

18-19 October 2018  
Lugano, Switzerland

FTAL conference  
on Industrial Applied  
Data Science

Proceedings



# Welcome

Dear colleagues, students and guests,

On behalf of FTAL and the hosting University of Applied Sciences and Arts of Southern Switzerland SUPSI, we would like to welcome you to the first FTAL conference 2018 in Lugano.

In a more and more competitive and dynamic global research and innovation framework, the Swiss Universities of Applied Sciences network may represent a crucial actor to support the leading position in innovation held by Switzerland and recognised at international level.

Therefore it will be of major relevance to strengthen the UAS applied research network by increasing mutual knowledge sharing, developing common research projects and acting as networked community towards larger international institutions and industries.

Knowing that and in order to move one step forward in achieving such a valuable objective, FTAL will promote further cooperation among the Swiss UAS systems and its stakeholders, with particular focus on applied research fields of major industrial relevance. In such a context, the first FTAL conference on the topic of Industrial Applied Data Science has been launched in Lugano in 2018.



We are confident that all participating UAS researchers and students, as well as industrial partners, may exploit such an opportunity to increase mutual knowledge, enforce their networks and enjoy our FTAL community: a key actor of growing relevance in the Swiss applied research and innovation system.

Finally, we would like to thank our sponsors, the contributors and all other persons involved in the organisation of this conference, especially the Department of Innovative Technologies of SUPSI, as well as Christine Menghini from the FTAL Office.

We wish you all a fruitful conference and pleasant stay in Lugano.

Prof. Olivier Naef  
President FTAL

Prof. Dr. Emanuele Carpanzano  
FTAL conference Chairman

# Introduction of the scientific committee

Dear colleagues, students and guests,

This first research conference of Swiss Universities of Applied Sciences is devoted to Industrial Applied Data Science. This topic has aroused great interest among researchers and students of the seven Swiss UAS. In total, we have accepted 58 papers divided in four categories, Industry Production and Logistics (12 oral papers and 13 posters), Energy and Environment (7 oral papers and 5 posters), Life Science and Healthcare (9 oral papers and 9 posters) and Finance, eCommerce, Blockchain (with 1 oral paper and 2 posters). Topics span from research on Deep Neural Networks, Advanced Statistics, Machine Learning, Data mining, Bayesian Networks to applications to real-world problems like (among others) 3-D printing, Stroke detection, Mobile data analysis, Time series prediction, Industrial anomaly detection, Microwave tomography and Risk investigation.

With these interesting papers, the conference has been organised with seven oral presentation sections, three sections the first day with three papers each, and four sections the second day with four papers each. A poster session during the first day is devoted to discuss these research subjects and to award the best poster.

The conference also proposes two plenary sessions: the first one with Dr. Alessandro Curioni, IBM Fellow, Vice President Europe and Director, IBM Research – Zurich, titled “Making the Impossible Possible with AI”, while the second plenary session is presented by Prof. Dr. Christian Lovis, Professor and chairman



Division of Medical Information Sciences,  
University Hospitals of Geneva (HUG) who will talk  
about "Big Data in Health: Hopes and Challenges".

In these two sessions, we will have the opportunity  
to discuss the state of the art methodologies  
and to investigate the next challenges in the Data  
Science discipline.

We also leave room to present UAS activities in data  
science, with a special section where each UAS  
is presenting and discussing his running activities in  
the domain, with the goal of creating further collab-  
orative research opportunities.

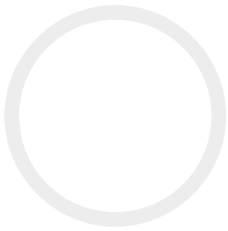
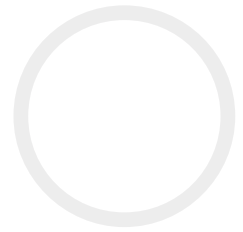
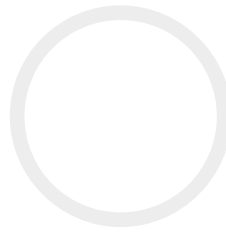
Lugano is a wonderful city in this period and you  
will enjoy the "aperitive riche", lunch and coffee  
breaks with the opportunity to take advantage  
of the conference also to engage in networking  
activities among participants.

