



Cramérsällskapet: höstmöte 2019

Ny statistik – ny undervisning?

SLU, campus Ultuna

30 september – 1 oktober

Här återfinns underlaget till flertalet av de presentationer som gavs under höstmötet. Undertecknad har valt att ordna dem i den följd de gavs under konferensen; listan för samtliga lärosäten:

Linköpings universitet

Stockholms universitet (statistik)

Uppsala universitet (matematisk statistik)

Sveriges lantbruksuniversitet

Chalmers och Göteborgs universitet

Kungliga tekniska högskolan

Stockholms universitet (matematisk statistik)

Universitetet i Oslo

Högskolan Dalarna

Uppsala universitet (statistik)

Linnéuniversitetet

Örebro universitet

Umeå universitet (statistik)

Umeå universitet (matematisk statistik)

Danmarks tekniske universitet

Sammanställning av inkomna filer gjord av Jesper Rydén (jesper.ryden@slu.se)

Statistik möter datavetenskap - erfarenheter från Linköpings universitet

Mattias Villani

**Avdelningen för statistik och maskininlärning
Institutionen för datavetenskap
Linköpings universitet**

Översikt

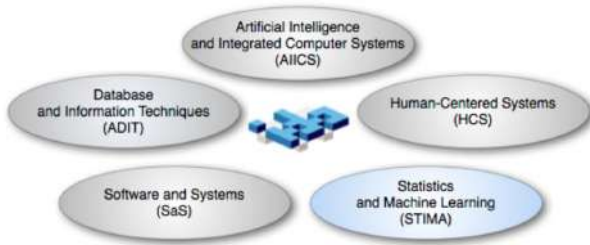
- ▶ Organisation
- ▶ Undervisning
- ▶ Forskning

Slides:

<https://github.com/mattiasvillani/Talks/raw/master/CramerSept2019.pdf>

Statistikämnet tillhör datavetenskaplig institution

- **Avdelningen för statistik och maskininläring** är sedan 2008 en av fem avdelningar vid institutionen för datavetenskap.



- *Frontiers in Massive Data Analysis (US National Research Council):*

*“**Computer scientists** involved in building big-data systems must develop a deeper awareness of inferential issues, while **statisticians** must concern themselves with scalability, algorithmic issues, and real-time decision-making.”*

Masterprogrammet Statistics and Machine Learning

- ▶ 2-årigt internationellt **masterprogram i statistik** med start 2008.
- ▶ **Studenter** från statistik, datavetenskap, ingenjörsvetenskaper, tillämpad matematik.
- ▶ Antal studenter: 2017-2019: **24, 44, 63** (varav 41 betalande).
- ▶ Under senare år mer **probabilistiska modeller** och **likelihoodbaserade och bayesianska metoder**.
- ▶ **Prediktivt fokus.**
- ▶ **Programmering. Datorlaborationer** och **datortentor.**
- ▶ Kurser samläses med **masterprofil inom AI och Maskininlärning på ingenjörsprogram.**

Year 1			
Semester 1		Semester 2	
Period 1	Period 2	Period 3	Period 4
Advanced Academic Studies (732A60 , 3 credits)	Introduction to Machine Learning (732A95 , 9 credits)	Advanced Data Mining (732A75 , 6 credits)	Big Data Analytics (732A54 , 6 credits)
Visualization (732A98 , 6 credits)		Introduction to Python (732A74 , 3 credits)	Philosophy of science (720A04 , 3 credits)
Advanced R programming (732A94 , 6 credits)		Computational statistics (732A90 , 6 credits)	Bayesian learning, (732A91 , 6 credits)
Statistical methods (732A93 , 6 credits)		Neural Networks and Learning Systems (732A55 , 6 credits)	
	Bioinformatics (732A51 , 6 credits)	Web programming (732A56 , 4 credits)	

Year 2			
Semester 3		Semester 4	
Period 1	Period 2	Period 3	Period 4
Time series analysis(732A62 , 6 credits)	Text Mining (732A92 , 6 credits)	MASTER THESIS (732A64 , 30 credits)	
Probability theory (732A63 , 6 credits)	Multivariate statistical methods (732A97 , 6 credits)		
Advanced Machine Learning (732A96 , 6 credits)	Database Technology (732A57 , 6 credits)		
Data mining project (732A65 , 6 credits)			
Decision theory (732A66 , 6 credits)			
EXCHANGE STUDIES			

Kurs: Sannolikhetslära och statistik, 6 hp

- ▶ **Grundläggande kurs** i Sannolikhetslära och statistik för **ingenjörer**.
- ▶ Sannolikhetslära + Inferens + **Prediktion** + **Beslut**
- ▶ Både **frekventistisk** och **Bayesiansk inferens**
- ▶ Tre **regjäla datorlaborationer**. Simulering för att förstå teorin.
- ▶ **Exempel från maskininlärning/AI** från dag 1 för motivationen.
- ▶ Kurssida:
<https://www.ida.liu.se/~TDAB01/info/courseinfo.sv.shtml>.

Machine learning, 9 hp

- ▶ Avancerad nivå.
- ▶ Bred översiktskurs:
 - ▶ Basic Concepts in Machine Learning
 - ▶ Regression, Regularization and Model Selection
 - ▶ Classification Methods
 - ▶ Dimensionality Reduction and Uncertainty Estimation
 - ▶ Kernel Methods and Support Vector Machines.
 - ▶ Neural Networks and Deep Learning
 - ▶ Model Inference and Variable Selection
 - ▶ Ensemble Methods and Mixture Models
 - ▶ Online Learning
 - ▶ Splines and Additive Models
 - ▶ High-Dimensional Problems
- ▶ Antal studenter 2019: **63 master + 100 ingenjörer** (efter stopp).
- ▶ Kurssida:
<https://www.ida.liu.se/~732A95/info/courseinfo.en.shtml>.

Bayesian learning, 6 hp

- ▶ Avancerad nivå.
- ▶ **Fyra moment:**
 - ▶ The Bayesics
 - ▶ Bayesian Regression and Classification
 - ▶ Bayesian Computations: MCMC, HMC and Variational Bayes
 - ▶ Model Inference and Variable Selection
- ▶ **Bayesiansk inferens** passar ML:
 - ▶ **Prediktion** och **beslut** på ett naturligt sätt
 - ▶ **Simuleringsvänligt** (MCMC etc)
 - ▶ **Regularisering** av flexibla icke-linjära modeller via mjukhetspriors
- ▶ Kurssida: <https://www.ida.liu.se/~732A91/info/courseinfo.en.shtml>.

Advanced Machine learning, 6 hp

- ▶ Avancerad nivå.
- ▶ Djupdykning i mindre antal probabilistiska modeller. Bayes.
- ▶ Moment:
 - ▶ **Hidden Markov Models**
 - ▶ **State Space Models**
 - ▶ **Graphical Models and Bayesian Networks**
 - ▶ **Gaussian Process Regression and Classification**
- ▶ Kurssida: <https://www.ida.liu.se/~732A96/info/courseinfo.en.shtml>.

Gaussiska processer för ML

- ▶ Bok: **Gaussian Processes for Machine Learning** (Rasmussen-Williams).
- ▶ Innehåll:
 - ▶ Resultat om **multivariat normal** (täthet, marginella och betingade fördelningar, linj.transf).
 - ▶ **Definition Gaussisk process** (GP) som sannolikhetsfördelning över funktioner.
 - ▶ **Regression** med GPs
 - ▶ **Klassifikation** med GPs
 - ▶ **Probabilistisk optimering** med GPs.
 - ▶ Numeriskt stabil **implementation av GPs**.
 - ▶ **Skalbara GPs** för stora datamängder

Text Mining, 6 hp

- ▶ Avancerad nivå.
- ▶ Samarbete mellan **STIMA**, datorlingvistik och databasgruppen.
- ▶ Hela pipeline:
 - ▶ **web-scraping**
 - ▶ **linguistisk pre-processing**
 - ▶ **probabilistisk modellering**
- ▶ Moment:
 - ▶ **Information Retrieval**
 - ▶ **Natural Language Processing**
 - ▶ **Statistical Analysis of Textual Data**
- ▶ Kurssida: <https://www.ida.liu.se/~732A92/courseinfo.en.shtml>.
- ▶ Cramérpriset 2019 till Måns Magnusson för avhandlingen '*Scalable and Efficient Probabilistic Topic Model Inference for Textual Data*'.

Time Series Analysis, 6 hp

- ▶ Planerad för HT2020
- ▶ Avancerad nivå.
- ▶ Modernisering av traditionell tidsseriekurs
- ▶ Innehåll:
 - ▶ **ARIMA**
 - ▶ **State-space modeller** (Kalman + Partikelfilter)
 - ▶ **Recurrent Neural Networks**
 - ▶ **Convolutional Neural Networks** i tidsdomänen

Programmering

- ▶ Bör vara obligatorisk kunskap för en statistiker
- ▶ Statistiker vs Data Scientist
- ▶ Kurser:
 - ▶ **R programmering**, 7.5 hp - Årskurs 1 kandidatprogrammet
 - ▶ **SAS programmering**, 7.5 hp - Årskurs 2 kandidatprogrammet
 - ▶ **Advanced R**, 6 hp - Första kursen på masterprogrammet
 - ▶ **Python**, 3 hp, Masterkurs
- ▶ **Datortentor**
- ▶ Kombinerad **dator- och papperstenta**
 - ▶ Tenta i datorsal, med speciellt mjukvarusystem för datortenta.
 - ▶ 3/4 löses med dator, 1/4 löses med papper och penna.
 - ▶ Studentens labbrapporter finns tillgängliga under tentan.

Machine Learning for Industry, 6 hp

- ▶ Del av regeringens satsning på AI Competence Sweden.
- ▶ Vidareutbildning för studenter som redan har kvantitativt inriktad examen (t ex civilingenjör), men saknar maskininlärning.
- ▶ Fyra delmoment (varje moment under 1.5 dagar)
 - ▶ **Grunderna i maskininlärning och regulariserad regression**
 - ▶ **Klassifikation och oövervakad inlärning**
 - ▶ **Neurala nätverk och deep learning**
 - ▶ **Reinforcement learning**
- ▶ Examination genom 4 datorlaborationer.

