# Ειδκά Συστήματα Ελέγχου Πλοίου

## ΣΝΜΜ 2019

## Μάθημα 3Β: Νευρωνικά Δίκτυα - Υπολογιστικά Εργαλεία

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Εθνικό Μετσοβιο Πολυτεχνείο

March 19, 2019

# Περιεχόμενα

# Περιεχόμενο Μαθήματος

- Μ3Α: Εισαγωγή στην Μηχανική Μάθηση, Νευρωνικά Δίκτυα. Βιβλιογραφία.
- Μ3Β: ΝΔ: Υπολογιστικά εργαλεία
- Μ3Γ: Εφαρμογή ΝΔ σε μηχανές εσωτερικής καύσης/virtual sensors

# Σύγχρονα εργαλεία για την σχεδίαση ΝΔ

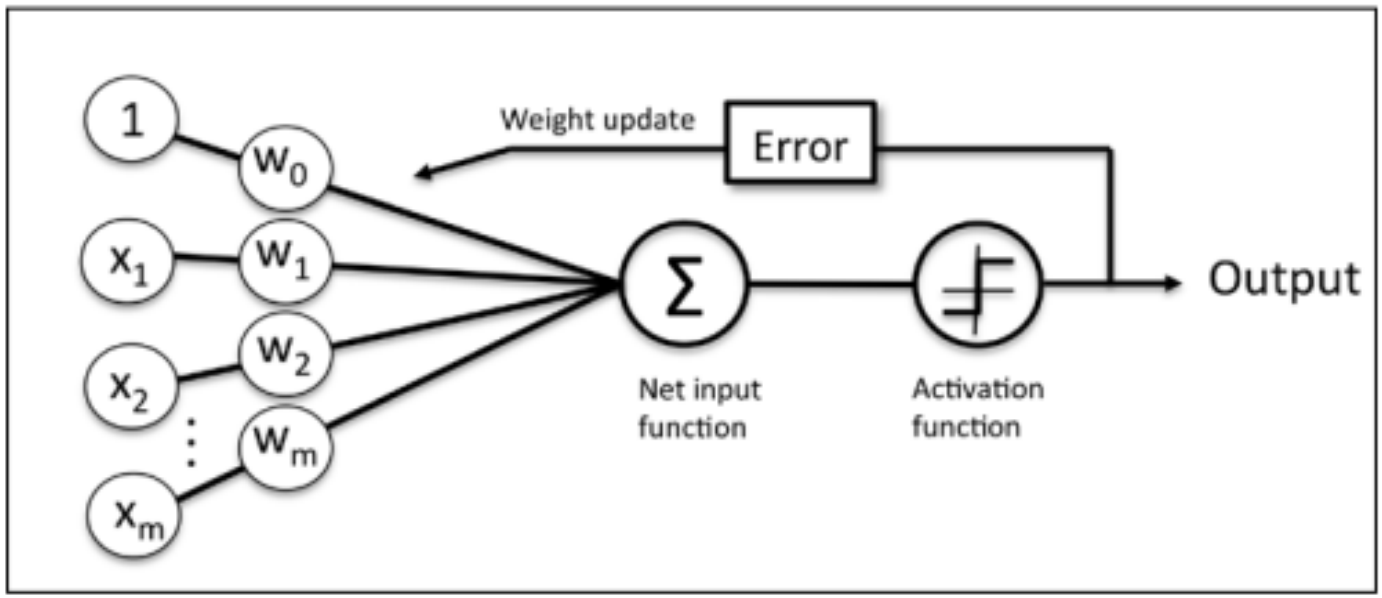
Βασικές πηγές:

- Τα τελευταία χρόνια η σχεδίαση ενός ΝΔ γίνεται με ευρεία χρήση της γλώσσας Python, του MATLAB, αλλά και με άλλες πλατφόρμες (Tensor Flow, Keras, κλπ).
- Για το μάθημα 2019, η σχεδίαση θα γίνει σε MATLAB.

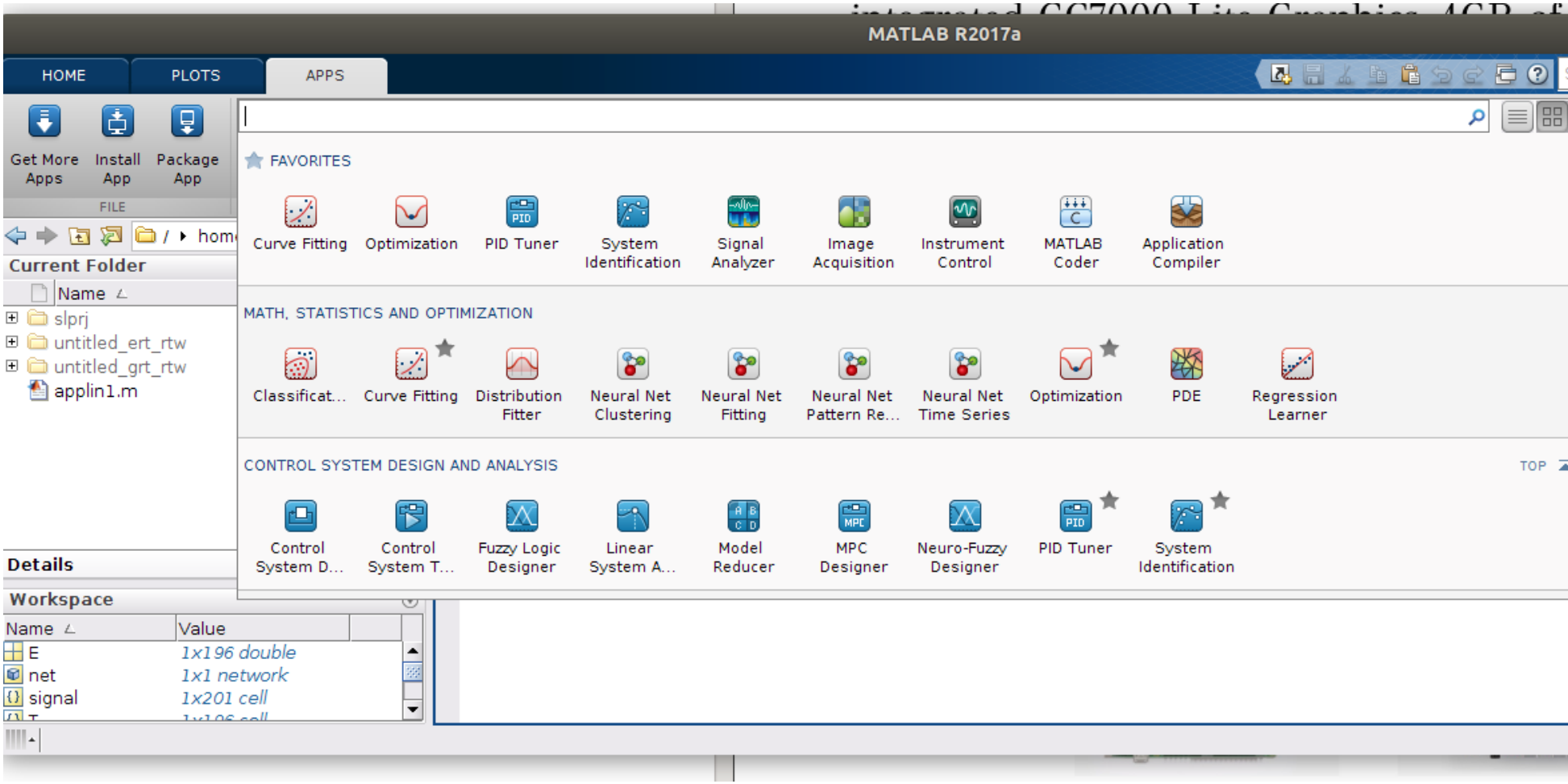
# Σύγχρονα εργαλεία σε Python

- Βιβλίο Sebastian Raschka: Python Machine Learning, 2nd Edition.
- Γίνεται χρήση Python και βιβλιοθηκών numpy, SciPy, Scikit-learn για ΝΔ single - και multi - layer.
- https://sebastianraschka.com/books.html

