# Theses


Data Base and Data Mining Group of Politecnico di Torino

Daniele Apiletti, Elena Baralis, Luca Cagliero, Tania Cerquitelli,
Silvia Chiusano, Paolo Garza, Danilo Giordano, Alessandro Fiori

# General information

- Duration: 5-6 months full time
  - equivalent overall duration if part time
- *Internal* thesis
  - cooperation on active research topic or research project
  - good programming and analytical skills required
  - supervised by a group member
  - can work at home or in our lab (LAB5)
- *External* thesis (stage)
  - supervised by external tutor

To get more info on specific topics

please contact the reference person of the thematic area of interest by email (*name dot surname at polito dot it*)

# Main topics

- Data mining and machine learning algorithms
  - Design and implementation of novel ML algorithms
- Data science pipeline
  - Design, personalization and implementation of KDD processes in diverse application areas
    - Industry, health, finance, …
- Big data analytics
  - Design of scalable data mining and machine learning algorithms
  - Design of scalable KDD processes
- Database management
  - Data warehouse and NoSQL data modeling

# Data mining and machine learning algorithms

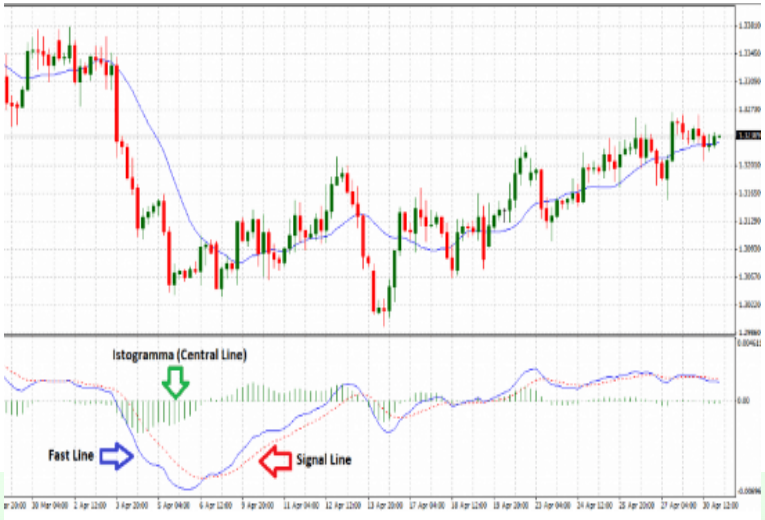
- *Clustering* and *semi-supervised clustering*
- *Scalable* data mining *algorithms* for *big data*
  - E.g., (approximate) clustering
- *Time series* analysis
  - Forecasting models, trend detection
- *Textual data* analysis
  - Summarization, clustering, classification
- *Predictive maintenance* for
  - Industrial processes, robots, automotive components, ...

# Data science pipeline

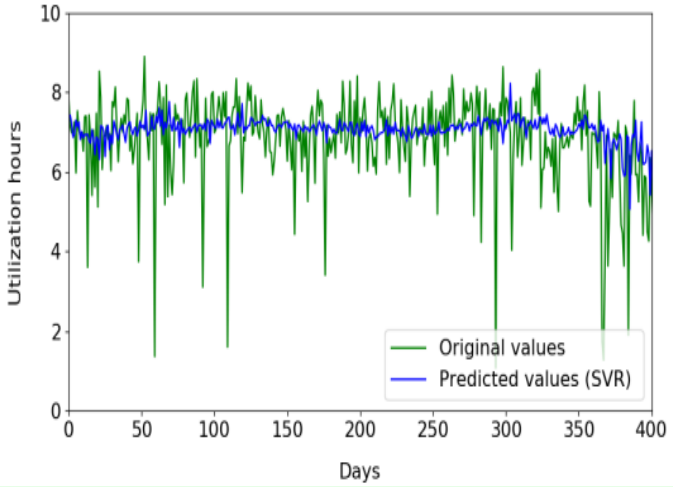
- Design and implementation of *personalized KDD processes*
- Black-box *prediction interpretation*
- *KDD process automation* by means of *self-tuning* and *concept drift detection* techniques
- *Semantic enrichment* by means of entity recognition and latent-based models