Forskning

- ▶ Grundtema:
 - ▶ statistisk analys baserat på sannolikhetsmodeller
 - ▶ med fokus på prediktion och beslutsfattande
 - ▶ genom effektiva skalbara beräkningar för
 - ▶ stora komplexa datamängder.
- ▶ Ex på ML-publikationer vid STIMA under senaste två åren:
 - ▶ *Journal of Machine Learning Research*
 - ▶ *IEEE Transactions on Pattern Analysis and Machine Intelligence*
 - ▶ *NeurIPS*
 - ▶ *Uncertainty in Artificial Intelligence (UAI)*
 - ▶ *IEEE Transactions on Signal Processing*
 - ▶ *Journal of the American Statistical Association*
 - ▶ *Journal of Computational and Graphical Statistics*
 - ▶ *Annals of Applied Statistics*

Övrig forskningsverksamhet inom ML

- ▶ STIMA leder **IDA Machine Learning Research Group** vid institutionen för datavetenskap (IDA).
<https://liu.se/machinelearning/>
- ▶ **IDA Machine Learning Seminars**. STIMA-ledd internationell månatlig seminarier i maskininlärning med världsledande forskare.
<https://liu.se/machinelearning/seminars>
- ▶ **LiU Seminars in Statistics and Mathematical Statistics**. Gemensam seminarier tillsammans med MatStat.
<http://www.ida.liu.se/divisions/stima/seminarier/StatSeminars.shtml>

AI, Autonomous Systems and Software Program (WASP) vid STIMA

WASP machine learning



Probabilistic models and deep learning - bridging the gap

Probabilistic models and deep learning are two successful branches of machine learning. In this project, we will develop theory and methods related to the interplay between these technologies, enabling us to take advantage of the strengths of both.



Machine learning for 5G System Control and Automation

There is a plethora of new applications envisioned for 5G, ranging from traditional efficient broadband communication links to more strictly reliable communication links or massive communication that is typically associated with Internet of Things.



Bayesian Learning for Spatiotemporal Processes in Transportation

The rapid deployment of streaming sensors have made spatiotemporal data increasingly common. In this project we develop probabilistic models for spatiotemporal data with applications in the field of transportation.

► Med robotikgruppen: *Methods for Scalable and Safe Robot Learning.*

Vad krävs för att närma sig ML? Vill vi?

- ▶ Statistiker måste vara **genuint intresserade** av skalbara beräkningar och algoritmer (och inte bara av AI-miljarder).
- ▶ **Helhetssyn** på
 - ▶ sannolikhetsmodeller (**flexibla**)
 - ▶ inferens (**Bayes**, aka penalised likelihood)
 - ▶ **prediktion** och **beslut**
 - ▶ **implementering**. Beräkningseffektivt och skalbart.
- ▶ **Forskningsverksamhet** inom computational statistics och maskininlärning. ML-tillämpningar i undervisning.
- ▶ Nytt ska in, **vad ska bort?**
- ▶ **Behåll vår statistiska integritet.**

Statistiska institutionen, SU

Modernisering av kursutbudet på avancerad nivå

Ellinor Fackle Fornius, Jessica Franzén och Mattias Villani

Projekt för kvalitetsutveckling av utbildning

- Utveckling av 2 nya kärnkurser i Data Science på avancerad nivå
 1. R programmering
 2. Maskininlärning
- kompetensutveckling av lärare
- möta behovet och efterfrågan på arbetsmarknaden av kompetens inom området
- studenterna är drivande
- mål att attrahera även andra studenter med kvantitativ inriktning

Planerat upplägg på masterprogrammet

Termin 1

Matematik för ekonomisk och statistisk analys 7.5 hp obligatorisk	R Programmering 7.5 hp obligatorisk	Sannolikhetsteori 7.5 hp obligatorisk	Inferensteori 7.5 hp obligatorisk
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Termin 2

Statistiska beräkningar 7.5 hp obligatorisk	Bayesianska metoder 7.5 hp obligatorisk	Multivariat analys 7.5 hp obligatorisk	Maskininläring 7.5 hp obligatorisk?
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Termin 3

Valbar kurs 7.5 hp	Valbar kurs 7.5 hp	Valbar kurs 7.5 hp	Valbar kurs 7.5 hp
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Termin 4

Examensarbete i statistik för masterexamen 30 hp
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Exempel valbara kurser:

- GLM
- Urval och estimation
- Försöksplanering
- Analys av surveydata
- Icke-parametriska metoder



R programmering, 7.5 hp

- Avancerad nivå, termin 1 inom masterprogrammet
- Innehåll
 - datastrukturer, funktioner och objekt
 - strängar
 - styrande satser, upprepning
 - prestandaoptimering, felsökning
 - numerisk linjär algebra
 - utveckling av R-paket
 - introduktion till objektorienterad programmering och parallell programmering
- Examination
 - datorlaborationer, 3 hp
 - datortenta, 4.5 hp

Maskininlärning, 7.5 hp

- Avancerad nivå, R programmering och Bayesianska metoder som förkunskapskrav
- - I. Supervised learning
 - II. Supervised learning
 - III. Unsupervised learning
 - IV. Semisupervised and active learning
- Innehåll
 - flexibel regression och klassificering
 - regularisering
 - metoder för prediktiv modellutvärdering
 - Gaussiska processer
 - klustringsalgoritmer
 - mixture models
- Examination
 - datorlaborationer, 3 hp
 - datortenta, 4.5 hp

SLU och den nya statistiken

Claudia von Brömssen och Jesper Rydén
Inst. för energi och teknik, Sveriges lantbruksuniversitet

SLU, Sveriges lantbruksuniversitet. 4 större campus i Sverige:

Umeå

Uppsala

Skara

Alnarp



Nuläge:

Servicekurser (matematik, statistik):

Agronomprogram, ekonomer, veterinärer,
civilingenjör Energisystem, ...

Nya kurser på masternivå:

Basic statistics; Regression and analysis of variance

Doktorandkurser, ges årligen:

Statistics I, II, III, IV



Framtiden:

För någon vecka sedan vid SLU,
halvdag, samtliga fakulteter och campus:

*Big data and artificial intelligence:
harnessing the power for SLU*

Diskussioner har initierats:

- Vilken "ny statistik" behövs, för grundutbildning resp. forskning?
- Formerna för att undervisa detta?



Utbildningar i matematisk statistik vid Stockholms universitet

Tom Britton

Bakgrund

- 3 kandidatprogram med möjlighet att ta examen i matematisk statistik
 - Kandidatprogram i matematik
 - Kandidatprogram i matematik och ekonomi
 - Kandidatprogram i matematik och datavetenskap
- Nr 3 sjösattes HT19: ett KANDIDAT-program med mycket maskininlärning/"ny statistik" (annars oftare på masternivå).

Masterprogram och kandidatprogram

- 2 masterprogram
 - Masterprogram i matematisk statistik
 - Masterprogram i försäkringsmatematik (aktuarieprogrammet)
- Årligen utfärdas ca 25 kandidatexamina i matematisk statistik + knappt 10 masterarbeten
- Ökat intresse för maskininlärning (lite färre i försäkring)

Några kandidatarbeten 2019

- Classification of Music Genres with eXtreme Gradient Boosting
- Predictive Power of Logistic Regression versus Random Forest: A simulation study
- Living with Trees - Predicting Swedish Apartment Prices with eXtreme Gradient Boosting
- A comparison of Logistic Regression and Vanilla Neural Networks in binary classification problems
- A Comparative Study of Linear Discriminant Analysis and K-Nearest Neighbors for Statistical Classification

Kurser

- Studenterna börjar redan på de inledande kurserna arbeta i R och skriva laborationsrapporter med dynamisk kod i Rmarkdown.
- Statistisk databehandling 7,5hp (kandidatnivå)
 - Introducerar Git/GitHub som ett verktyg för reproducerbar dataanalys.
 - Tränar metoder för att städa, omforma och kombinera datamaterial (tidyverse)
 - Hämta data från nätet (APIs och webbskrapning), grundläggande SQL
 - Visualisering och presentering av data

Kurser

- Statistisk inläring 7,5hp (masternivå)
 - Valda delar ur "The Elements of Statistical Learning" av Hastie, Tibshirani & Friedman.
- Statistisk informationsteori 7,5hp (masternivå)
 - Informationsteori från ett lite bredare perspektiv med tillämpningar ibland annat maskininläring.
- Ökat samarbete med institutionens nya avdelning Beräkningsteknik



Education in Statistics and Data Science at the University of Oslo

Geir Storvik
Department of Mathematics

October 1, 2019



Overview

- 1 Statistics and Data Science at UiO
- 2 Bachelor level
- 3 Master level
 - Master in Statistics
 - Master in Data Science
 - Master in Computational Science
 - Single courses
- 4 Continuing education
- 5 Centers

Statistics and Data Science at UiO

- Section within Department of Mathematics (8 permanent positions)



- Oslo Center for Biostatistics and Epidemiology (OCBE)
- Many people in other departments with applications/methodological developments in statistics/machine learning
- Machine learning **everywhere!**



Bachelor in Mathematics with informatics

3. semester	MAT1120 – Lineær algebra	STK1110 – Statistiske metoder og dataanalyse	IN1910 – Programmering for naturvitenskapelige anvendelser
2. semester	MAT1110 – Kalkulus og lineær algebra	<u>MEK1100 – Feltteori og vektoranalyse</u>	STK1100 – Sannsynlighetsregning og statistisk modellering
1. semester	MAT1100 – Kalkulus og HMS-emner	MAT-INF1100 – Modellering og beregninger	IN1900 – Introduksjon til programmering for naturvitenskapelige anvendelser
	10 studiepoeng	10 studiepoeng	10 studiepoeng



Bachelor Statistics and Data Science

- Specialization within the Mathematics with Informatics program
- Compulsory courses
 - 30 credit points **Mathematics**
 - 30 credit points **Statistics**
 - including one course in Machine/Statistical learning in 4th semester
 - 30 credit points **Computer Science**
- Computational Science in education
 - Faculty project using computational science as an educational tool
 - Integrated in **all** science bachelor programmes
- New programmes fall 2017
 - More broad programmes, should qualify for several master programmes
 - Less statistics courses in the Statistics specialization



Specialization towards Statistics and Data Science

6. semester	Fritt emne / STK-MAT2011 – Prosjektarbeid i finans, forsikring, risiko og dataanalyse	EXPHIL03 – Examen philosophicum	Fritt emne
5. semester	Utviklingssemester		
4. semester	MAT2400 – Reell analyse / MAT2100 – Elementær reell analyse	STK2100 – Maskinlæring og statistiske metoder for prediksjon og klassifikasjon	STK2130 – Modellering av stokastiske prosesser
3. semester	MAT1120 – Lineær algebra	STK1110 – Statistiske metoder og dataanalyse	IN1910 – Programmering for naturvitenskapelige anvendelser
2. semester	MAT1110 – Kalkulus og lineær algebra	MEK1100 – Felteori og vektoranalyse	STK1100 – Sannsynlighetsregning og statistisk modellering
1. semester	MAT1100 – Kalkulus og HMS-emner	MAT-INF1100 – Modellering og beregninger	IN1900 – Introduksjon til programmering for naturvitenskapelige anvendelser



Bachelor programmes in Informatics

- Many specializations want to include machine learning (statistics)
- Most programmes lack mathematics
 - Challenge when they want to take **our** machine learning courses
 - Many of their **own** courses focus on **using** machine learning tools
- Some students take mathematics at the end of bachelor to qualify for master program in Data Science