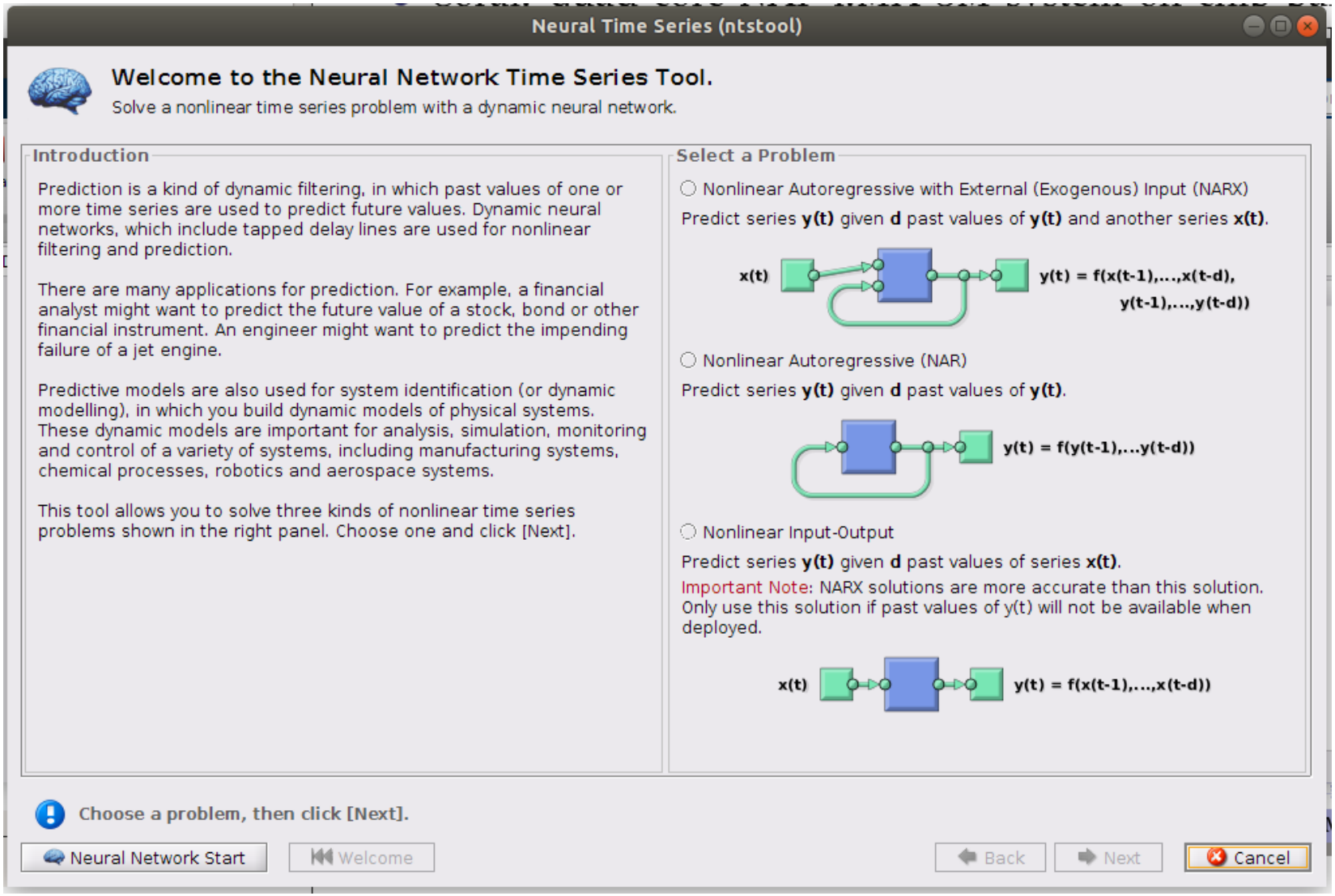
# Βιβλίο Sebastian Raschka



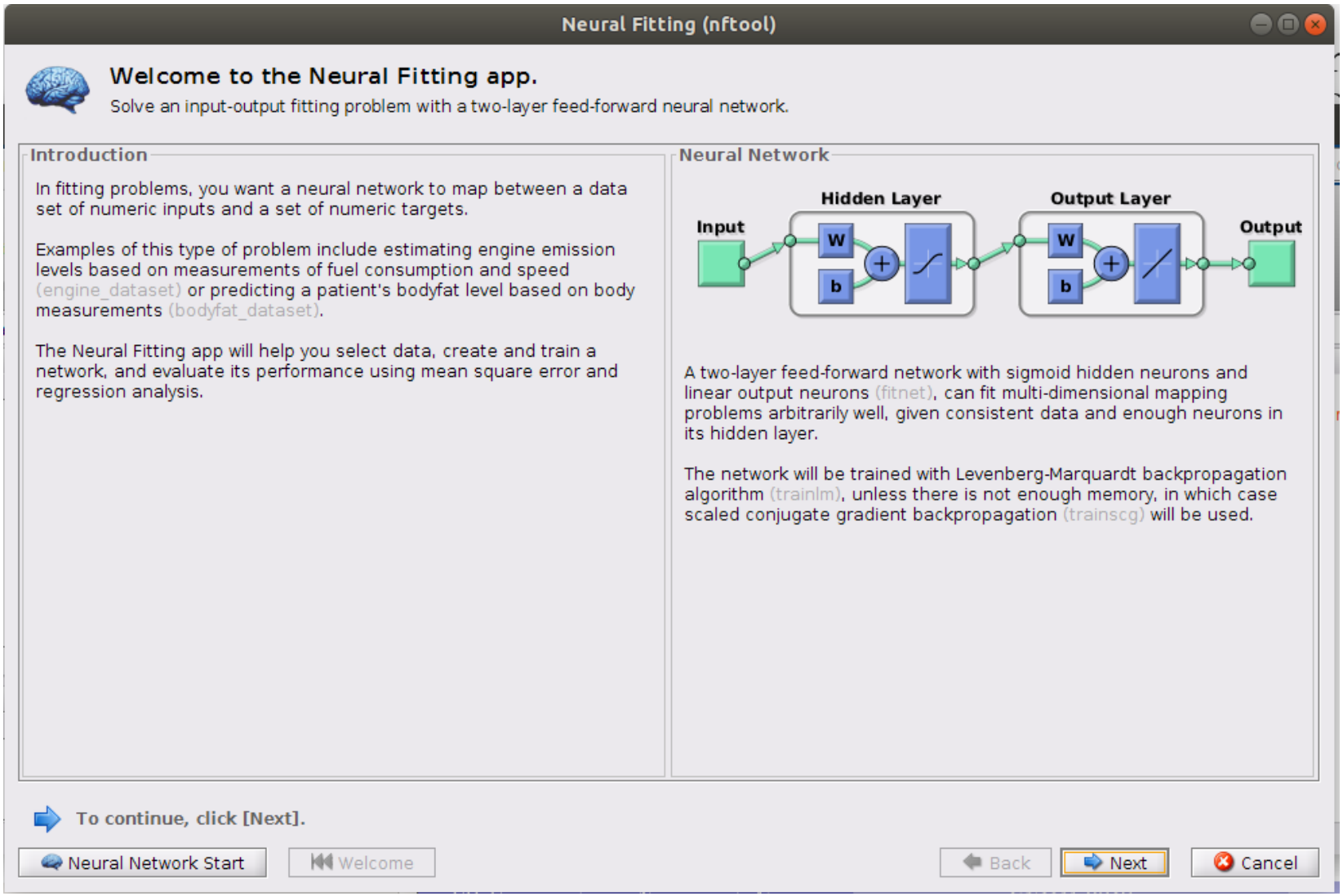
# MATLAB NN Toolbox



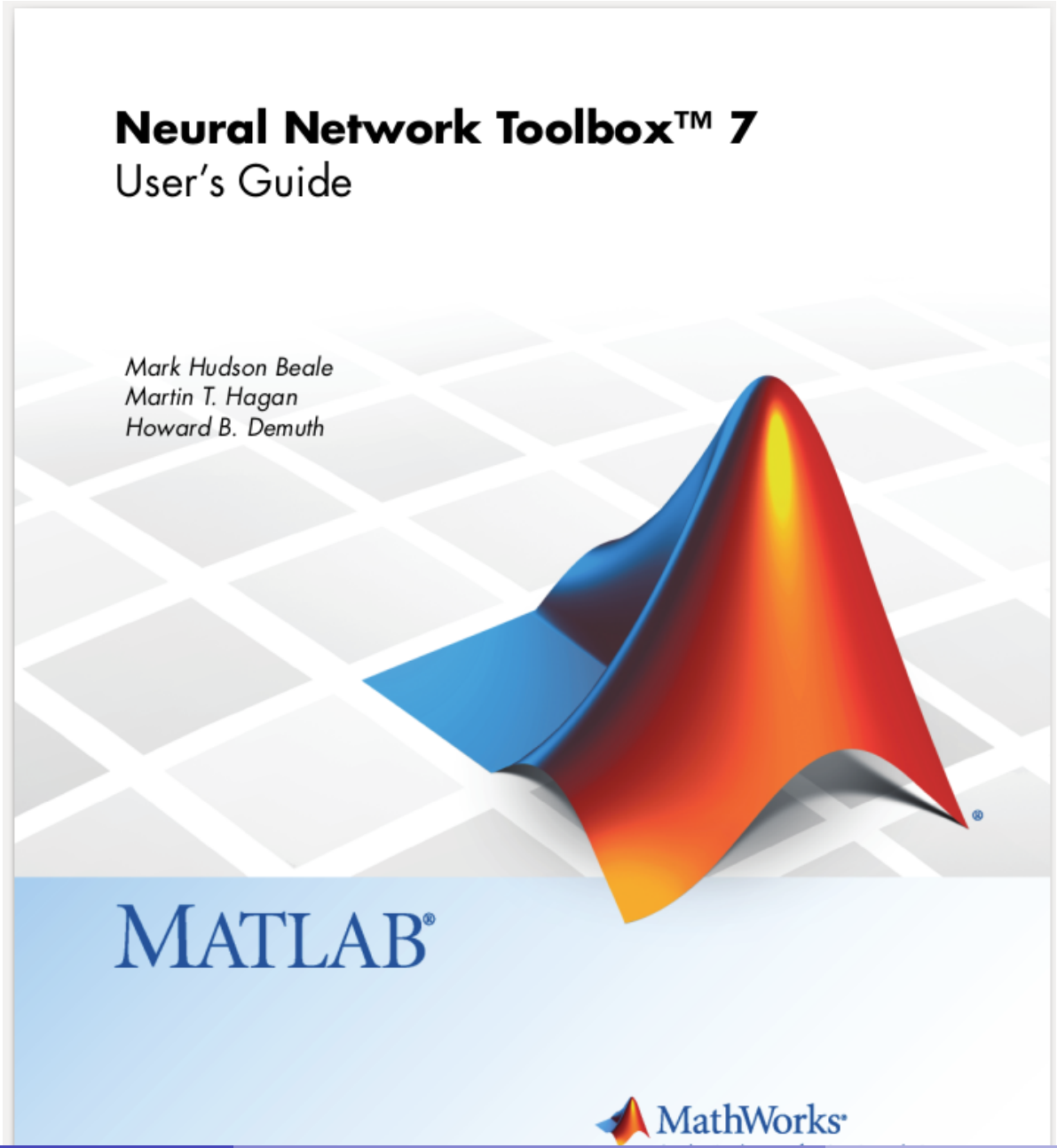
# MATLAB


Neural Time Series (ntstool)
Welcome to the Neural Network Time Series Tool.
Solve a nonlinear time series problem with a dynamic neural network.
Introduction
Prediction is a kind of dynamic filtering, in which past values of one or more time series are used to predict future values. Dynamic neural networks, which include tapped delay lines are used for nonlinear filtering and prediction.
There are many applications for prediction. For example, a financial analyst might want to predict the future value of a stock, bond or other financial instrument. An engineer might want to predict the impending failure of a jet engine.
Predictive models are also used for system identification (or dynamic modelling), in which you build dynamic models of physical systems. These dynamic models are important for analysis, simulation, monitoring and control of a variety of systems, including manufacturing systems, chemical processes, robotics and aerospace systems.
This tool allows you to solve three kinds of nonlinear time series problems shown in the right panel. Choose one and click [Next].
Select a Problem
Nonlinear Autoregressive with External (Exogenous) Input (NARX)
Predict series y(t) given d past values of y(t) and another series x(t).
x(t)
y(t) = f(x(t-1),...,x(t-d), y(t-1),...,y(t-d))
Nonlinear Autoregressive (NAR)
Predict series y(t) given d past values of y(t).
y(t) = f(y(t-1),...y(t-d))
Nonlinear Input-Output
Predict series y(t) given d past values of series x(t).
Important Note: NARX solutions are more accurate than this solution. Only use this solution if past values of y(t) will not be available when deployed.
x(t)
y(t) = f(x(t-1),...,x(t-d))
Choose a problem, then click [Next].
Neural Network Start
Welcome
Back
Next
Cancel