On behalf of the Scientific committee, I would like  
to welcome all of you to this special event.

Prof. Dr. Luca Maria Gambardella  
Head of the Scientific committee FTAL conference 2018

# fi+al

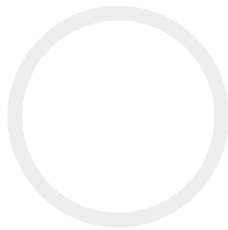
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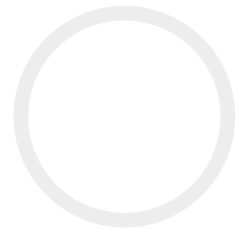
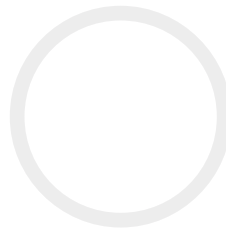
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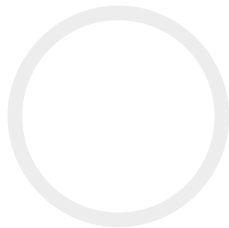
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# Organisation

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Matteo Cremaschi, Flavio Righi,  
Mariangela Ferracini, Yathusan Ramasamy.

## *Helpers and volunteers*

Staff and students from the University of Applied Sciences and Arts of Southern Switzerland (SUPSI), Department of Innovative Technologies.



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Finance, e Commerce and Blockchain

# DISCOVER - Deep-Web Knowledge Extraction and Fusion for Improved Decision Making

Albert Weichselbraun, Adrian M.P.Brasoveanu, Norman Süsstrunk, Philipp Kuntschik, Sandro Hörler

FHO; HTW Chur

Swiss Institute for Information Research University of Applied Sciences

## Abstract

### Introduction and motivation

Biotechgate is a business development database that focuses on life sciences covering over 50,000 companies and 19,000 BioTech, Pharma and Medtech assets. The system has been developed by Venture Valuation and supports startups and decision makers in tasks such as (i) locating suitable investors, (ii) identifying potential business partners, (iii) discovering new leads, and (iv) benchmarking licensing deals based on key financial information.

Maintaining the continually growing wealth of information available in Biotechgate is a labor and cost-intensive task, which requires domain experts to adapt, extend and refine data based on publicly available information such as company web sites, domain-specific databases and press releases. The DISCOVER project addresses these issues by researching high-performance machine learning methods that support data acquisition processes.

### Project goals and major challenges.

The project develops industry-strength components for the automatic acquisition, extraction and integration of decision-relevant information from company web sites and deep web repositories with business information systems by applying big data technologies to these tasks. DISCOVER addresses the following three challenges to identify, extract and fuse knowledge with Biotechgate:

1. *Web and deep web knowledge discovery and acquisition:* Deep web resources are not accessible by standard web crawls since they expose data over custom search interfaces [1]. Such sources also may impose query limits and restrictions on the number of results to be obtained by one client. DISCOVER focuses on acquiring data from clinical trial databases such as the *World Health Organization's International Clinical Trials Registry Platform (ICTRP)*, the *Clinical Trial Database* published by the U.S. National Institutes of Health, and the *EU Clinical Trials Register*. An information value model in conjunction with an intelligent querying and caching strategy that draws upon optimal stopping algorithms ensure that information is retrieved in the order of its expected usefulness without flooding the original data source with unnecessary queries. DISCOVER draws upon background knowledge retrieved from Biotechgate to assess the value of information and to generate queries for relevant content. The

project also applies sophisticated update strategies to crawls of company Web pages that are then used to detect changes to a company's products and services.