Master program in Statistics

- Admission criteria:
 - 30 credit points Mathematics
 - Require more mathematics?
 - 30 credit points Statistics
 - 10 credit points Computer Science
- Compulsory courses
 - STK4011 – Statistical Inference Theory
 - STK4100 – Introduction to generalized linear models
- Other courses
 - STK4021 – Applied Bayesian Analysis
 - STK4051 – Computational statistics
 - STK4060 – Time series
 - STK4080 – Survival and event history analysis
 - STK4150 – Environmental and spatial statistics
 - STK4160 – Statistical Model Selection
 - STK4180 – Confidence distributions
 - STK4190 – Bayesian nonparametrics
 - STK-IN4300 – Statistical learning methods in Data Science



Master program in Data Science

- Second year, 11 students first year, 12 second
- Admission criteria:
 - 30 credit points Mathematics
 - 20 credit points Statistics
 - 20 credit points Computer Science
 - 20 extra in Statistics or Computer Science
- Compulsory courses
 - **STK-IN4300 – Statistical learning methods in Data Science**
 - **IN-STK5000 – Adaptive Methods for Data-Based Decision Making**
- Internship course
- Several specializations with **recommended courses**:
 - Statistics and Machine learning
 - Database Integration and Semantic Web
 - Data Science and Life Science
 - Language Technology
 - Digital Image Processing



Master in Computational Science

*Modern scientists increasingly rely on computational modeling and **data analysis** to explore and understand the natural world. Given the ubiquitous use in science and its critical importance to the future of science and engineering, computational modeling plays a central role in progress and scientific developments in the 21st Century.*

- Cross-disciplinary study
- Crash course in statistics/Machine learning first semester
- Half of the students wants master projects towards machine learning
- Good background in mathematics, less/no in statistics



Experience/challenges master studies

- Start of Data Science program did not lead to decrease in statistics students!
- Unclear so far on choice between programmes
 - Difficult for students to see differences between
 - Data Science and Statistics
 - Data Science and Computational Science
 - Different admission criteria
- Collaborations between departments
 - Avoided fights on "ownership" on machine learning
 - Money follows
 - host department of course
 - host department of main supervisor
 - Challenges with different cultures and rules on different departments
- Computational Science students want more statistics/machine learning courses but lack appropriate background
- The faculty wants closer integration between Data Science and Computational Science



Single courses in statistics/machine learning

- Very popular among
 - students from other fields
 - former students
- Master courses within statistics section
 - Students from other fields struggle due to lack of sufficient background
 - Former students can follow courses for free (but need to be formal students to take exam)
- Most popular:
 - STK4021 – **Applied Bayesian Analysis**
 - STK4051 – **Computational statistics**
 - STK-IN4300 – **Statistical learning methods in Data Science**



Courses in Statistics/Machine learning at other departments

- Long tradition in **statistics** courses at other departments
 - Taught by non-statisticians
- Now: Even more courses in **machine learning**
 - Typically taught by **domain experts**
 - Very **popular**
 - No good system for looking at **overlap**
 - Very sensitive to interest from **single persons**



Supervision

- Increasing number of internal master students
 - Also many companies outside that offer master projects
- Increasing number of internal PhD students
- Industrial PhD's
- Co-supervision on PhD's from other departments



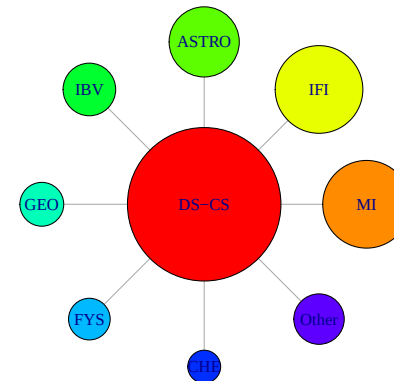
Continuing education

- Huge **demand**
- **No system** at UiO to deal with this!
- Mainly organized by externals (Startuplab), hiring in staff from UiO
- Companies willing to **pay** a lot!
- Some efforts on making industry sponsor positions

Centers

- BigInight
 - Mainly PhD students but also master projects with partners
- The Norwegian Artificial Intelligence Research Consortium
 - Aims to strengthen Norwegian research and education within artificial intelligence, machine learning and robotics
- Center for Data Science and Computing

- Internal UiO center
- Research and education
- Responsibility for master programs in Data Science and Computational Science



Experiences/challenges

- Renewed interest in statistics
 - Introductory courses still "old-fashioned"
 - First probability theory, then inference
 - Need for more direct approach to **prediction**?
- A large number of courses in machine learning
 - No clear distinction between these
 - Oriented towards different applications, in many cases learning how to use software
 - A fool with a tool is still a fool*
 - Typically large courses
 - Ok that it is taught by non-experts?
- (TOO?) many things happening
 - Many centers/departments involved
 - All want to be involved in education

Utveckling av program på avancerad nivå vid Högskolan Dalarna

Vad har hänt sen 2004?

Lars Rönnegård

Utbildningar i statistik och mikrodataanalys

Program på avancerad nivå

2004 – 2010

- 1-årigt magisterprogram i statistik

2010 – 2019

- Business Intelligence – 2-årigt masterprogram

2019 –

- 1-årigt magisterprogram i BI
- 2-årig master i Data Science

Forskarutbildning

2012 –

- Mikrodataanalys



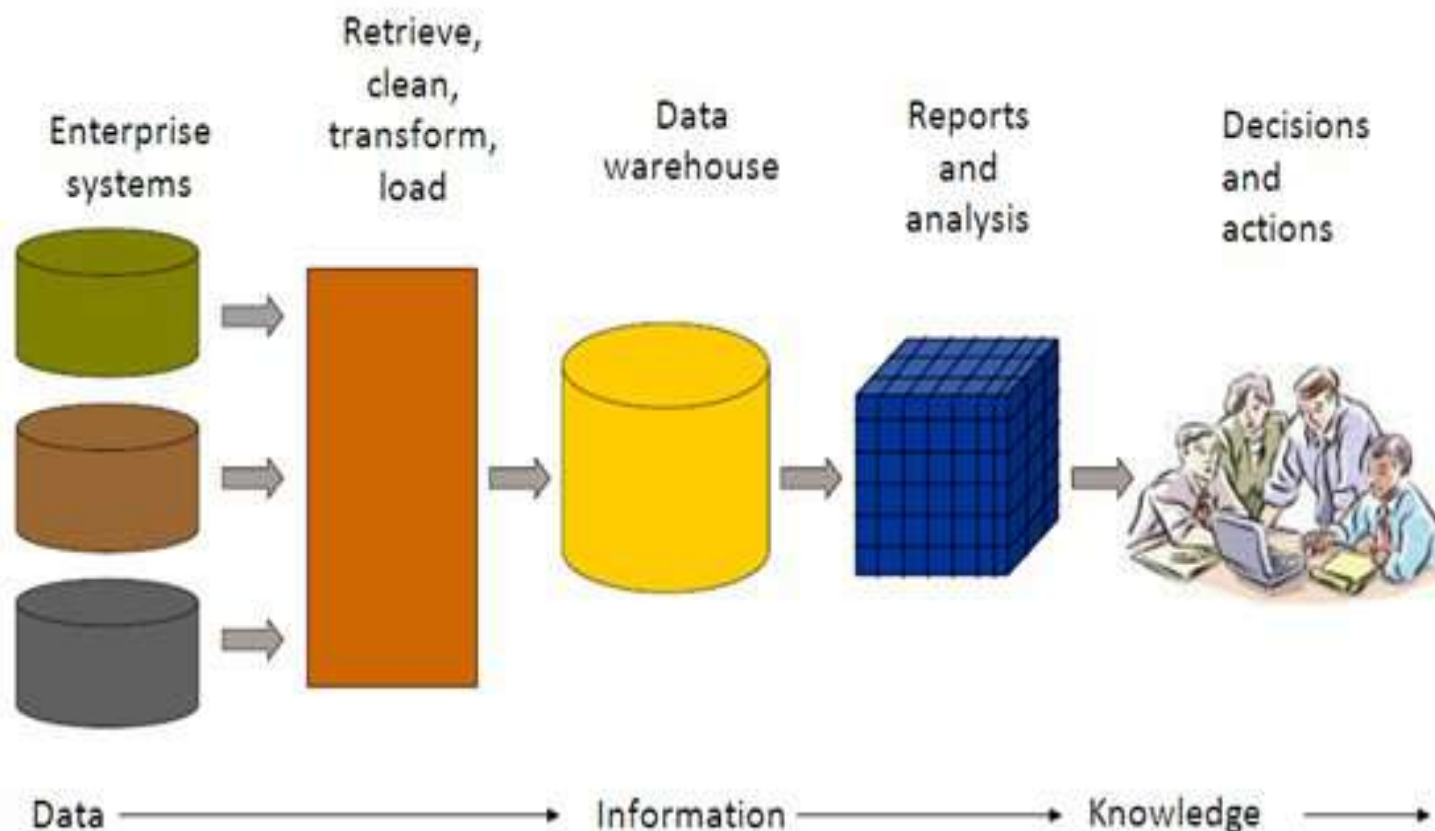
**HÖGSKOLAN
DALARNA**

Magisterprogram i statistik 2004 – 2010



- Studenter rekryterades främst från Renmin University i Beijing och Tianjin University of Finance & Economics
- ~50% gick vidare till forskarstudier i Sverige och runt om i världen
- 2011 infördes studieavgifter
- Siktade på tvärvetenskaplig forskarutbildning

Mikrodataanalys



BI programmet 2010 – 2019

First year BI

Period 1 (Pick two optional courses)	Period 2	Period 3	Period 4
- Mathematics for microdata analysis - Introduction to Object-oriented Programming - Data Analysis and Statistics I - Intermediate Microeconomics - Database Systems for masterprogram in Business Intelligence	- Probability theory, Markov processes - Economics of leadership	- Statistical Computing with R - Artificial Intelligence	- Data collection - Business Intelligence

Second year

Period 1	Period 2 (Pick two optional courses)	Period 3	Period 4
- Generalized linear models - Datamining	- Intelligent agents for distributed problem solving - Statistical modeling - GIS and spatial data - Economic Geography - Neural networks	Master Thesis in Business intelligence	Master Thesis in Business intelligence

First year BI for analytics

Period 1 (Pick two optional courses)	Period 2	Period 3	Period 4
- Mathematics for microdata analysis - Introduction to Object-oriented Programming Data Analysis and Statistics I - Intermediate Microeconomics - Database Systems for masterprogram in Business Intelligence	Probability theory, Markov processes - Economics of leadership	Statistical Computing with R - Artificial Intelligence	- Data collection - Business Intelligence

Second year

Period 1	Period 2 (Pick two optional courses)	Period 3	Period 4
Generalized linear models - Datamining	- Intelligent agents for distributed problem solving Statistical modeling - GIS and spatial data - Economic Geography - Neural networks	Master Thesis in Business intelligence	Master Thesis in Business intelligence

Nya program vt 2019

Programansvariga
Kenneth Carling
Ola Nääs

Data Science: Master programme

Harness the power of data analytics to solve the practical problems of companies and organisations worldwide.