# Multivariate time series forecasting

- *Predict the future values* of a time series (e.g., physiological signals, historical stock prices) based on the analysis of *multiple series* (e.g., consider all the stocks of the same sector)
- *Extract* ad hoc features summarizing series *trends* (e.g., moving averages) and the related context (e.g., news articles, social data)




*Stock price forecasting*




*Prediction of vehicle utilization hours*

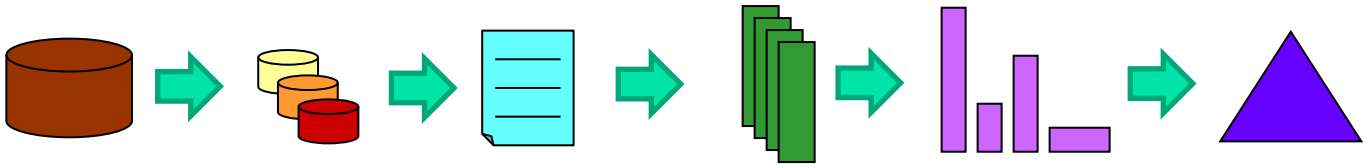
# Big data mining

- Study of innovative, parallel, and distributed data mining approaches for
  - Pattern mining algorithms
  - Clustering techniques
  - Classification algorithms
  - Summarization algorithms

  to efficiently gain interesting insights from huge data volume
- Design and development of novel cloud-based data mining services based on
  - HADOOP and Spark frameworks
  - MapReduce paradigm


- Exploitation of the cloud-based services for novel big data analytics applications (e.g., network traffic data, fraud detection, social networks)
- Analysis modules based on HADOOP and Spark Ecosystems