2. *Data and knowledge extraction:* DISCOVER extracts structured data and domain knowledge from the content obtained by the web and deep web knowledge discovery and acquisition component. A named entity linking module based on the Recognize framework [2] identifies entities such as products, clinical studies, companies and contacts grounding them against the Biotechgate database. Slot filling algorithms transform the extracted information into complex records such as persons and the corresponding contact data, and companies, products, clinical studies and the stage their products have reached in its development circle. The developed approaches leverage background knowledge (e.g., Linked Open Data sources like DBpedia, Geonames, LinkedGeoData and Linked Enterprise Data like Biotechgate), patterns (e.g., relations) and machine learning (e.g., support vector machines for name variants generation) to extract relevant knowledge.
3. *Data fusion:* Data fusion deals with integrating the extracted knowledge into the Biotechgate database. It deals with duplicates, conflicts, missing or outdated values and aims at increasing the usefulness and quality of the information to provide more recent and reliable knowledge to support decision making processes. Data fusion, therefore, yields more recent and reliable information that supports complex processes such as valuating biotech companies, their products and product portfolios, finding suitable industry partners and identifying key success factors for optimizing their business strategies. DISCOVER integrates the minded knowledge by combining data records extraction, Recognize's graph disambiguation algorithms, and ontology alignment techniques [3] creating incremental updates for integration into the Biotechgate database.

### Outlook and conclusion

DISCOVER applies big data technologies to improve the efficiency and productivity of knowledge workers, and demonstrates how big data and semantic technologies can trigger process and product innovations in small and medium- sized enterprises. The project enables its industry partner to considerably improve the efficiency, quality and extend of its knowledge acquisition processes, providing the company's customers with more comprehensive and up-to-date information to support decision making processes. These improvements will lead to significant innovations in Venture Valuation's products and services, substantially adding to their attractiveness and customer value.

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Industry, Production and Logistics

# A cloud based IoT approach for food safety and quality prediction

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## Abstract

Safety and quality prediction is obviously a topical issue in food industry. We present here a novel IoT approach currently under development in the framework of a collaboration involving three main partners, Genossenschaft Migros Zürich (GMZ), ZHAW (Wädenswil) and Axino Solutions AG. The main goal of the project is to provide a robust, reliable and cost-effective method for real-time monitoring of core temperatures of food products in various types of coolers, normally employed in MIGROS shops. Temperature measurements, are provided at regular time intervals by novel sensors positioned at specific locations in the coolers. In real circumstances (i.e., in a MIGROS shop) core temperatures cannot be measured directly since we are not allowed to have sensors inside food items. Therefore, core temperatures have to be estimated using only environment temperatures and an appropriate mathematical model describing the physics of the cooling process. The dynamics of such complex systems cannot be described by a comprehensive physical model including all possible variables, parameters and processes. Therefore, a very general approach consists in designing conceptual models including only a selection of a few state variables and system parameters. In this reductionist approach, dominant processes of interest are described by a physics-compliant deterministic model expressed in terms of a differential equation (ODE), while all other processes involving unpredictable and uncontrollable random events, such as interactions with customers in a crowded shop, are included in the model as noise. Noise is expressed mathematically by a random term that has the effect of perturbing in a stochastic way the dynamics described by the deterministic part of the model. This leads in a natural way to a so-called stochastic differential equation model.

For making reliable predictions, the model needs to be calibrated on some measured data. In other words, model parameters need to be estimated so that the model can reproduce observations. This data-driven model calibration, called parameter inference, represents a fundamental step in any mathematical modelling process. Once the model parameters are duly calibrated, an adequate forward model allows us to make real-time predictions of core temperatures, given only local air temperature observations. A previously defined cooler- dependent temperature field map will allow us to make an approximate estimation of the air-temperature anywhere inside a cooler, given a single measurement at a specific pre- determined location.

A network of temperature sensors, appropriately installed in the coolers in a variety of different shops spread over the territory, will provide the necessary real-time temperature data. The real-time, food-specific temperature estimation is one

element in a larger predictive maintenance framework, where we employ time-series analysis to identify possible cooler malfunction signs in the shops and continuously monitor the food quality. The system shall in the end be able to detect early warning signals to deploy interventions like technical maintenance or initiate quality management actions.

Industry, Production and Logistics

# Machine Learning for Anomaly Detection in Time-Series Produced by Industrial Processes

Lorenz Rychener, J. Hennebert

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## Abstract

In the recent years, anomaly detection in time series has gained lots of attention. New paradigms like Industry 4.0 and Internet of Things are indeed pushing for digitalization of many industrial processes. Automating the detection of anomalies is a challenging problem due to the diversity of the processes that can produce them, due to the rarity of such events and due to the real-time nature of the problem. Machine Learning (ML) has the potential to offer solutions to these challenges by learning automatically from streamed data and avoiding the cumbersome work of handcrafting rule-based systems. This paper is written in the context of a PhD thesis focusing on this domain and supported by different applied research project. We present here a short survey of anomaly detection, a summary of the 3 main challenges and a taxonomy of ML systems applicable in industrial context.