120 Credits Second Cycle

[To Programme Syllabus](#)

PAGE CONTENT

A Programme for Fast-Paced Data Management

Should you apply?

How To Apply

Entry Requirements (Academic Year 2019/2020)

Tuition Fees

Scholarships

Programme Overview

Career Opportunities

A Programme for Fast-Paced Data Management

The sheer amount of data that is being produced each and every day is redefining our world: according to IBM, 90 percent of all current data has been created in the last two years alone. The collection and evaluation of this data can transform behaviours, business models, markets and every imaginable organisational structure. The Data Science Programme at Dalarna University prepares you to be at the centre of this transformation working within private companies, public organisations and research institutions.

Our programme provides you with both hands-on training in the collection and interpretation of data as well as broad knowledge and an understanding of how data analysis is used for decision-making within organisations. You will gain a unique cross-disciplinary skill-set that will prepare you for jobs both in the present day and in the future.

Should you apply?

If you want to have an impact on data-driven decisions that affect the daily operations of companies and organisations, then you will find your calling in our Data Science Programme. If you have previously received a degree in Computer Science, Computer Information Systems or IT from an internationally recognised university and if you have documented knowledge of English proficiency, then you are strongly encouraged to apply to our Data Science Programme.

Please note that if you have a degree in Statistics, Economics or Business then you can apply for our [Master's Programme in Business Intelligence](#) with the possibility of continuing to the second year of the Master's Programme in Data Science.



HÖGSKOLAN
DALARNA

Layout – Fall intake (BI + DS)

Period 1 • Risk Analysis • Python- and R-programming	Period 2 • Economics of Leadership • Data Warehousing	Period 3 • Thesis, 15 cts • Data Analysis and Visualization • Logic & Maths	Period 4 • Thesis, 15 cts • Business Intelligence • Statistical Learning
Period 5 • Machine Learning • Data Collection and Data Quality	Period 6 • Thesis, 30 cts • Internship	Period 7 • Thesis, 30 cts • Complexity and Operations Research Methods	Period 8 • Thesis, 30 cts



Layout – Spring intake (BI + DS)

Period 1 • Data Analysis and Visualization • Python- and R-programming	Period 2 • Business Intelligence • Statistical Learning	Period 3 • Thesis, 15 cts • Risk Analysis • Data Collection and Data Quality	Period 4 • Thesis, 15 cts • Economics of Leadership • Data Warehousing
Period 5 • Logic & Maths • Internship	Period 6 • Thesis, 30 cts • Spatial Data and Geographical Information Systems	Period 7 • Thesis, 30 cts • Machine Learning	Period 8 • Thesis, 30 cts



Sammanfattning

- Ren statistik till bredare datavetenskapliga/dataanalys program
- Uppdelade kurser till integrerade kurser

Fråga

- 300 behöriga sökande på 40 platser.
Hur gör man ett vettigt urval
 - Lottning?
 - Statement of purpose?
 - Mensa test?
 - ??



Utbildningar i statistik vid Örebro universitet

Yuli Liang

Universitetet i siffror

15 200 studenter

82 program

950 kurser

1 500 anställda

135 professorer

400 doktorander

3 fakulteter

8 institutioner



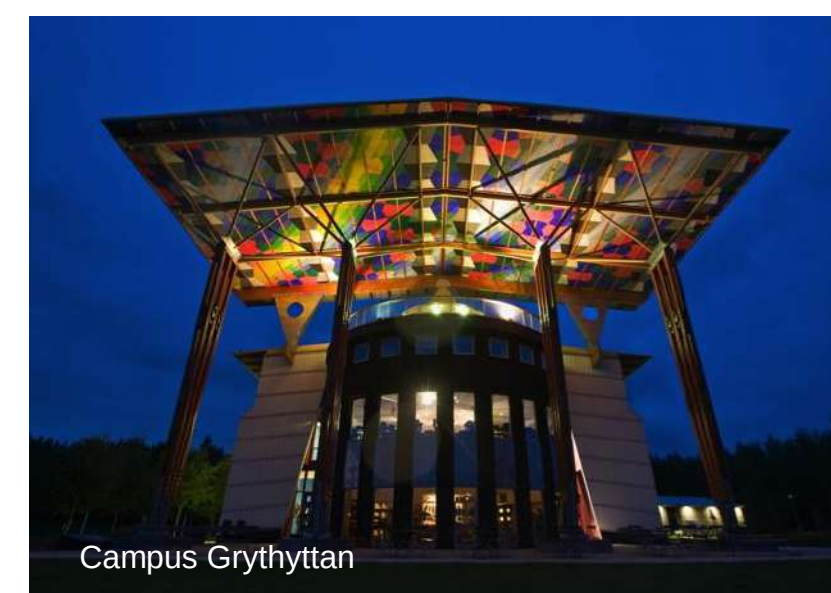
Tre campusområden med institutioner



- Medicinska vetenskaper



- Handelshögskolan
- Hälsovetenskaper
- Humaniora, utbildnings- och samhällsvetenskap
- Juridik, psykologi och socialt arbete
- Musikhögskolan
- Naturvetenskap och Teknik



- Restaurang- och hotellhögskolan

Kandidatprogrammet i statistik



Termin 1	Grundläggande statistik 15hp			Regressionsanalys 7,5hp		
HT				Inledande matematik för statistiker, 7,5hp		
Termin 2	Ekonometri 7,5hp	Tidsserieanalys och prognosmetodik 7,5hp		Biostatistik 7,5hp	Självständigt arbete 7,5hp	
VT						
Termin 3	Matematik, Elementär algebra 7,5 hp			Matematik, Linjär algebra 7,5 hp		
HT	Matematisk analys för statistiker, 7,5 hp			Datateknik, Databasteknik 7,5 hp		
Termin 4	Valfria kurser					
VT						
Termin 5	Statistisk teori 15hp			Beräkningsintensiva metoder 7,5hp		
HT	Delkurs 1, Sannolikhetslära, 7,5 hp	Delkurs 2, Inferensteori, 7,5 hp		Urvalsmetodik 7,5hp		
Termin 6	Statistiska metoder 7,5hp			Kandidatuppsats 15hp		
VT	Statistisk inläring 7,5 hp					

Kursen Statistik inlärnning

- har bara getts en gång i våras på svenska under sista terminen av kandidatprogrammet
- kommer att ge den på engelska nu till våren, och öppna upp den som en möjlig valfri kurs även för masterstudenterna.
- i sammanfattning täcker vi boken "Introduction to statistical learning" av Hastie m fl.

Master in Applied Statistics



Year 1	Autumn	Mathematics for Statistical and Economic Analysis	7.5
		Statistical Theory	7.5
		Econometrics	7.5
		Computational Statistics	7.5
	Spring	Micro Econometrics	7.5
		Bayesian Statistics	7.5
		Survey Sampling	7.5
		Sample Survey Methodology	7.5
Year 2	Autumn	Independent Project I	15
		Optional courses (Statistics, Mathematics, Database Management or Programming courses)	15
	Spring	Independent Project II	15
		Optional courses (Statistics, Mathematics, Database Management or Programming courses)	15

EMOS (European Master in Official Statistics)



- Vi har fått förläggning av EMOS-stämpel t o m 2023
- EMOS kräver idag två speciella kurser Production of Official Statistics (7,5 hp) och Register Data Analysis (7,5 hp) samt en praktik på SCB (15 hp).
- Hittills har vi endast haft en (av två studenter totalt 2017) som verkligen genomgått hela programmet, i år (2019) får vi räkna med att upp till två (av de fyra som kan förväntas följa hela programmet) kommer att göra det.

Några tankar inom enheten kring data science

- Öka rörlighet och samverkan mellan enheten och näringsliv (t.ex. gästföreläsning, projektarbete)

- Data science i officiell statistik

En masterstudent Rikard Gård blev årets surveyuppsatsvinnare med sin uppsats

En skattningsmetod med hjälp av machine learning

NY STATISTIK - NY UNDERVISNING?

Hur tänker vi om detta?

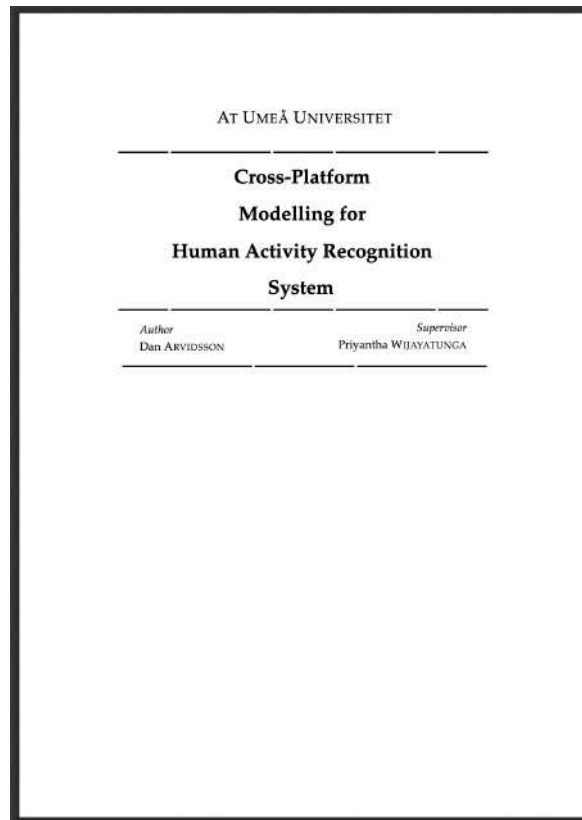
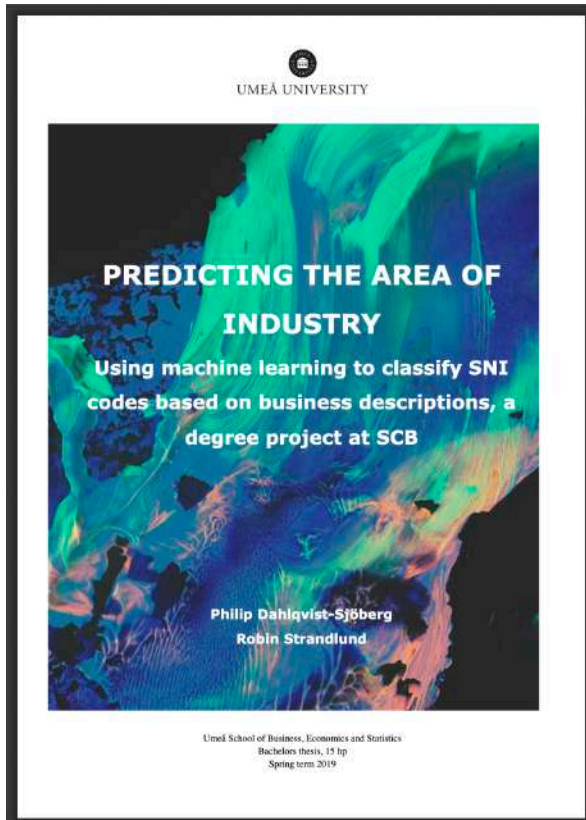
Maria Karlsson

Handelshögskolan vid Umeå universitet
Enheten för statistik



UMEÅ UNIVERSITET

OM STUDENTEN SJÄLV FÅR VÄLJA...