# MATLAB

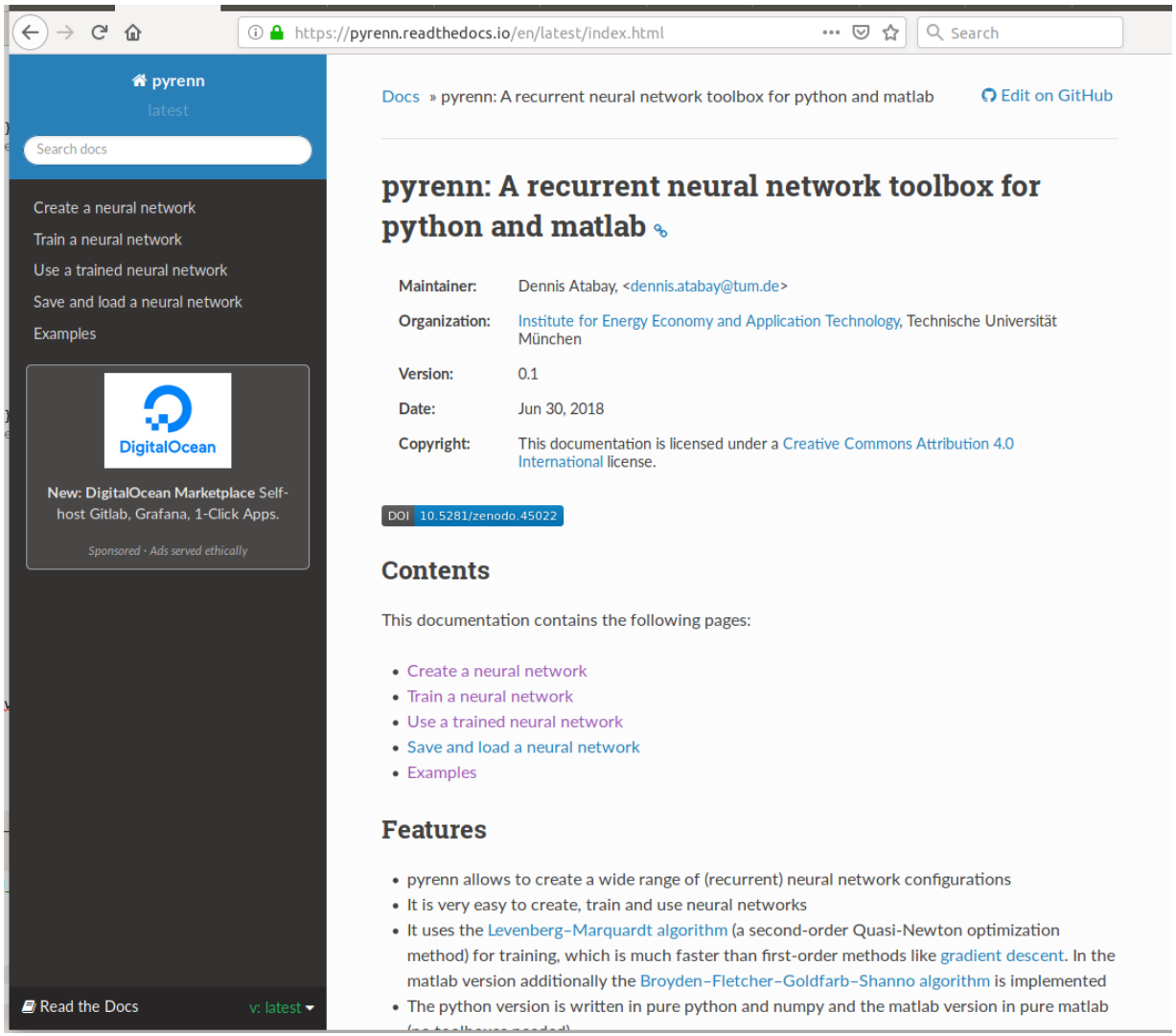

Neural Fitting (nftool)
Welcome to the Neural Fitting app.
Solve an input-output fitting problem with a two-layer feed-forward neural network.
Introduction
In fitting problems, you want a neural network to map between a data set of numeric inputs and a set of numeric targets.
Examples of this type of problem include estimating engine emission levels based on measurements of fuel consumption and speed (engine_dataset) or predicting a patient's bodyfat level based on body measurements (bodyfat_dataset).
The Neural Fitting app will help you select data, create and train a network, and evaluate its performance using mean square error and regression analysis.
Neural Network
Input
Hidden Layer
Output Layer
Output
W
b
W
b
A two-layer feed-forward network with sigmoid hidden neurons and linear output neurons (fitnet), can fit multi-dimensional mapping problems arbitrarily well, given consistent data and enough neurons in its hidden layer.
The network will be trained with Levenberg-Marquardt backpropagation algorithm (trainlm), unless there is not enough memory, in which case scaled conjugate gradient backpropagation (trainscg) will be used.
To continue, click [Next].
Neural Network Start
Welcome
Back
Next
Cancel