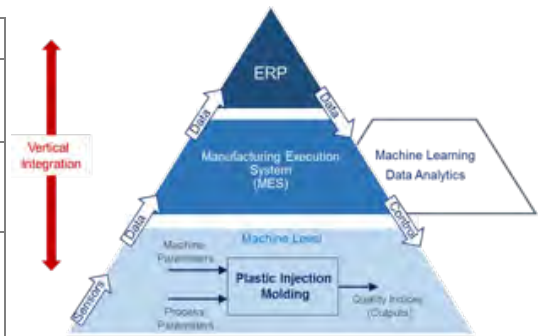
An anomaly in data is a measurement that deviated from the standard, the normal distribution or the expected behaviour [1]. Anomaly detection is an active field that has found many applications such as in telecommunications for network monitoring [2], in finance for detection of fraudulent use of credit cards [3], or in medicine for pathology detection [4]. A strong emerging field is in the supervision, optimisation and proactive maintenance of industrial processes where physical and software components are deeply intertwined forming cyber-physical systems [5][6]. In this field, we are usually facing 3 challenges.

**Diversity.** Industrial processes are diverse and the associated data can be stationary, cyclic, or including random variabilities. For each industrial process, multiple types of anomalies can also be observed such as drop, drift or time-related asynchronisation. Finally, values of a given sensor may be correlated to other sensors making the anomaly detection a multi-variate problem. By learning on exemplar data, ML is allowing adaptation to a multitude of processes and types of anomalies.

**Rarity.** Another difficulty is in the de-facto rarity of anomalies making it difficult to build a priori rules or models of such events. Again, machine learning allows to build robust models of normality where the data is abundant. The problem is then shifted to the detection of a deviation from the normality. When examples of anomalies are available, models of anomalies can also be built to discriminate against the model of normality.

**Reactivity and density.** The current trend for industrial machine is indeed to incorporate numerous sensors to observe the vital parameters of the machine and also, for production

	Type A	Type B	Type C
<b>Examples of anomalies</b>	None	Few	Many
<b>ML category</b>	Unsupervised	Semi-supervised / active learning	Supervised
<b>Typical applications</b>	Detect deviations from normality	Discriminate normal from abnormal	Classify types of anomalies



machines, to collect measurement related to the quality of the objects under production. The shift is going towards real-time anomaly detection in rather dense streaming of heterogeneous data. The top right Figure above illustrates this concept of *Vertical Integration* in the context of plastic injection where machines in a shop floor will be connected by Manufacturing Execution Systems themselves connected to ERP Systems, providing ML systems with large quantities of data [6]. Again, ML and more specifically Deep Learning can leverage on efficient GPU based hardware to cope with these challenges.

In the field of industrial processes, we can propose a taxonomy of three types of ML systems (see Table above). **Type A** – where there is no history of anomalies available. The ML approach is here unsupervised with the objective to model underlying data structures of normality and to compute a deviation from this model to detect anomalies. Potential methods include non-parametric distance based approaches such as K Nearest Neighbours, parametric probabilistic approaches such as Gaussian Mixture Models (GMMs) or deep learning systems to build prediction models. In this last case, an anomaly is detected when the actual value diverges too much from the predicted value [4][7]. **Type B** – where there are few examples of anomalies. Different strategies can be used to cope with the rarity of examples. A first one is to perform incremental learning from the normality model using for example MAP adaptation on top of GMMs. Other semi-supervised or active learning approaches can also be used to augment the quantity of anomaly examples and to improve the quality of the anomaly models [6]. **Type C** – where there are many examples of anomalies. In this situation, discriminant supervised classification systems can be used leading typically to the best performance of anomaly detection [7]. Ultimately, such systems could classify the types of anomalies, enabling automated control of machine settings to actively solve or avoid the anomaly.