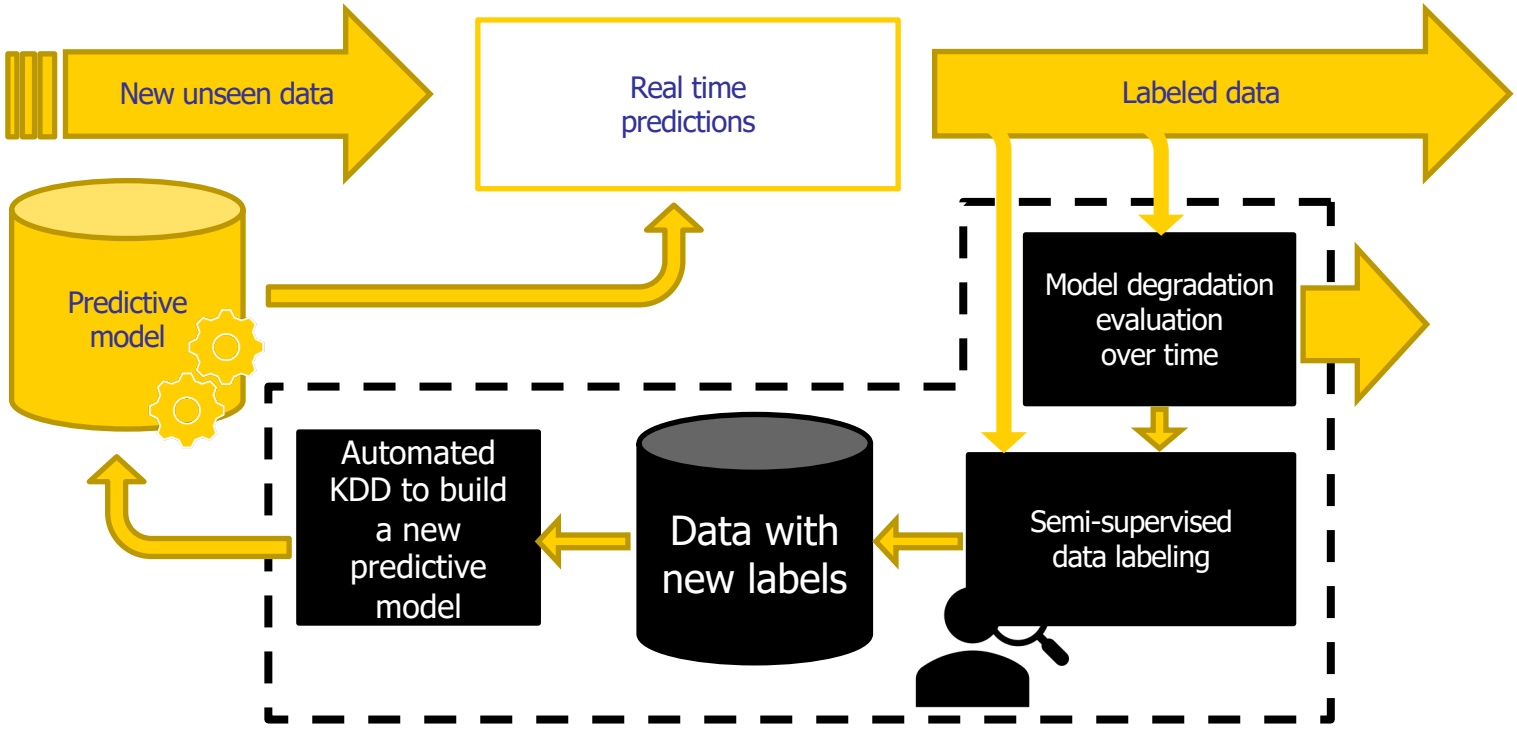
# Automated data science pipeline




## Automation in the data analytics process

- **Tailor** the **analytic** steps to the different key aspects of the **data under analysis**
- **Automate** the analytic workflow to **reduce manual user interventions**
- Translate the domain-expert knowledge into **automated procedures**
- Automatically configure input parameters by means of **self-tuning strategies**
- Design **informative dashboards** and **explanation techniques** to support the translation of the extracted knowledge into effective actions

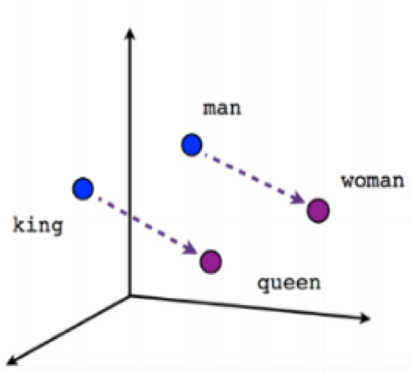
# Automated concept drift management




- Predictive model performance usually degrades over time
  - New incoming data can widely differ from the data distribution on which the model was trained
  - Not all possible classes (labels) are known at training time
  - Real time predictions performed on new unseen data may be misleading or totally wrong

# Deep Natural Language Processing

- Vector representations of text data
  - Trained using Deep Learning models
  - Commonly used to address NLP tasks
  - Examples: Word2Vec, FastText, BERT, GPT-3
- Open issues
  - Text generation
  - Semantic specialization of distributional word vectors
- Methods
  - GAN
  - Seq2Seq models