# MATLAB, User's Guide, ver. 7 (pdf)



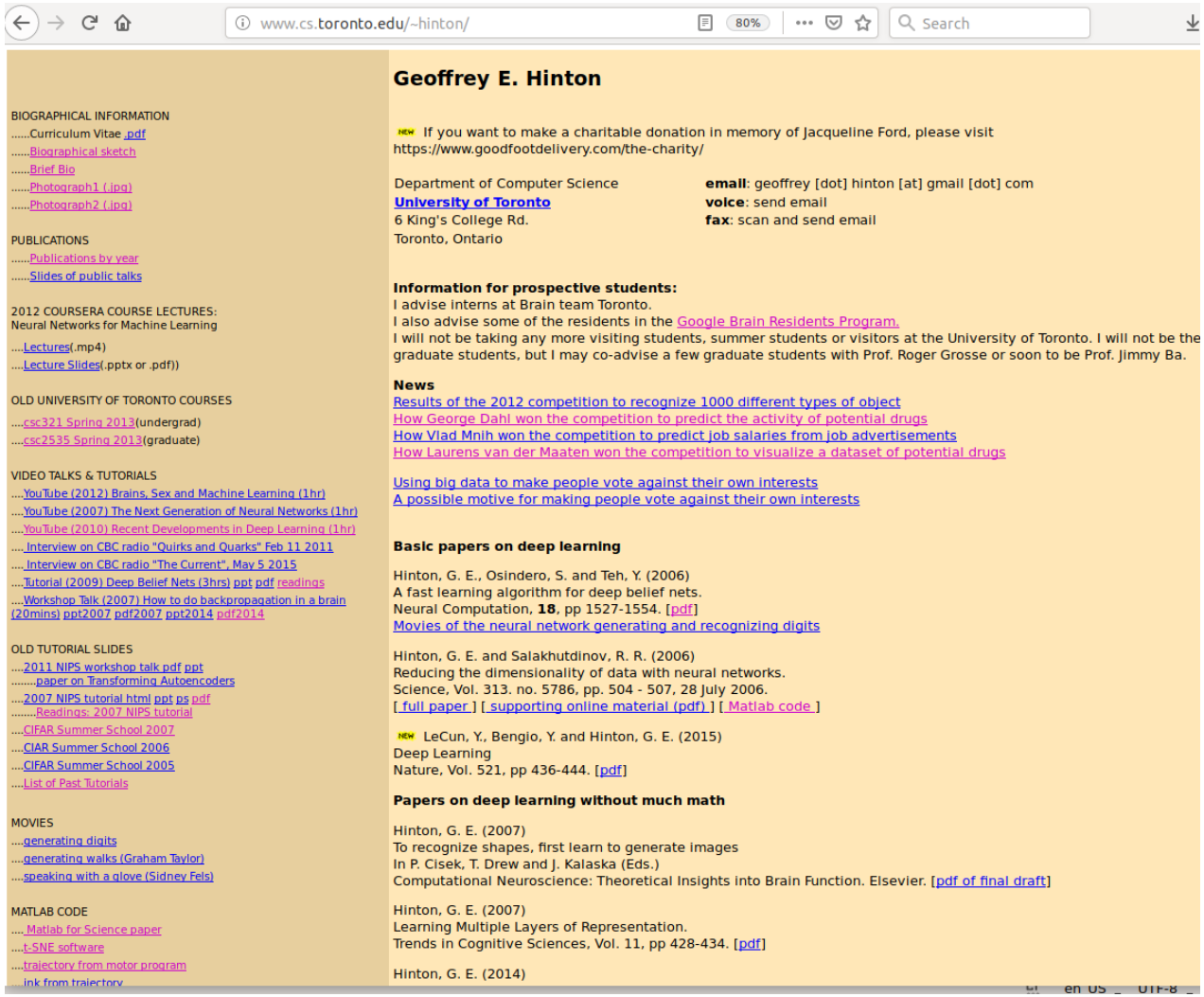
# PYRENN

- Ανοιχτή πλατφόρμα για σχεδίαση ΝΔ, με Python, MATLAB.



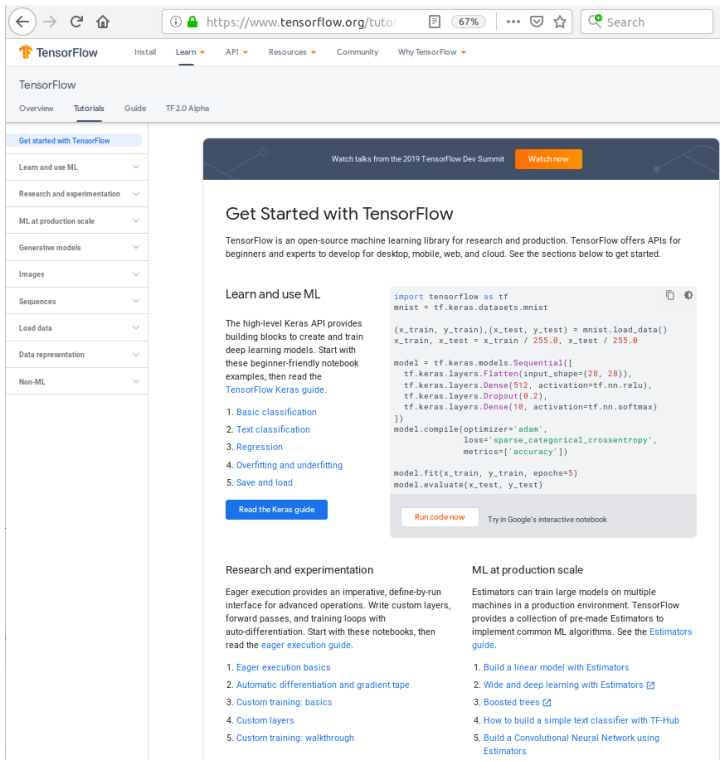
# G. Hinton, UTor, Ca

- Στο site www.cs.toronto.edu/ hinton υπάρχουν οι δημοσιεύσεις, tutorials, MATLAB codes, κλπ.



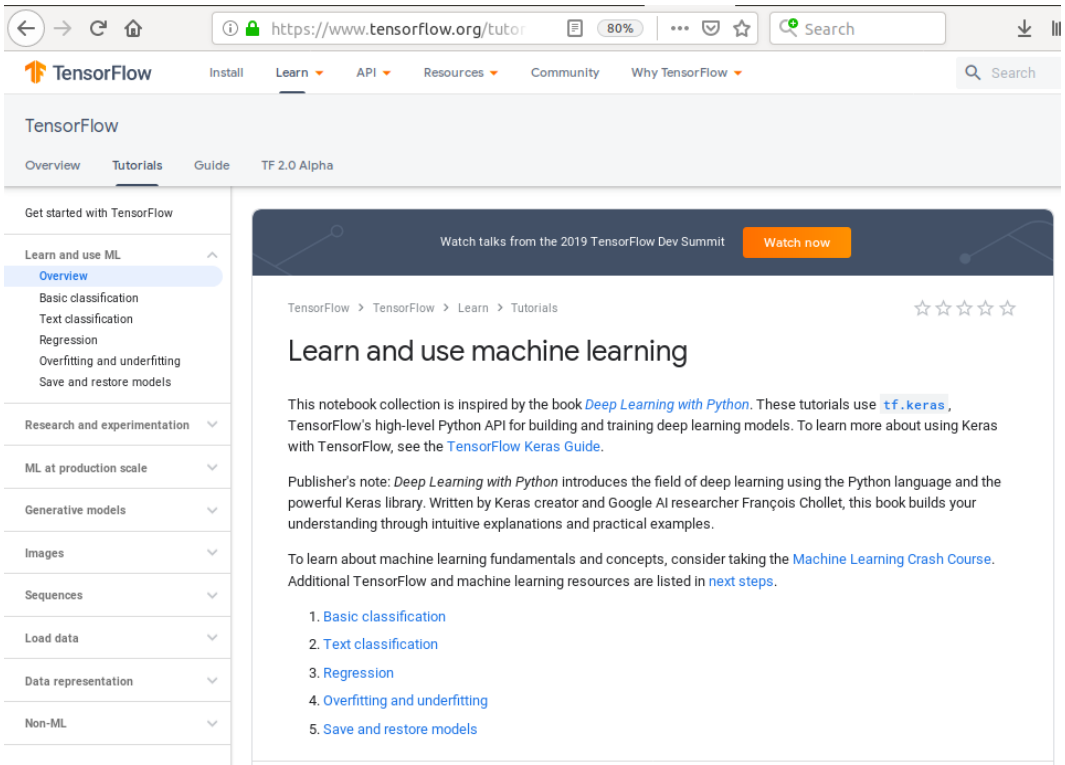
# Tensor Flow

- TensorFlow is a free and open-source software library for dataflow and differentiable programming across a range of tasks. It is a symbolic math library, and is also used for machine learning applications such as neural networks. It is used for both research and production at Google...(Wikipedia)