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Life Sciences and Healthcare

# High-level activity recognition for cognitive support in older adults

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## Abstract

Supporting quality of life in our increasingly older population is one of the most urgent challenges facing our societies. By 2020, in Switzerland, one in 5 persons will be 65+ years old, and among them one of 4 will be 80+ years old. With great age comes neuro- degenerative diseases (e.g. Parkinson, Alzheimer), dementia, memory loss, increased risks of falls, and broken limbs. However, more than 90% of the elderly population does not need nursing care for Activities of Daily Living (ADL). This large proportion of "autonomous community-dwelling" elderly is in growing need of solutions to keep up their quality of life, reduce risks, prevent deterioration, but also stimulate their abilities through training and support, and essentially support their *independent living* for a successful aging. Ongoing developments in ICT (in particular in wearable & ubiquitous computing, signal processing, machine learning and artificial intelligence) have led to miniature systems, worn on the body or integrated to the environment, that are capable of "activity- awareness". Activity-awareness is a key enabler of personalized assistants that can support elderly people in their Activities of Daily Living. By recognizing specific activities, gestures, or situations, an activity-aware system can provide information or support by the right means, at the right time, unobtrusively and proactively. Currently, most systems deal with primitive activities (e.g., grasping, cutting) instead of high-level activities (e.g., cooking, eating) [1].

We have been working on a methodology where we select a set of primitive gestures, in an unsupervised manner using the Gamma-GNG algorithm [2], as the building blocks of high-level activities, with the aim of automatically segmenting a recording of ADLs. The atomic activities detected in the first level are further clustered using a topic-model approach similar to the "bag of words" approach used in text mining, once again, in an unsupervised manner. The resulting groups become a second level of activities whose boundaries are not extracted from the annotations given by the user, but by directly processing the data captured by the sensors worn by the person.

In Figure 1 we show an example of high-level activity segmentation. A typical application will consist on providing an automatic log of activities that can be used as a "memory reminder" by people with memory loss.

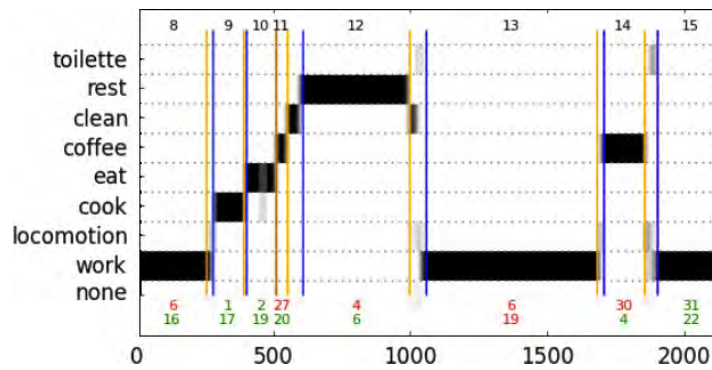


Figure 1. Example of automatic segmentation. Black blocks indicate the activity being performed by the user (expert annotation), and vertical blue and yellow lines indicate the boundaries ('start' and 'end' respectively) detected by the system in an unsupervised manner.

Another application has been envisioned based on the hypothesis that certain activities, the duration of those activities, their location and even their sequence can influence mood [3]. Indeed, activity recognition paired with recommender systems can be used to support coping strategies and send “nudging” reminders to users. For example, this could be prompting users to engage in physical exercise during stressful periods, reaching out for social contact when depression is sensed, or suggesting relaxing activities when prolonged tension is sensed. To illustrate the feasibility of such a tool we recorded wearable data using smartwatch and smartphone sensors from 18 people during several weeks. By means of a smartwatch app we collected labels from the users regarding the activity they were performing and their mood over 93 user-days. In [3] we proposed a natural way to evaluate mood inference based on the well-known Circumplex Model of Affect [4], where mood is represented and inferred via angular quantities. Calculating the hit-rate of angle inferences within  $\pi/4$  of the actual mood angle, we were correct for 60% of the instances.

Our future work will consist on developing a physical and cognitive monitoring system that might be useful to anticipate cognitive decline in older adults.