UMEÅ UNIVERSITET

PROGRAMUTBUD 19/20

- Statistikerprogrammet (180 hp)
- Master's Programme in Statistical Sciences (60 Credits)
Magisterprogram i statistik



PROGRAMUTBUD 20/21

- Programmet i statistik och data science (180 hp)
- Master's Programme in Statistics and Data Science (60 Credits)

Magisterprogrammet i statistik och data science



UMEÅ UNIVERSITET

PROGRAMMET I STATISTIK OCH DATA SCIENCE

- Termin 1: Statistik A (30 hp)
- Termin 2: - Visualisering av data (7.5 hp)
 - Statistiska tillämpningar (7.5 hp)
 - Statistisk kommunikation (7.5 hp)
 - **Ny kurs/-er i statistik fr.o.m. VT 2021 (totalt 7.5 hp)**
- Termin 3: Statistik B (30 hp)
- Termin 4: Valfria/valbara kurser (30 hp)
- Termin 5: Matematik och informatik-kurser (15 + 15 hp)
- Termin 6: - Statistik C1 (15 hp)
 - Statistik C2: Självständigt arbete (15 hp)



PROGRAMMET I STATISTIK OCH DATA SCIENCE

Förslag på ny programstruktur

	Höstterminen	Vårterminen
År 1	Statistik A	Visualisering av data, 7,5 hp (halvfart) Vetenskapsteori, 7,5 hp Urvalsdesign och analys, 4,5 hp (halvfart) Introduction to data science, 3 hp (halvfart, eng.) Statistiska tillämpningar, 7,5 hp (helfart) Statistisk kommunikation 7,5 hp (helfart)
År 2	Statistik B - Matematik för statistiker (7.5 hp) - Sannolikhetsteori och statistisk inferensteori (9 hp) - R-programmering / simulering, 6 hp - Statistisk och ekonometrisk modellering med R (7.5 hp) Sampling: design och analys (4 hp) Inlämningsuppgift i sampling och modellering (2 hp)	Valfria / Valbara kurser Ny valbar kurs: Handledd studiepraktik, 15hp
År 3	Informatik, 15hp - Programmeringens grunder (Java) - Databasdesign (SQL) Matematik, 15hp - Analys för ingenjörer - Linjär algebra	Statistik C1 - Statistisk inferensteori (5 hp) - Statistisk analys av stora och komplexa datamängder med R (7 hp) - Inlämningsuppgifter i analys av ... (3 hp) Statistik C2 – självständigt arbete



MASTER'S PROGRAMME IN STATISTICS AND DATA SCIENCE

- Termin 1:

- Programming in Statistics (7.5 hp)

→ - Valbar kurs (7.5 hp)

- Causal inference (7.5 hp)

- Valbar kurs (7.5 hp)

- Termin 2:

- One Year Master's Thesis in Statistics (15 hp)

- Valfri (15 hp)

MATEMATISK
STATISTIK

?



UMEÅ UNIVERSITET

HUR UNDERVISAR VI DÅ?

- Studerandeaktivt (få föreläsningar, lektionsplaner)
- Inlämningsuppgifter i separata moduler
- "Statistical learning-modulen" på Statistik C1 med "flipped classroom-pedagogik"
- Datortenta på kursen Visualisering av data (i egen datasal med egen skrivvakt). Önskvärt på fler kurser...
- R



BONUSBILD OM JAG HINNER...

Application for AI Education Development 2019

AI Competence for Sweden is a national effort to increase competence in AI in Sweden. As part of the AI Competence for Sweden efforts at Umeå University, we hereby invite researchers and teachers at Umeå University to apply for resources to be spent at Umeå University during 2019 to:

- 1) Transform/develop existing AI-courses to make them accessible to professionals in industry and in the AI Sweden portal,
- 2) Further develop AI modules, or include (more) AI in existing courses at basic or advanced levels.

We would like to encourage in particular development initiatives at the Humanities, Social Sciences and Medical faculties.

Beviljat medel för kursutveckling

Maria Karlsson (Statistik) och Galina Biedenbach (Företagsekonomi) har beviljats medel inom satsningen "AI educational development 2019, AI Competence for Sweden @ UmU".

Maria för att utveckla en ny kurs med arbetsnamnet "Statistical Machine Learning for the Social Sciences".

Galina för kursen "Marketing" (International Business Program) där målet är att utveckla kursinnehåll med fokus på AI och för att öka studenternas kunskap om AI inom marknadsföring.

Grattis!



MATHEMATICAL STATISTICS

Oleg Seleznev
Umeå university



UMEÅ UNIVERSITET

PERSONAL

- 3 professors



- 6 lecturers



- 2 assistant lecturers



UMEÅ UNIVERSITET

PERSONAL

- 7 PhD students



A new one during
recruitment
WASP Math4AI

- 1 senior research engineer



- 4 postdoktors



Two new recruits
WASP Math4AI



UMEÅ UNIVERSITET

BASIC EDUCATION

- The bachelor's program in Mathematics / Mathematical statistics has been put on ice for a couple of years (due to few applicants).
- We decided in 2007 not to start any master's program in Mathematical statistics.
- Instead, the Master's program in Computational technology was started, with the possibility of profiling itself against Mathematical statistics (but very few who do)



BASIC EDUCATION

- Through independent courses, a student can take the bachelor's degree in Mathematics (with many courses and degree work in Mathematical statistics) as well as the master's degree in Mathematical statistics.
- A handful of students per academic year choose to take a bachelor's and master's degree. Most are civil engineering students who want to have dual degrees.



BASIC EDUCATION

- Our main education in mathematical statistics is now the [Civil engineering program in Industrial economics profile against industrial statistics](#).
- The Department of Mathematics and Mathematical Statistics has primary responsibility for the program. The students read about 1/3 of the courses at the School of Business, Economics and Statistics (Handelshögskolan).
- We take in 55 students per year. About 40 graduate, of which about 10 per year on the profile against industrial statistics.



År 1	Ht	Introduktion till industriell ekonomi	Programmeringsteknik med Python och Matlab	Envariabelanalys 1	Envariabelanalys 2
	Vt	Marknadsföring	Ekonomisk teori och marknadsorganisation	Linjär algebra	
				Industriell utveckling och ekonomisk förändring	
År 2	Ht	Flervariabelanalys och differentialekvationer		Organisation och ledarskap i arbetslivet	
		Statistik för teknologer		Stokastiska processer och simulering	
	Vt	Datastrukturer och algoritmer		Linjärprogrammering	
		Industridesign		Ingenjörens roll i arbetslivet	
År 3	Ht	Strategier och verktyg för kvalitetsarbete		Finansiering och kalkylering	Mekanik och energifysik
		Kontinuerlig optimering			
	Vt	Entreprenörskap och affärsutveckling	Projektledning och organisering	Valbara/fria kurser	
År 4	Ht	Financial management (30hp)			
	Vt	Valbara/fria kurser (15hp) (bl.a. Statistikisk modellering med Excel och VBA 7,5 hp)		Specialiseringskurser (15hp)	
År 5	Ht	Specialiseringskurs		Specialiseringskurs	
		Valbar/fri kurs		Valbar/fri kurs	
	Vt	Examensarbete/självständigt arbete			

Logistik och optimering

År 4	Ht	Financial management (30hp)		
	Vt	Valbara/fria kurser	Supply Chain Management 1 för civilingenjörer	
			Heltalsprogrammering	
År 5	Ht	Valbara/fria kurser	Diskret modellering	Supply Chain Management 2

Risk management

År 4	Ht	Financial management (30hp)		
	Vt	Valbara/fria kurser	Finansiell matematik	Monte Carlo-metoder för finansiella tillämpningar
År 5	Ht	Riskbaserad portfölj- och företagsstyrning		
		Valbara/fria kurser	Valbara/fria kurser	

Industriell statistik

År 4	Ht	Financial management (30hp)		
	Vt	Valbara/fria kurser	Försöksplanering	
			Avancerad statistisk modellering	
År 5	Ht	Multivariat dataanalys	Big Data och analys av högdimensionella data	
		Valbara/fria kurser	Valbara/fria kurser	

NEW MASTER PROGRAMS

- *These new Master's Programs will start in 2020:*
- Master's Program in Mathematical Statistics, 120 credits;
- Master's Program in Artificial Intelligence, 120 credits.
- Program in AI is assumed sure a close cooperation with
Department of Computing Science
(Institutionen för Datavetenskap)



COURSES AT THE ADVANCED LEVEL IN MATHEMATICAL STATISTICS

- Below the courses in Mathematical Statistics that are suitably read within the new Programs and are included in the degree. On a basic course, the student following the program has a place guarantee.
- Inference theory (advanced);
Probability Theory (advanced);
Big data and high-dimensional data analysis;
Time series analysis and spatial statistics;
Stochastic processes;
Research in mathematical sciences;
Experimental planning and advanced statistical modeling;
Multivariate data analysis;
Statistical methods in genetics.



BIG DATA AND H-D DATA ANALYSIS

- For statisticians, how to get usable information out of databases that are so huge and complex that many of the traditional or classical methods cannot handle.
- For computer scientists, Big Data pose problems of data storage and management, communication and computation.
- For citizens, Big Data brings up questions of ethics, privacy and confidentiality.
- The present century is the century of data. We are collecting and processing data of all kinds on scales un imaginable earlier. Examples of such data are internet traffic, financial tick-by-tick data and DNA Microarrays which feed data in large streams into scientific and business bases worldwide.



EXPECTED LEARNING OUTCOMES

- Thoroughly describe several classification and cluster analysis algorithms, such as logistic regression, LDA, QDA, KNN, random forest, SVM, k-means, hierarchical cluster analysis and SOM(Self-Organizing Map).
- Describe several methods for variable selection and dimension reduction, such as ridge regression, lasso, PCA and MDS.
- Describe several validation methods, such as cross validation, evaluation with independent test data and bootstrap methods
- Analyze Big data with the methods above and the statistical R packages.