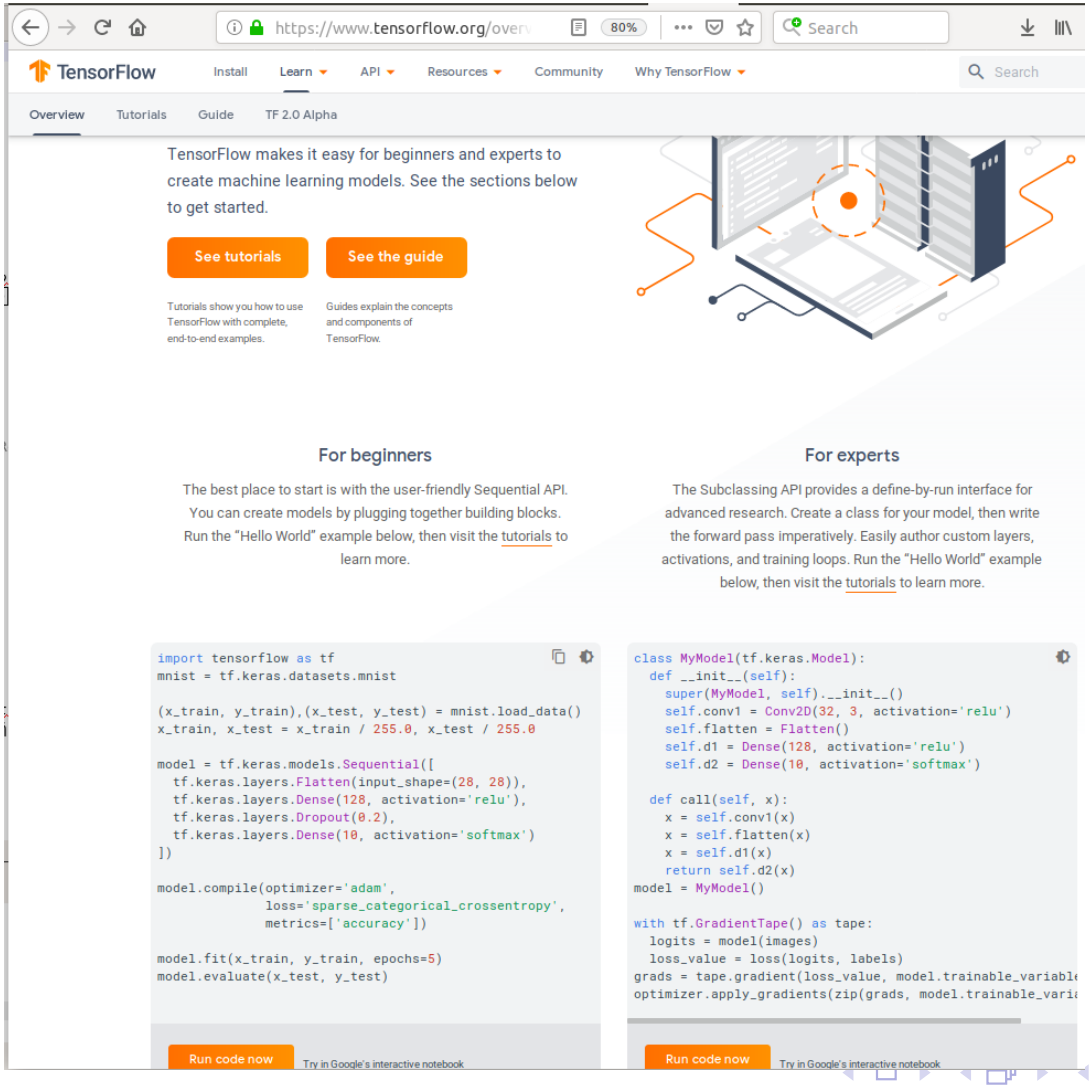
# Tensor Flow

- Το βασικό interface είναι σε γλώσσα Python, αλλά για λόγους ταχύτητας είναι γραμμένο σε C++.



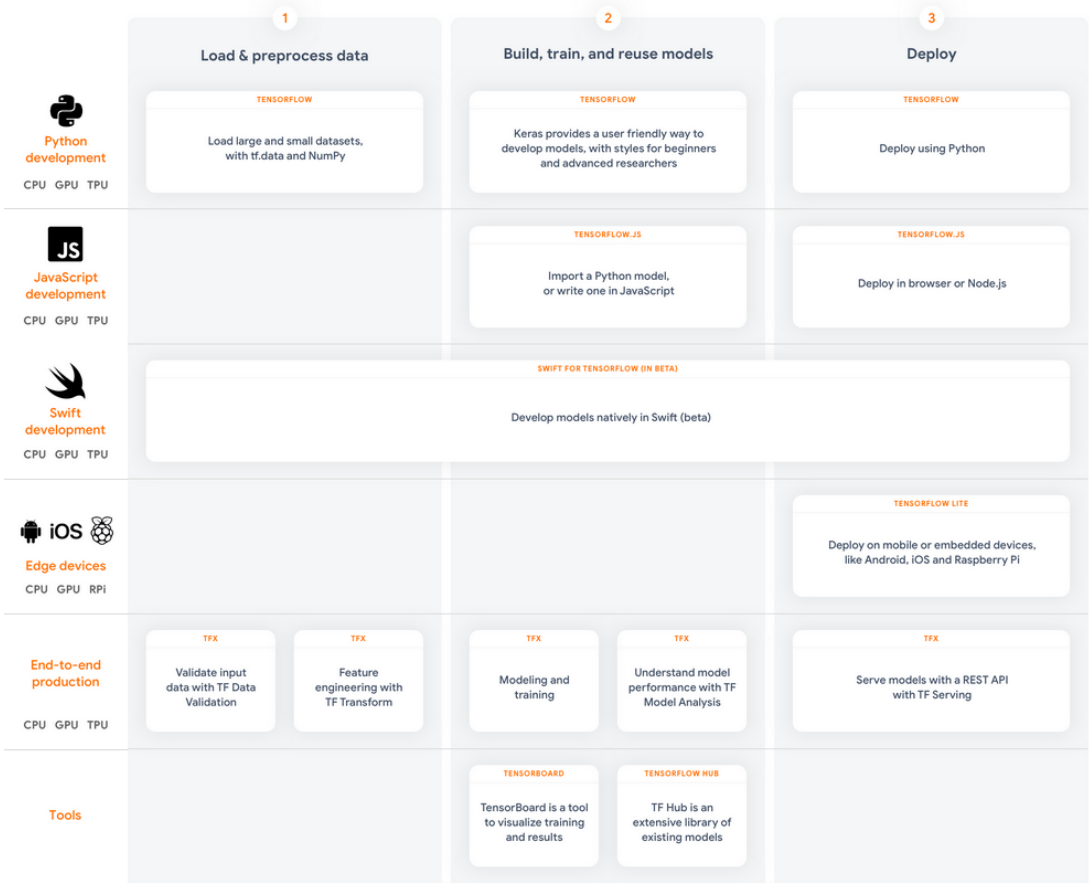
# Tensor Flow

- Συνήθως το TF τρέχει ως η βασική μηχανή και σε υψηλότερο επίπεδο υπάρχουν (απλούστερα) APIs όπως το Keras κα.



# Tensor Flow

- Το TF παρέχει μια συλλογή workflows για την ανάπτυξη και εκπαίδευση μοντέλων που χρησιμοποιούν Python, JavaScript για εύκολη ανάπτυξη σε cloud, browser ή συσκευές (πχ RPi), ανεξάρτητα από τη γλώσσα που χρησιμοποιείτε.