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Life Sciences and Healthcare

# Early Detection of Food Intoxication in Switzerland using Twitter

Jacky Casas, Laurent Zufferey, Omar Abou Khaled, Elena Mugellini

HES-SO, HEIA Fribourg, HumanTech Institute

## Abstract

This project aims to detect as early as possible a food-related epidemic in Switzerland by analyzing what citizens post on social networks. For this purpose, a modular platform has been developed. It collects tweets according to predefined keywords, it localizes them as accurately as possible and it classifies them according to their relevance to epidemics. Almost 35 % of the tweets are precisely localized and in average 4.5 Swiss relevant tweets are detected each day. This allows the system to detect any suspicious activity and warn the competent authority at the Federal Food Safety and Veterinary Office (FSVO).

## Introduction

The detection of food intoxication or food fraud in Switzerland takes time. The first victims have to consult their doctor, who needs to put a diagnostic and transmit the information to the FSVO. It usually takes days or even weeks. It is therefore too late for them to take action before the epidemic is extinct.

The city of Le Locle (NE) suffered water contamination in July 2015. Almost 1200 people became ill, so nearly 10% of the population. An analysis of Twitter activity in the region during this episode show that a few people (9 tweets collected) posted on social media that they were suffering from various symptoms related to this epidemic. Shortly after that, tweets from information medias have been collected, confirming the epidemic (13 tweets). Based on this numbers, it would have been possible to detect the contamination a few days earlier, which would have prevented a lot of people from getting sick, saved money on health system and put the appropriate structures into place to take care of the contamination.

## System Overview

The system extracts in real time the tweets that contain specific keywords related to food intoxication. It then uses multiple algorithms to localize [1] with different granularities each tweet collected. Metadata such as time zone, geolocalization information is used to localize them, but also data from the tweet's authors like the location field or location names in the tweet text [2]. A machine learning model was trained on hand labelled tweets to classify them by their relevance: either related to food intoxication or not related. This model is used to classify each tweet. The tweets are stored in a MongoDB database and each module get the data from it.

And finally, the last part was to visualize and to understand the augmented data collected. The visualization dashboard is a webpage developed with Vue.js, a Javascript framework, and the data is loaded on the interface via a homemade API developed in Python with Flask. All the modules communicate with a MongoDB

database. The dashboard contains many charts and maps to visualize the tweets but also has many features like the possibility to modify the keywords or setting threshold to receive alerts by email.

## Results

The real-time collection of tweets is operational, with around 75'000 tweets collected every day (containing at least one keyword from the given list). The localization algorithms are able to find information on about 80% of them (i.e. time zone, country) and localize precisely almost 35% of them (i.e. city, geolocalization). Each day, around 1'000 tweets are localized in Switzerland. As for the classification process, between 400 and 500 tweets are considered as relevant every day. The score of the machine learning model is 89%, even if it is sometimes hard for a human to say if it's relevant or not. The average quantity of Swiss relevant tweets per day is equal to 4.2 on a duration of 30 days.

A dashboard allows the supervisors to have access to numerous representation of the data collected: general statistics, maps with pin point of every tweet (relevant or with a certain keyword), tweet feeds with link to Twitter and to the tweet's author, graphs with keywords statistics. It also allows the supervisors to manually label a tweet to relevant (or to non- relevant in case of a false-positive). An email alert will be sent to every registered user if anything suspicious occurs.

## Future Work

The system is currently being extended to German and Italian tweets. The localization algorithms will be updated in order to improve the precision, core element of the project. This could be reached through indirect localization (i.e. followers, friends), named entities recognition (i.e. place, companies, restaurant and so on) and more. Some preliminary tests are on the way. It is also possible to improve the understanding of the tweet text itself by analyzing the content of it. The first step will be to improve the text by correcting grammatical mistakes and by replacing slang and typos. Then a lexical, syntactic and semantic analysis can be done to extract the real meaning of the tweet. Regarding the dashboard, data export functions will be developed mainly.

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Life Sciences and Healthcare

# Zero-inflated meta-analysis to model rare side effects of medical interventions

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## Abstract

For novel medical interventions, but also for routine clinical procedures, it is of key interest to understand their safety profile. When randomized clinical trials of the interventions are available, typically a meta-analysis of adverse events is conducted. However, for clinical procedures which often are introduced without being studied in randomized trials, this is impossible. Therefore, one has to rely on evidence generated by observational (single- arm) studies. Usually, only serious adverse events are reported, which occur rarely in practice. As a consequence, meta-analyses of these observational studies often include a high fraction of studies in which no event was observed, e.g. because the sample size was too small, or the observation time too short. This may lead to an underestimation of the true event rate.