HIERARCHICAL TIME SERIES

- A *Hierarchical time series* is a collection of several time series that are linked together in a hierarchical structure.
- *Example:* Pharmaceutical products are organized in a hierarchy under the Anatomical Therapeutic Chemical (ATC) Classification System.
- A *Grouped time series* is a collection of time series that are aggregated in a number of non-hierarchical ways.
- *Example:* Australian tourism demand is grouped by region and purpose of travel.
(Rob Hyndman, HTS in R, Forecasting:Principles & Practice)



WELCOME IN UMU



UMEÅ UNIVERSITET

WELCOME IN UMU



UMEÅ UNIVERSITET

What is machine learning and AI and how it fits into statistics teaching

Ole Winther

Department of Biology/Rigshospitalet
University of Copenhagen (KU)

DTU Compute
Technical University of Denmark (DTU)



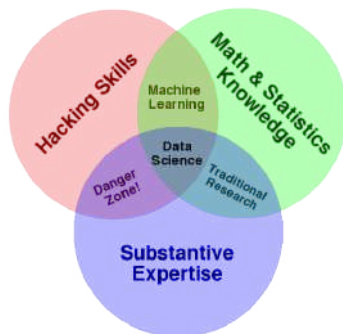
October 1, 2019

Solving perception tasks with deep learning



Contents of talk

- Machine learning and AI -
Too important to leave to computer scientists!
- What is **statistical artificial intelligence**?
- **Deep learning** - case stories
- **ML and AI in statistics education**
 - Possible? Yes!
 - Desirable? Up for discussion.
- A bit about myself



Computing - why we are here!

1 The accelerating pace of change ...



2 ... and exponential growth in computing power ...

Computer technology, shown here climbing dramatically by powers of 10, is now progressing more each hour than it did in its entire first 90 years

COMPUTER RANKINGS

80 calculations per second per \$1,000



Analytical engine
Never fully built, Charles Babbage's invent on was designed to solve computational and logical problems.



Colossus
The electronic computer, with 1,500 vacuum tubes, helped the British crack German codes during WW II



UNIVAC I
The first commercially marketed computer, used to tabulate the U.S. Census, occupied 543 cu. ft.



Apple II
At a price of \$1,298, the compact machine was one of the first massively popular personal computers.



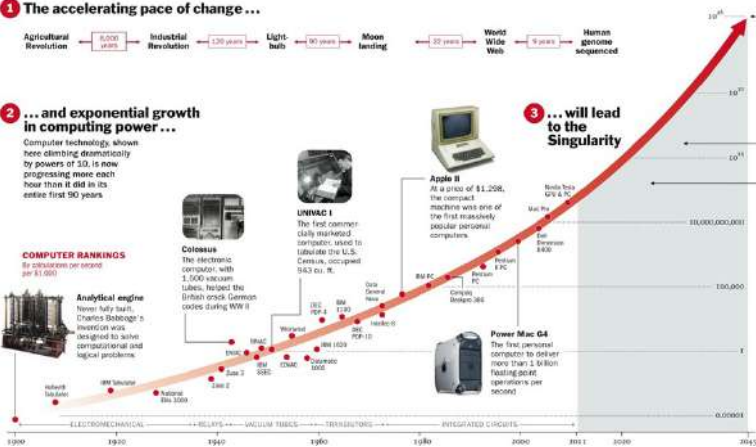
Power Mac G4
The first personal computer to deliver more than 1 billion floating point operations per second

3 ... will lead to the Singularity

2045
Superintelligent brainpower equivalent to that of all human brains combined

Superhuman brainpower of human in 2023

Superhuman brainpower of machine in 2015

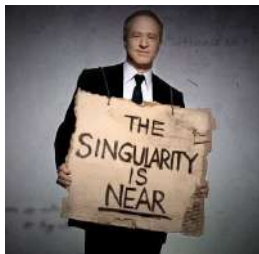


Data - why we will have self-driving cars



The Cityscapes dataset

Are we heading towards the singularity?



kurzweilai.net



- Elon Musk at MIT AeroAstro Symp:
- If I were to guess at what our biggest existential threat is, it's probably that...
- With artificial intelligence, we are summoning the demon..
- Inofficial quotes (email to friend):
- The risk of something seriously dangerous happening is in the five year timeframe. 10 years at most,
- Unless you have direct exposure to groups like Deepmind, you have no idea how fast — it is growing at a pace close to exponential.
- mashable.com/2014/11/17/elon-musk-singularity/

Growth in computer power

1 The accelerating pace of change ...



2 ... and exponential growth in computing power ...

Computer technology, shown here climbing dramatically by powers of 10, is now progressing more each hour than it did in its entire first 90 years

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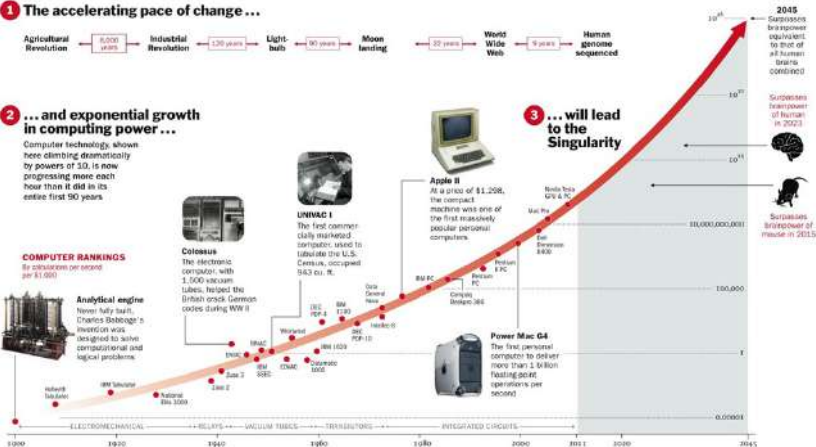


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Power Mac G4
The first personal computer to deliver more than 1 billion floating point operations per second

3 ... will lead to the Singularity



2045
Surpasses
brainpower
equivalent
to that of
all human
brains
combined

Surpasses
brainpower
of human
in 2023



Surpasses
brainpower
of machine in 2015



We used to call it machine learning...



Demis Hassabis, DeepMind CEO mission statement: “**solving (general artificial) intelligence, and then using that to solve everything else**”

Reinforcement learning



- An agent learning to take actions in an environment so as to maximize some notion of cumulative reward.
- Actions taken now will affect future reward.

Part 2:

Neural network primer

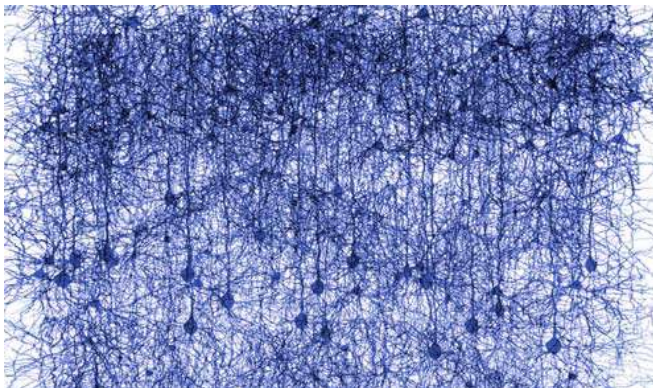
Major areas in AI

- Speech recognition
- Image classification
- Machine translation
- Question-answering
- Self-driving vehicles
- Dialogue systems
- General
unsupervised
learning



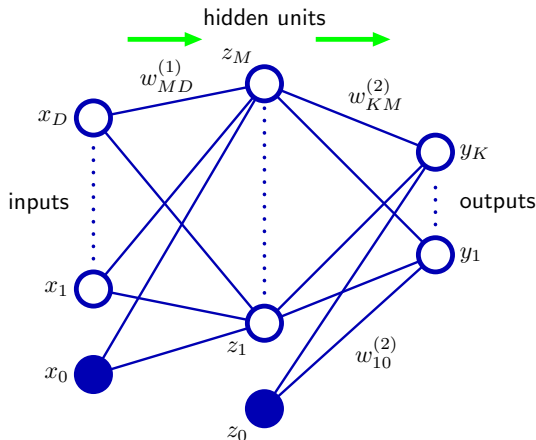
Deep learning

- Feedforward neural networks
- Convolutional neural networks (CNN) - images
- Recurrent neural networks - sequences



Approx. 10^{11} neurons and 10^{14} synapses in a human brain

Feed forward neural networks



$$y_k(\mathbf{x}, \mathbf{w}) = \sigma \left(\sum_{j=0}^M w_{kj}^{(2)} \underbrace{f \left(\sum_{i=0}^D w_{ji}^{(1)} x_i \right)}_{z_j} \right)$$

Statistical and probability concepts central

- Likelihood function, regularization
- Probability and distributions
- Statistical learning theory
- Training, validation and test set
- Overfitting!



- Not used so much: **statistical tests, p-values, ...**

Part 3:

The deep learning revolution - some cases

Achilles' heel of traditional AI: Perception in natural environment



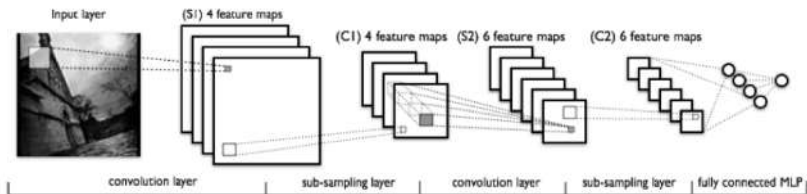
xkcd.com/1425

ImageNet - image classification



- 1.000 different classes - including many types of dogs!
- 1.000.000 training images

Convolutional neural networks



$$\begin{bmatrix} 10 & 0 & -10 \\ 0 & 0 & 0 \\ -10 & 0 & 10 \end{bmatrix}$$



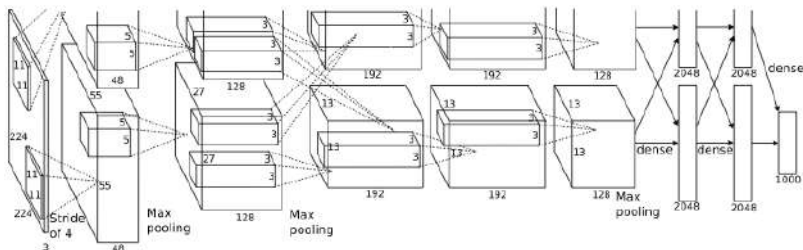
Feature engineering vs engineered models

ImageNet Classification with Deep Convolutional Neural Networks

Alex Krizhevsky
University of Toronto
kriz@cs.utoronto.ca

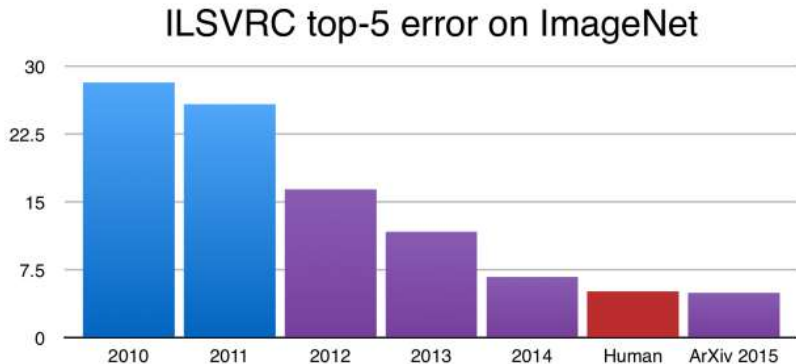
Ilya Sutskever
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University of Toronto
hinton@cs.utoronto.ca