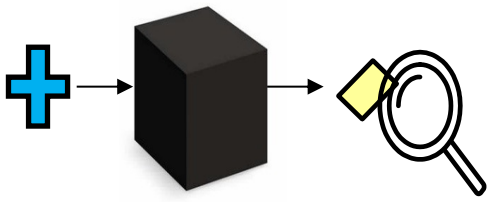


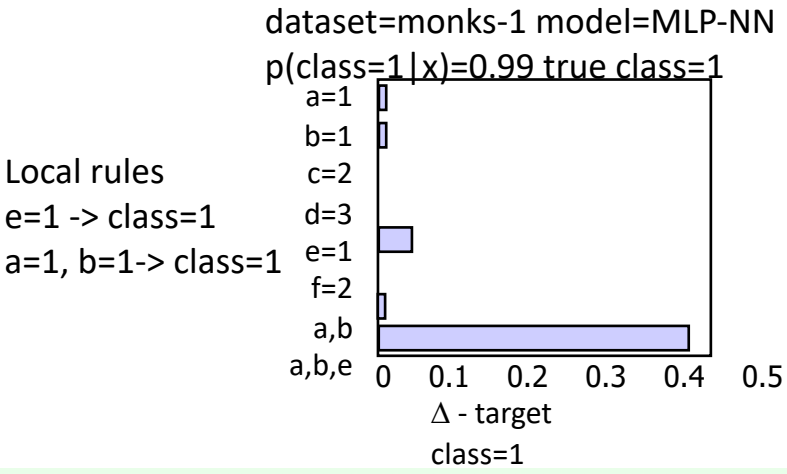
# Text summarization

- Problem
  - identification of salient knowledge from news articles, scientific publications, learning materials, social data
  - generation of sound and easy-to-read summaries of large document collections
- Current issues
  - Fine-tuning of Deep NLP-based solutions to specific domains
    - E.g., BERT, BART
  - Cross-lingual summarization
    - Summaries of collections of documents written in different languages
- Methods
  - Neural summarization
  - Itemset-based summarization

# Explainable AI

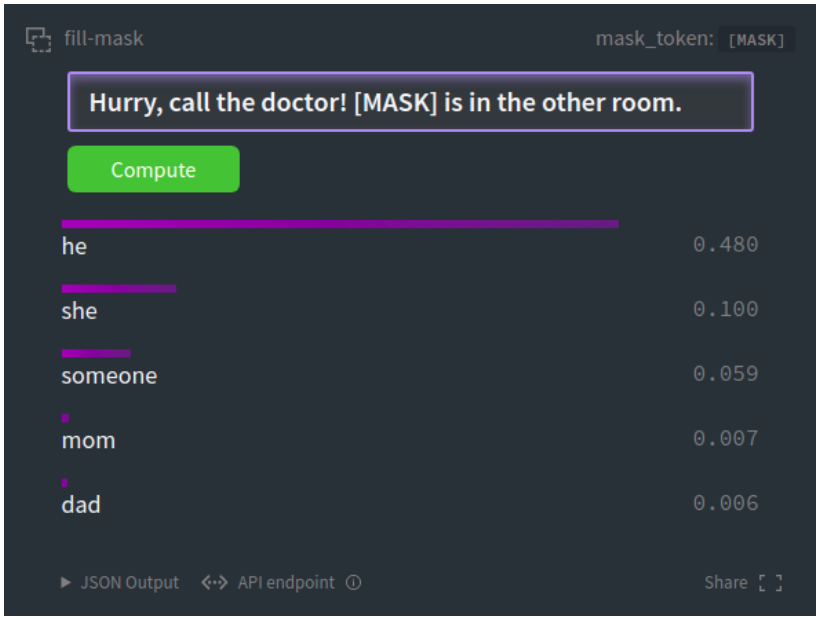
- Model-agnostic explanation methods to explain classifier predictions on single instances
  - Analysis of the joint effect of feature subsets on the prediction
  - Local properties of the original model to be explained are exploited by learning a local rule-based model in its neighborhood
- Dual form of provided explanations
  - Qualitative insight -> local rules
  - Quantitative insight -> prediction difference





# Interpretability of NLP models

- Inspect modern NLP architectures to understand how they encode linguistic features
  - Regularization purposes (e.g. reduction of gender bias)




Mask-fill predictions from Google's BERT

# Vulnerability of interpretability

- Analyze SoTA interpretability techniques to assess vulnerabilities and countermeasures
  - Exploitation of both Offensive and Defensive techniques