One way to deal with the above problem is to use zero-inflated models. These models account for the situation where the number of studies with zero events observed is higher than what would be expected, if the true event rate were known. By distinguishing between the “real zeros” (i.e. those which would be expected due to the true underlying event rate) and the “inflationary zeros”, they allow a better understanding of the data generating process. This helps to quantify more appropriately the risk of serious adverse events.

Here, we describe two zero-inflated meta-analytic models which are applicable to situations as they typically occur in practice. The first one relies on the Poisson distribution, assuming a constant event rate over time. It requires knowledge of both, the total follow-up time and the number of events per study. Sometimes, however, the follow-up time is unknown, and only the number of participants is reported. In this case, we use a Binomial distribution, which is appropriate if only one event per participant can occur, or if only the first event per participant is reported. Such models have been described, e.g. by Hall (Hall, 2000).

The models are fitted within a fully probabilistic (Bayesian) framework using Markov Chain Monte Carlo (MCMC) techniques. A particular strength of the Bayesian framework is its ability to appropriately infer the uncertainty of all parameters. Another advantage is the simplicity with which predictions can be made. The latter is particularly useful since often, a prospective (forward looking) view, quantifying the risk to which future patients are exposed, is more interesting than a retrospective view.

From a mathematical point of view, the binomial model can be described as follows:

$$P(r_i = k) = \begin{cases} \pi_i + (1 - \pi_i)(1 - p_i)^{n_i} & k=0 \\ (1 - \pi_i) \binom{n_i}{k} p_i^k (1 - p_i)^{n_i - k} & k \in \{1, \dots, n_i\} \end{cases}$$

We denote by  $i = 1, \dots, N$  the  $i$ -th study,  $r_i$  the number of events observed in the  $i$ -th study,  $p_i$  the study-specific event rate and by  $n_i$  the total number at risk in the  $i$ -th study. Instead of defining the sampling model classically by a binomial distribution  $r_i \sim \text{Bin}(n_i, p_i)$ , we model the zero-inflation by introducing an additional parameter  $\pi_i$ . This parameter captures the excess of zero events, which the binomial distribution cannot adequately describe. A natural explanation of such an excess of zero events is due to case mix, e.g. when medically complicated cases are referred to University hospitals, and regional hospitals are mainly treating non-complicated cases.

In an analogue manner the zero-inflated Poisson model can be described as

$$P(r_i = k) = \begin{cases} \pi_i + (1 - \pi_i)e^{-\lambda_i} & k=0 \\ (1 - \pi_i) \frac{\lambda_i^k}{k!} e^{-\lambda_i} & k \in \{1, \dots, n_i\} \end{cases},$$

whereas  $\lambda_i$  denotes the study-specific event rate. For both models, a hierarchical structure (not shown here) is used afterwards to link the study-specific rate parameters to each other, and prior distributions are placed on all parameters.

We illustrate the use of both models to a case study investigating the risk of death in infants who have experienced a brief resolved unexplained event (Brand & Fazzari, 2018). Results are compared to those obtained by the authors, who fitted a random effects Poisson-normal meta-analysis.

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## Energy and Environment

# Energy demand management by increased user awareness

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### Abstract

The current energy strategy of Switzerland and other countries such as Germany foresees a gradual abandonment of non-renewable energies, especially nuclear energy. This strategy is expected to put under stress the provision of sufficient energy to meet the current demand levels, as renewable alternatives are gaining momentum, but they cannot integrally substitute non-renewables. Most attention has so far focussed to how the progressive deployment of renewable energy sources (e.g. wind, solar) can match the dismantling of non-renewables, but another viable, and cost-effective, option is at our disposal: the containment and possible reduction of the end-user energy demand.

In the current end-use split of electrical energy in Switzerland, the biggest share of use is due to households (32,8% as reported BFE, 2017b), and within that share, heating takes up 68.3%, warm water 13.4%, cooking 4% and all the rest is due to washing and drying, lighting, and other electrical appliances.