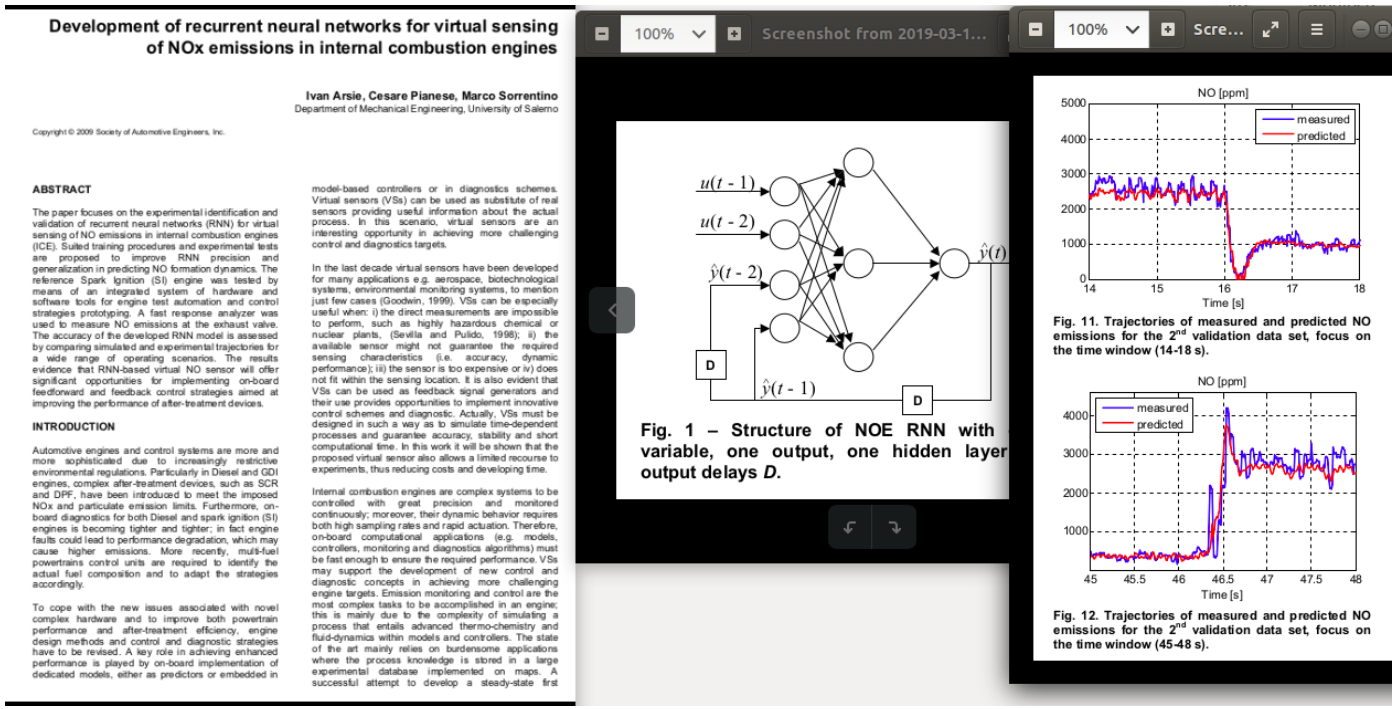


# Tensor Flow

- Coral: quad-core NXP i.MX 8M system-on-chip paired with integrated GC7000 Lite Graphics, 1GB of LPDDR4 RAM, and 8GB of eMMC storage. It has wireless chip that supports Wi-Fi 2.4/5GHz and Bluetooth, a 3.5mm audio jack, and a full-size HDMI 2.0a port, plus USB 2.0/3.0 ports, a 40-pin GPIO expansion header, and a Gigabit Ethernet port (150$).

# Virtual Sensors

- Μέσω 2 ΝΔ θα γίνεται εκτίμηση παραμέτρων lambda, NOx, για έλεγχο κλειστού βρόχου.
- Γίνεται έτσι εκτίμηση παραμέτρων μηχανής παράλληλα με τα αισθητήρια (=Virtual Sensors).



Development of recurrent neural networks for virtual sensing of NOx emissions in internal combustion engines

Ivan Arsie, Cesare Pianese, Marco Sorrentino
Department of Mechanical Engineering, University of Salerno

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ABSTRACT

The paper focuses on the experimental identification and validation of recurrent neural networks (RNN) for virtual sensing of NO emissions in internal combustion engines (ICE). Suited training procedures and experimental tests are proposed to improve RNN precision and generalization in predicting NO formation dynamics. The reference Spark Ignition (SI) engine was tested by means of an integrated system of hardware and software tools for engine test automation and control strategies prototyping. A fast response analyzer was used to measure NO emissions at the exhaust valve. The accuracy of the developed RNN model is assessed by comparing simulated and experimental trajectories for a wide range of operating scenarios. The results evidence that RNN-based virtual NO sensor will offer significant opportunities for implementing on-board feedforward and feedback control strategies aimed at improving the performance of after-treatment devices.

INTRODUCTION

Automotive engines and control systems are more and more sophisticated due to increasingly restrictive environmental regulations. Particularly in Diesel and GDI engines, complex after-treatment devices, such as SCR and DPF, have been introduced to meet the imposed NOx and particulate emission limits. Furthermore, on-board diagnostics for both Diesel and spark ignition (SI) engines is becoming tighter and tighter; in fact engine faults could lead to performance degradation, which may cause higher emissions. More recently, multi-fuel powertrains control units are required to identify the actual fuel composition and to adapt the strategies accordingly.

To cope with the new issues associated with novel complex hardware and to improve both powertrain performance and after-treatment efficiency, engine design methods and control and diagnostic strategies have to be revised. A key role in achieving enhanced performance is played by on-board implementation of dedicated models, either as predictors or embedded in model-based controllers or in diagnostics schemes. Virtual sensors (VSs) can be used as substitute of real sensors providing useful information about the actual process. In this scenario, virtual sensors are an interesting opportunity in achieving more challenging control and diagnostics targets.

In the last decade virtual sensors have been developed for many applications e.g. aerospace, biotechnological systems, environmental monitoring systems, to mention just few cases (Goodwin, 1999). VSs can be especially useful when: i) the direct measurements are impossible to perform, such as highly hazardous chemical or nuclear plants, (Sevilla and Pulido, 1998); ii) the available sensor might not guarantee the required sensing characteristics (i.e. accuracy, dynamic performance); iii) the sensor is too expensive or iv) does not fit within the sensing location. It is also evident that VSs can be used as feedback signal generators and their use provides opportunities to implement innovative control schemes and diagnostic. Actually, VSs must be designed in such a way as to simulate time-dependent processes and guarantee accuracy, stability and short computational time. In this work it will be shown that the proposed virtual sensor also allows a limited recourse to experiments, thus reducing costs and developing time.