From:
*Explanations can be manipulated and geometry is to blame, Dombrowski et al., NIPS 2019*

# Data analytics for healthcare

- Design and development of a smart software component to allow a patient-centered delivery of medical services
  - Collect and integrate heterogeneous data including data on the structures providing medical services, information related to patients, doctors, and staff
  - Study and develop architectural, technological and algorithmic solutions to efficiently manage the above collected data to suggest the optimal medical structure to each patient

Piedmont research project **CANP**

- Physiological data analysis
  - analyze physiological data collected to detect/predict discomfort conditions in automotive environnement
    - characterize discomfort conditions
    - reduce the effect of discomfort conditions

DBMG

REFERENCE PERSON: PROF. SILVIA CHIUSANO

# AI & Financial Data

- Design and implementation of data mining-oriented strategies for financial data analysis
  - Forecasting
    - generate accurate predictions for various markets (stock markets, crypto-currencies) to support long- and short-term quantitative trading strategies
  - Trend detection
    - Apply Seq2Seq models to produce multi-scale descriptions of financial series

# Data analysis for Smart Cities

- Mining urban data to increase the well-being of citizens by improving the efficiency and accessibility of services
  - Analysis of data on citizen mobility in urban area
    - e.g., car pooling and bike sharing systems data to forecast critical situations and characterize the cyclic mobility patterns
  - Analysis of air pollution data on urban area to detect possible critical conditions
  - Analysis of data for citizen security and urban safety
- Different types of data area analyzed as sensor data, open data, social network data, etc.

# Spatio-temporal data mining

- Problem
  - We are overloaded by heterogeneous spatio-temporal data
  - Satellite images and measurements (e.g., Copernicus data)
  - Ground-based sensor measurements
  - Etc.
- Thesis goals
  - Design and implement data mining algorithms for
    - Describing spatio-temporal phenomena
      - By means of sequential and/or graph-based patterns
    - Predicting spatio-temporal events
      - E.g., Spatio-temporal classification algorithms

# Vehicular traffic data analysis

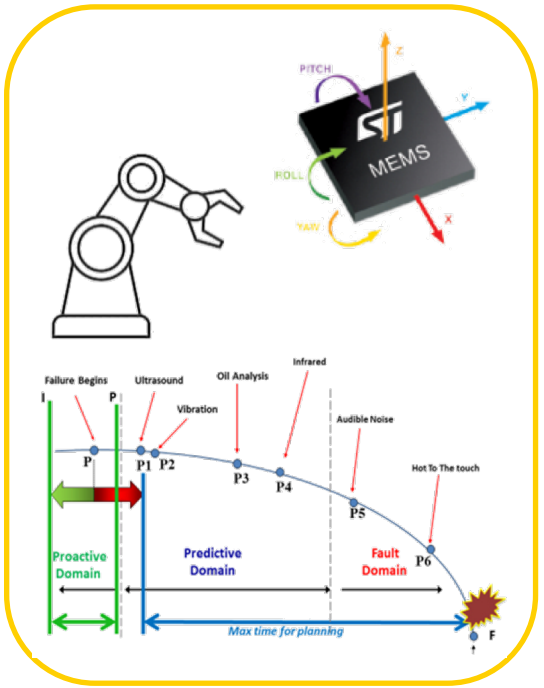
- Characterization of industrial vehicles' usage based on the analysis of BUS CAN bus data, routes, and driver profiles
- Predictive maintenance
  - Predict faults based on the analysis of diagnostic messages
- Profile vehicle duties
  - Cluster vehicle usage data
- Optimize signal transmission
  - Optimize schedules of CAN bus messages