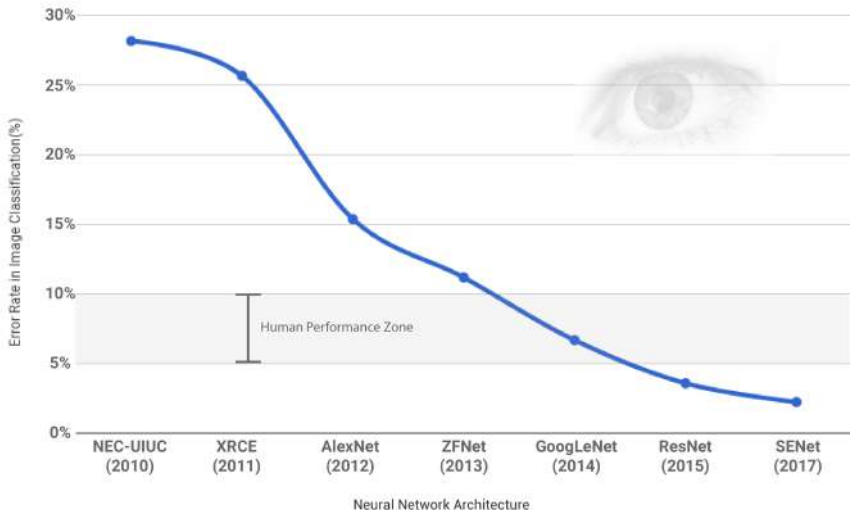
www.cs.toronto.edu/~fritz/absps/imagenet.pdf

ImageNet classification challenge



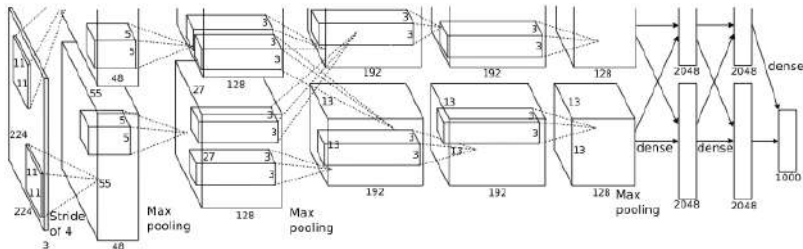
AlexNet - A Krizhevsky et al. (2012) won with huge margin (16.4% error compared to 26.2%) by deep learning.
Soon everyone started using deep learning and GPUs.

ImageNet classification challenge 2017 update

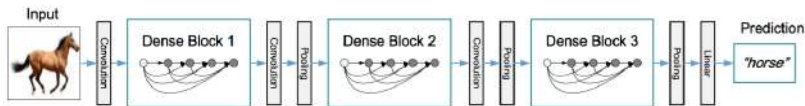


We need bigger brains

- AlexNet (2012): 16.4% error, 8 layers, 1.4 Gflop



- ResNet (2016): 3.5% error, 152 layers, 22.6 Gflop.



- (This is a so-called DenseNet and not a ResNet.)
- Source: [Source Jen-Hsun Huang, CEO NVIDIA, GTC Europe, 2016](#)

All filters are learned from training data

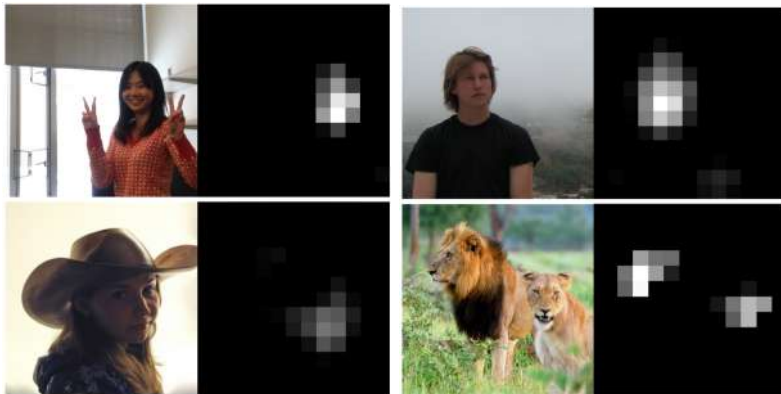
- First layer filters



- www.cs.toronto.edu/~fritz/absps/imagenet.pdf

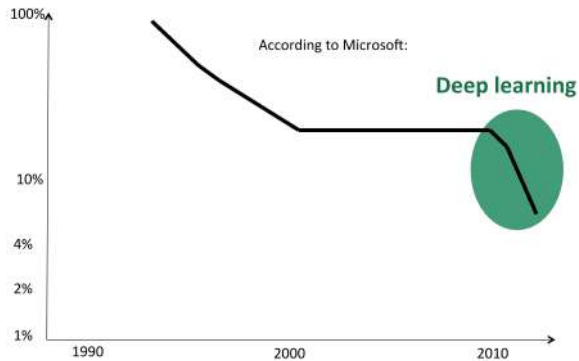
Emergent higher level abstractions

- Look at output of filter in 5th layer!



Yosinski et. al., ICML, google: [deepvis](#)

Speech recognition breakthrough



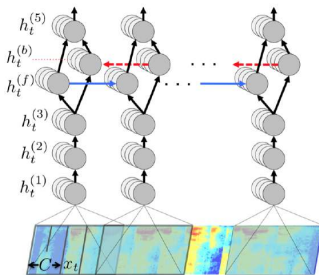
Plot from Yoshua Bengio

Recurrent neural networks – DeepSpeech

DeepSpeech: Scaling up end-to-end speech recognition

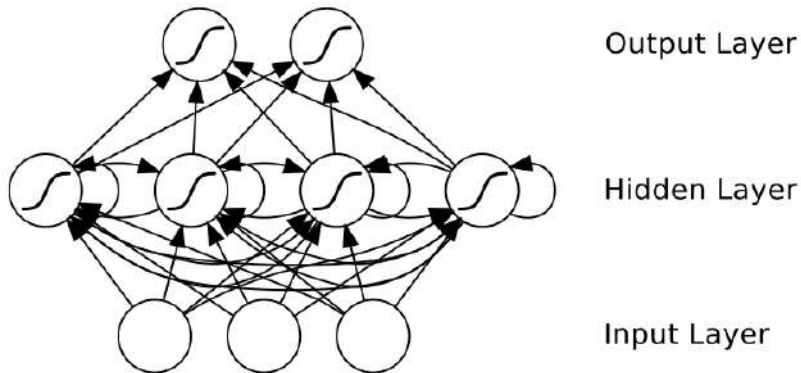
Awni Hannun,* Carl Case, Jared Casper, Bryan Catanzaro, Greg Diamos, Erich Elsen,
Ryan Prenger, Sanjeev Satheesh, Shubho Sengupta, Adam Coates, Andrew Y. Ng

Baidu Research – Silicon Valley AI Lab



Deep speech 2: ~human level performance + realtime server

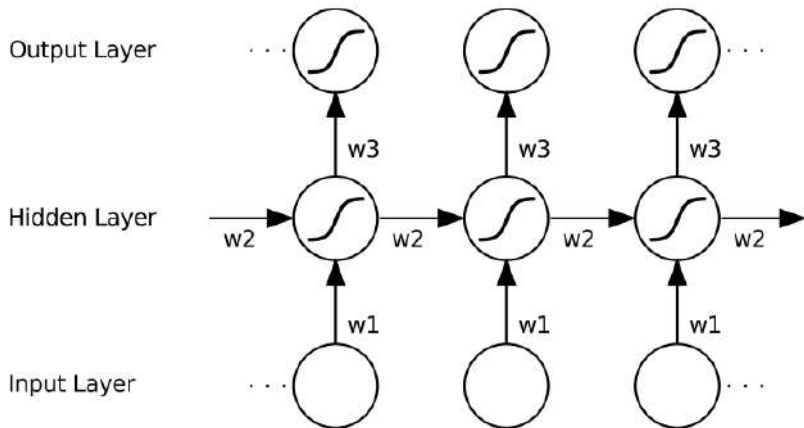
Recurrent neural networks



$$a_h^t = \sum_{i=1}^I w_{ih} x_i^t + \sum_{h'=1}^H w_{h'h} f(a_{h'}^{t-1})$$

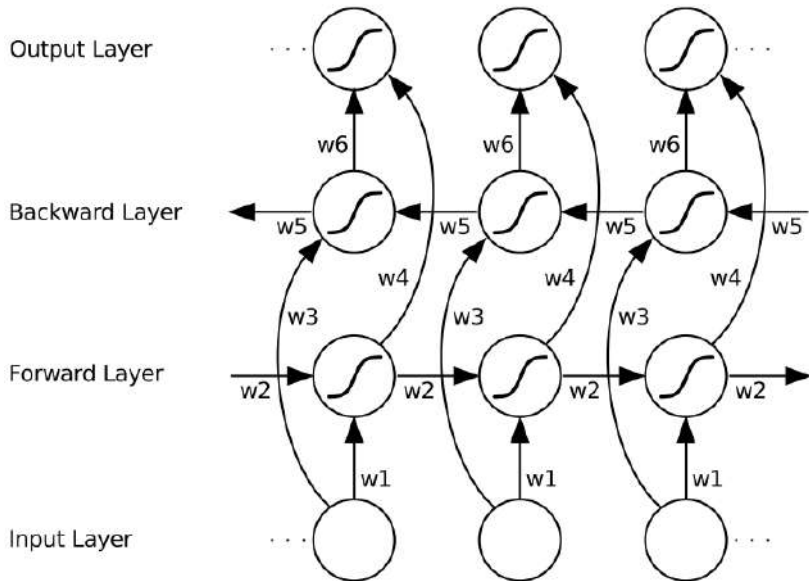
www.cs.toronto.edu/~graves/preprint.pdf

Recurrent neural networks unrolled

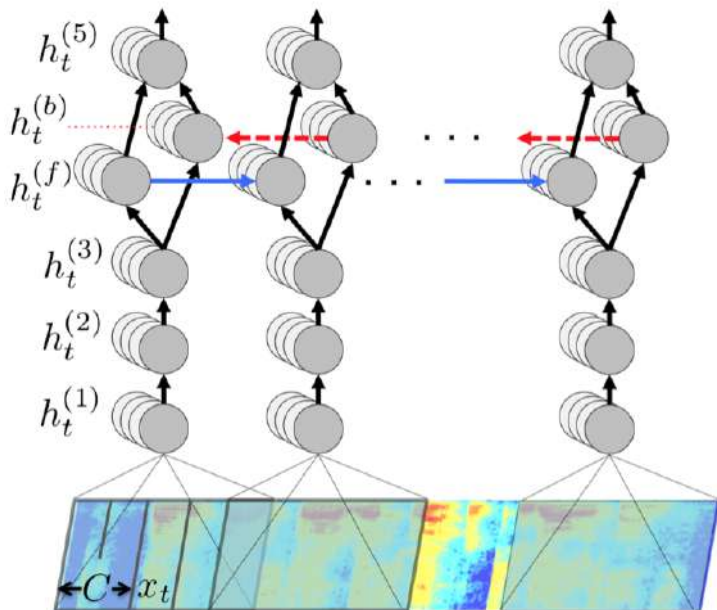


$$a_h^t = \sum_{i=1}^I w_{ih} x_i^t + \sum_{h'=1}^H w_{h'h} f(a_{h'}^{t-1})$$

Bidirectional recurrent neural networks unrolled

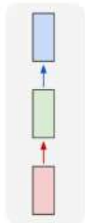


DeepSpeech



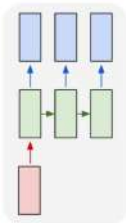
Overview recurrent architectures

one to one



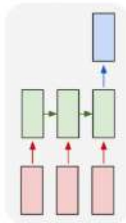
- Vanilla mode, no RNN.
- E.g. image classification

one to many



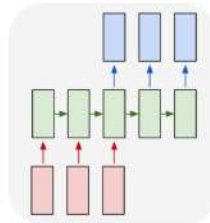
- Sequence output
- E.g. image captioning

many to one



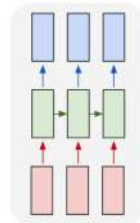
- Sequence input
- E.g. sentiment analysis

many to many



- Sequence input and output (*encoder-decoder, sequence-to-sequence*)
- E.g. translation, question answering

many to many



- Synced sequence input and output
- E.g. label each video frame

From Andrej Karpathy blog: The Unreasonable Effectiveness of Recurrent Neural Networks

