course invites you on a journey to crack the code of mathematics for machine learning

- If this isn't a challenge you want, then this is probably not the course for you

Topics

- Learning Theory

  ⋆ Bias-Variance
  ⋆ Overfitting, symmetry and regularisation
  ⋆ Ensembling, bagging and boosting▮

- Mathematics

  ⋆ Function Spaces: Kernel Methods and Gaussian Processes
  ⋆ Linear Algebra, embeddings, positive definiteness, subspace, determinants▮

Topics Continued

- Optimisation

  - ⋆ Newton/Quasi-Newton Methods: convergence rates
  - ⋆ SGD, momentum, ADAM▮

- Constrained Optimisation

  - ⋆ KKT conditions
  - ⋆ Duality Linear/Quadratic Programming
  - ⋆ SVMs▮

- Convexity

  - ⋆ Convex sets: linear constraints, PD matrices
  - ⋆ Convex functions
  - ⋆ SVMs, Lasso
  - ⋆ Jensen's inequality▮

Topics Continued

- Probability

  ⋆ Naive Bayes
  ⋆ Gaussian Processes
  ⋆ Dependencies and Graphical Models
  ⋆ Expectations and MCMC∎

- Advanced Methods

  ⋆ Divergences: KL and Wasserstein
  ⋆ VAEs and GANs
  ⋆ Entropy and information theory
  ⋆ Variational Approximation∎