TIERRA
TELEMATICS DESIGN

# Embedded ML for condition monitoring

life.augmented

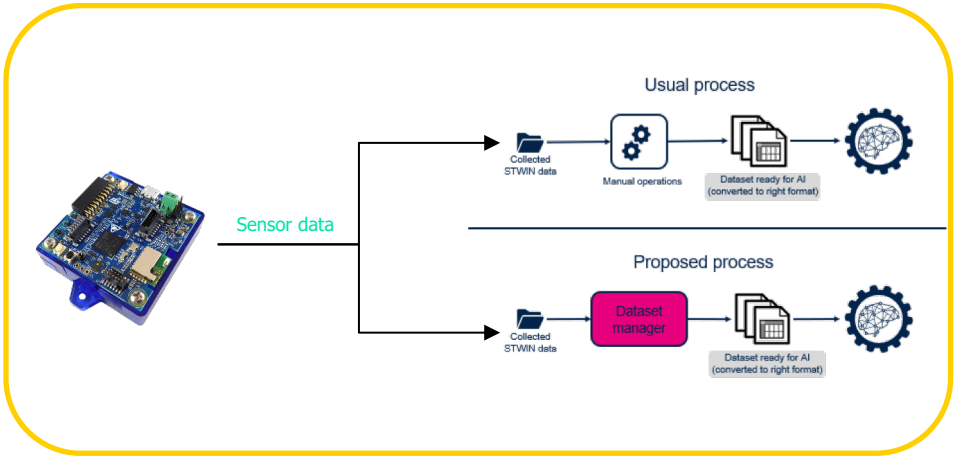
- Artificial intelligence and machine learning algorithms can be optimized to run embedded in small size and low power intelligent sensing nodes in order to enable efficient monitoring of industrial equipment and integration in Industrial IoT infrastructure.
- This project targets the development of algorithms and real-time architectures implementing data analytics based on the fusion of heterogeneous sensors such as accelerometers, inertial and environmental.
- The project involves many activities; the proposed stage will focus on one or more of the following:
  - Embedded software development and optimization
  - Algorithm design and implementation (Artificial Intelligence, Machine Learning)
  - Hardware design
  - Mechanical evaluation, simulations and characterization for the best sensors placement
  - Validation and Testing
  - Design and implementation of communication protocols over Bluetooth, WiFi
- Skills required
  - C, MATLAB programming
  - Basic Digital Signal Processing
  - Knowledge of Machine Intelligence and AI algorithms and tools
- Skills acquired during the work
  - Embedded system design
  - Signal processing and firmware development for innovative solutions




REFERENCE PEOPLE:
PROF. ELENA BARALIS, ROBERTO SANNINO (roberto.sannino@st.com)

# Dataset optimization tool

- Artificial intelligence and machine learning algorithms can be optimized to run embedded in small size and low power intelligent sensing nodes in order to enable efficient monitoring of industrial equipment and integration in Industrial IoT infrastructure.
- Data are key values for any kind of AI process, but there is a huge gap between data collected and proper dataset to be given as input to an AI algorithm, specifically for embedded systems. Often data preparation is manual, unpleasant and time-consuming.
- This project aims to build up a tool that can automize part of the data preprocessing (i.e.: Data Segmentation, Feature Extraction, Feature Selection, Dataset Balancing, …). This is needed in any AI problem, especially in embedded systems. This tool can be tuned to run entirely or partially in an embedded system or in a host (i.e.: PC).
- The project involves many activities; the proposed stage will focus on one or more of the following:
  - Embedded software development and optimization
  - Software architecture design and implementation
  - Data-driven methodologies and signal processing
  - Simulations, Validation and Testing
- Skills required
  - C and Python programming
  - Basic Digital Signal Processing and Data Science
  - Knowledge of Machine Intelligence and AI algorithms and tools
- Skills acquired during the work
  - Embedded system design
  - Signal processing and firmware development for innovative solutions




REFERENCE PEOPLE:
PROF. ELENA BARALIS, ROBERTO SANNINO (roberto.sannino@st.com), FILIPPO AUGUSTI (filippo.augusti@st.com)