Internal combustion engines are complex systems to be controlled with great precision and monitored continuously; moreover, their dynamic behavior requires both high sampling rates and rapid actuation. Therefore, on-board computational applications (e.g. models, controllers, monitoring and diagnostics algorithms) must be fast enough to ensure the required performance. VSs may support the development of new control and diagnostic concepts in achieving more challenging engine targets. Emission monitoring and control are the most complex tasks to be accomplished in an engine; this is mainly due to the complexity of simulating a process that entails advanced thermo-chemistry and fluid-dynamics within models and controllers. The state of the art mainly relies on burdensome applications where the process knowledge is stored in a large experimental database implemented on maps. A successful attempt to develop a steady-state first

100% Screenshot from 2019-03-1...



Fig. 1 – Structure of NOE RNN with variable, one output, one hidden layer output delays *D*.

100% Scre...



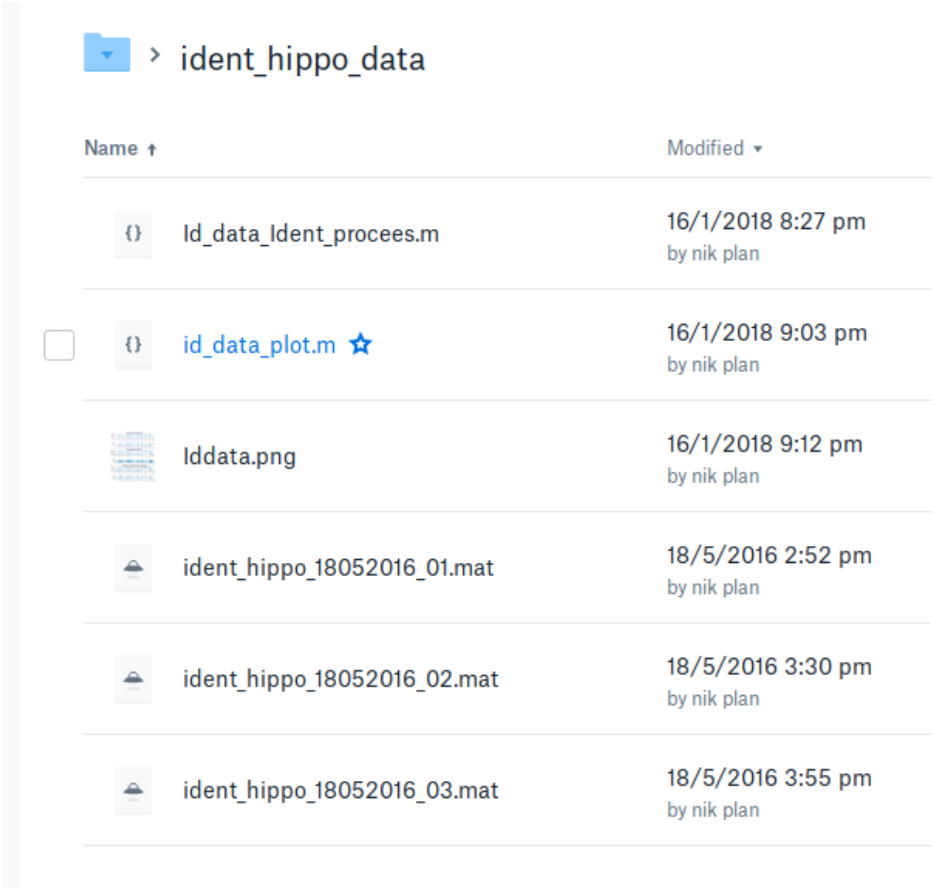

Fig. 11. Trajectories of measured and predicted NO emissions for the 2nd validation data set, focus on the time window (14-18 s).




Fig. 12. Trajectories of measured and predicted NO emissions for the 2nd validation data set, focus on the time window (45-48 s).

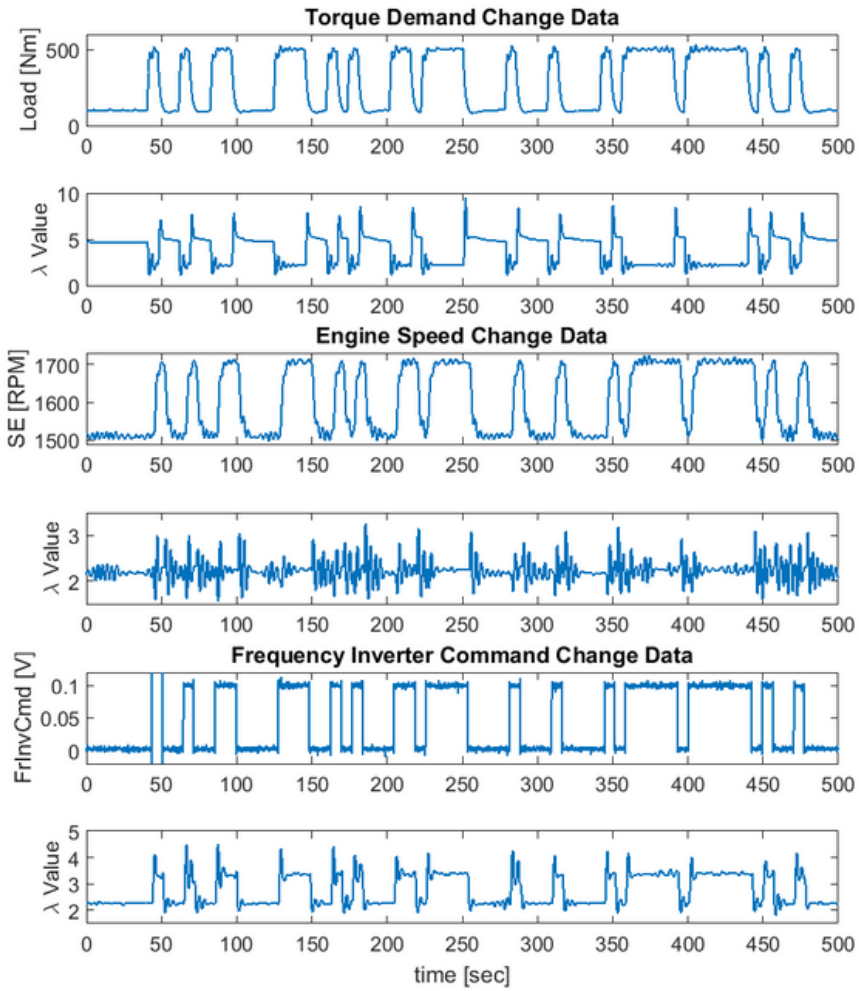
# Δεδομένα για το ΝΔ

- Υπάρχουν διαθέσιμα στο Dropbox του μαθήματος (link στο www.lme.ntua.gr) τα δεδομένα για την σχεδίαση του ΝΔ.



# Δεδομένα για το ΝΔ -2

- Με τα δεδομένα αυτά θα γίνει η σχεδίαση ΝΔ για εκτίμηση των παραμέτρων lambda και NOx της μηχανής.



# Δεδομένα για το ΝΔ -2

- Στο ίδιο link θα βρείτε τις 3 βιβλιογραφικές αναφορές (papers) για την σχεδίαση των ΝΔ (Arsie et al.)

# TO DO !

Μελετήστε από το:
Neural Networks: A Comprehensive Foundation, Simon Haykin, Macmillan, 1994
το κέφ. 1.