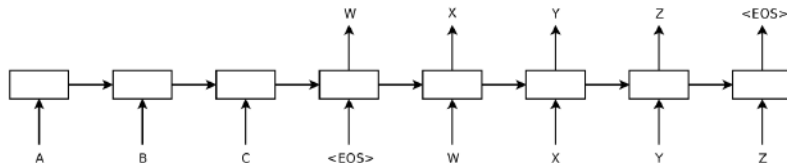
Encoder-decoder - machine translation

Sequence to Sequence Learning with Neural Networks

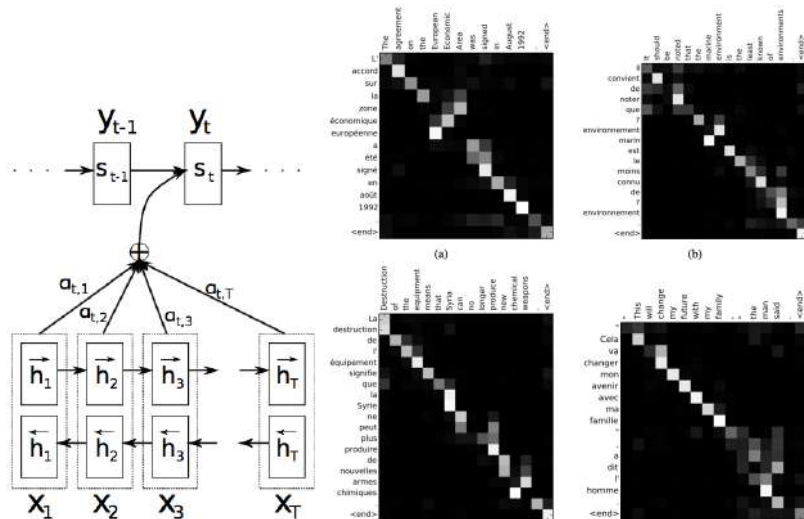
Ilya Sutskever
Google
ilyasu@google.com

Oriol Vinyals
Google
vinyals@google.com

Quoc V. Le
Google
qvl@google.com



Attention - machine translation



Bahdanau et. al., ICLR, 2015

The transformer - attention is all you need

SYSTEM PROMPT
(HUMAN-WRITTEN)

In a shocking finding, scientist discovered a herd of unicorns living in a remote, previously unexplored valley, in the Andes Mountains. Even more surprising to the researchers was the fact that the unicorns spoke perfect English.

MODEL
COMPLETION
(MACHINE-
WRITTEN, 10 TRIES)

The scientist named the population, after their distinctive horn, Ovid's Unicorn. These four-horned, silver-white unicorns were previously unknown to science.

Now, after almost two centuries, the mystery of what sparked this odd phenomenon is finally solved.

Dr. Jorge Pérez, an evolutionary biologist from the University of La Paz, and several companions, were exploring the Andes Mountains when they found a small valley, with no other animals or humans. Pérez noticed that the valley had what appeared to be a natural fountain, surrounded by two peaks of rock and silver snow.

Pérez and the others then ventured further into the valley. "By the time we reached the top of one peak, the water looked blue, with some crystals on top," said Pérez.

Pérez and his friends were astonished to see the unicorn herd. These creatures could be seen from the air without having to move too much to see them – they were so close they could touch their horns.

AGI coming?

While examining these bizarre creatures the scientists discovered that the creatures also spoke some fairly regular English. Pérez stated, "We can see, for example, that they have a common 'language,' something like a dialect or dialectic."

Dr. Pérez believes that the unicorns may have originated in Argentina, where the animals were believed to be descendants of a lost race of people who lived there before the arrival of humans in those parts of South America.

While their origins are still unclear, some believe that perhaps the creatures were created when a human and a unicorn met each other in a time before human civilization. According to Pérez, "In South America, such incidents seem to be quite common."

However, Pérez also pointed out that it is likely that the only way of knowing for sure if unicorns are indeed the descendants of a lost alien race is through DNA. "But they seem to be able to communicate in English quite well, which I believe is a sign of evolution, or at least a change in social organization," said the scientist.

OpenAI blog: Better Language Models and Their Implications

Document interpretation with `tradeshift.com`

SENDER → **TYRELL CORPORATION**
Dr. Eldon Street, 1, Los Angeles, CA 91020, USA

RECEIVE → **Stark Industries**
Howard Stark, 40
Palmdale,
CA 93550, USA
98-7654321

INVOICE NUMBER → Invoice number.: inv. 123456

DATE → Invoice date: 14/02/2015

ITEM REF.	ITEM DESCRIPTION	QTY	PRICE	TOTAL
RF673	Flux capacitor (DeLorean compatible)	1	95.000,-	95.000,-
A5245	Cell phone Samsung SPH-N270	10	345,-	3450,-
ZS304	Psychomagnotheric Slime	100 l.	17.00	1700,-

ITEMS →

SUBTOTAL: USD 100.150.00

TAX (20% VAT) : USD 20.030,00 → **TAX**

TOTAL: USD 120.170,00 → **TOTAL**

The payment must be done 14 days after the invoice date, while any claim must be done within 10 days. Bunch of other words in very small font that nobody reads. They do not follow any format and may repeat text that it was previously included in the invoice. For our purpose, there is nothing interesting here.

Learning sequential reasoning

1 2 3 4 5 6 7 8 9	- - - - - - - - -	- - - - - - - - -	1 - - - - - -	1 2 2 4 5 6 7 8 9	1 2 2 4 5 6 7 8 9	1 2 2 4 5 6 7 8 9	1 2 2 4 5 6 7 8 9	1 2 2 4 5 6 7 8 9
1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	- - - 5 - - - - -	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	2 - - - - - -	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
- - - 5 - - - - -	- - - 3 - - - - -	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	4 - - - - - -	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
- - - 2 - - - - -	1 2 2 4 5 6 7 8 9	1 2 2 4 5 6 7 8 9	1 2 2 4 5 6 7 8 9	1 2 2 4 5 6 7 8 9	1 2 2 4 5 6 7 8 9	1 2 2 4 5 6 7 8 9	1 2 2 4 5 6 7 8 9	- - - 3 - - - - -
1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	- - - - - - 8 - -	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
1 - - - - - -	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	- - - 3 - - - - -	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	- - - - - - 9 - -	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	8 - - - - - -	1 2 3 4 5 6 7 8 9
1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9	5 - - - - - -	- - - 6 - - - - -	6 - - - - - -	1 2 3 4 5 6 7 8 9

Part 4:

Teaching machine learning at DTU

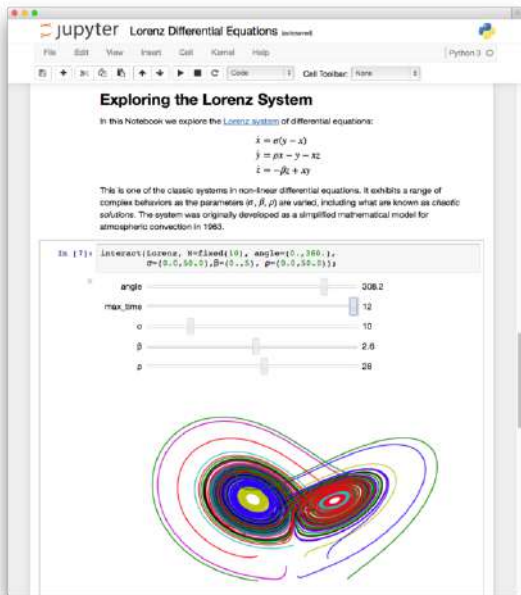
Example: DTU course 02456 Deep learning

- 5 ects points.
- Flipped class room - videos not watched so much.
- Mandatory exercices from textbook to ensure reading.
- 8 weeks with labs mostly programming oriented
- 7 week project
- Poster exam and final report based upon project.
- 300 students - BSc, MSc, PhD, industry.
- Approximately 30% women.
- Relatively few with strong statistics background.

TensorFlow Playground

playground.tensorflow.org

Jupyter notebooks



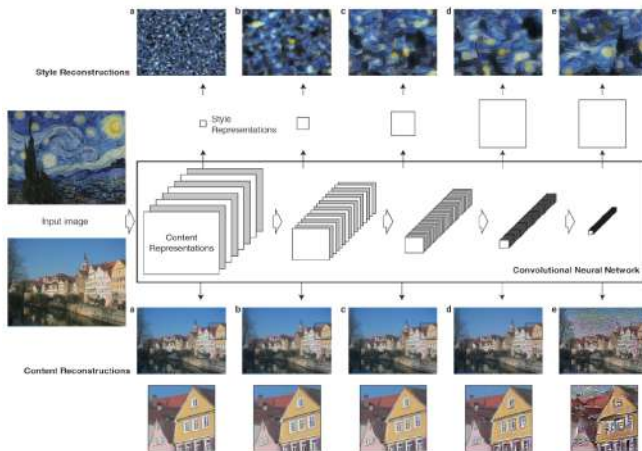
Perspectives - empowering education

- Deep learning is the enabler of progress in AI
- Lesson: we have so far used too small and inflexible models
- Faster computers = better performance
- Programming and data science tools are maturing
- Will enable a new type of computer literacy



A Neural Algorithm of Artistic Style

- Gatys, Ecker and Bethge
<http://arxiv.org/pdf/1508.06576v2.pdf>
- Idea: Separate content and style



Borrowing the style from the masters!

A



B



Borrowing the style from the masters!



Borrowing the style from the masters!



Neural artistic style - The Movie

Sintel movie, IV