The average energy consumption per year ranges from 570 kWh/year in a country such as Nigeria to a whopping 12000 kWh/year in the US, while Switzerland is closer to its European neighbours with its 4400 kWh/year. These are averages and the actual values depend a lot on the size of the house, the type of building, the composition of the household, but there is a big margin for reduction of such consumption, as the difference between Nigeria and the US show, and also the personal experience of the author who consumes approximately 1000 kWh/year in a flat with a surface of 110 sqm in a household of four. That is one fourth of the Swiss average.

The above data have led many researchers to investigate how users can be motivated to save energy in order to reduce their overall demand, or at least to shift it in off-peak times or when renewables produce their maximum output, in order to shave peaks in demand and supply (Degen et al. 2013, Smale et al. 2017)

We are currently conducting a controlled experiment to evaluate the impact of increased user awareness on energy consumption in the context of the enCOMPASS EU-funded project. In the enCOMPASS project we aim to implement and validate an integrated socio-technical approach to behavioural change for energy saving, by developing innovative user-friendly digital tools to make energy consumption data available and understandable for different stakeholders (residents, visitors, public actors, building managers, utilities and ICT-providers). In the experimental set-up three different pilots have been organised in Switzerland (Gambarogno TI), Greece (Thessaloniki) and Germany (Haßfurt, Bayern). In each pilot around 100 households have been involved, different public buildings and

schools.

The energy consumption of the buildings is recorded thanks to smart meters at a 15min resolution. Temperature, humidity, luminance and presence sensors have also been deployed, and their measurement are also taken every 15 minutes. Such data provide the basis to provide feedback to the users on their energy performance. Personalised recommendations are issued on the basis of psychographic data which include the type of building, the composition of the household, the presence or absence of certain electrical appliances, the type of heating system. Moreover, energy data are processed and disaggregated into end uses to provide more accurate feedback to the users.

The participants in the experiment are also motivated towards energy saving by a gamified approach: users must download and install the enCOMPASS which provides them with a captivating user interface where they can set saving goals and receive points and badges if they meet their target and perform the recommended energy saving actions.

The project has launched the App and started its experimental phases in the three sites in June 2018. The experiment will last until September 2019 and at the end the saving of the intervention group in each pilot will be compared to those of control groups that have been recruited in each city. The comparison will not be made on purely numerical terms that is the amount of energy that has been saved, but also with respect to the environmental awareness of the participants: to this purpose three different questionnaires have been designed and will be issued to both the intervention and the control group.

We expect to see a sensible reduction of the consumption of the intervention group, and we have set ourselves the high target of a 20% overall reduction. While this might be difficult to attain, the output of the project will highlight whether different psychographic variables do have an impact on the potential to save and at the same time we will make a comparison across the three pilots, which range from the peri-urban setting of Gambarogno (CH) to the small city of Haßfurt (DE) to the larger city of Thessaloniki (GR), which have also different socio-economic settings.

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## Energy and Environment

# Estimating the Signal Strength of LoRaWAN with Regression Kriging

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## Abstract

In the emerging field of Internet of Things (IoT) the paradigm of connecting literally any object to the internet is a key feature. Establishing an everyday life filled with wireless devices improving the aspects of our existence, however, imposes several requirements on these systems: long battery life, low price of devices and long-range coverage. LoRaWAN is a low-power wide-area network (LPWAN) protocol that accounts for the last requirement. It stands for Long Range Wide Area Network and is an open standard maintained by the LoRa Alliance (Lora Alliance, 2015). LoRa is the physical layer of the protocol. It is based on the Chirp Spread Spectrum (CSS) modulation technique and uses the ISM band between 863- 870 MHz in Europe.

The topology of a LoRaWAN is sketched in Figure 1. Several IoT devices send and receive data via the LoRaWAN protocol to and from one or more gateways simultaneously in a single hop. From there, all packages are forwarded to a network server via standard TCP/IP. The data can then be disaggregated and used for specific applications. The devices are identified by a unique ID, which is registered in the network server. There are several network provider as for example the open source project *The ThingsNetwork (TTN)*.

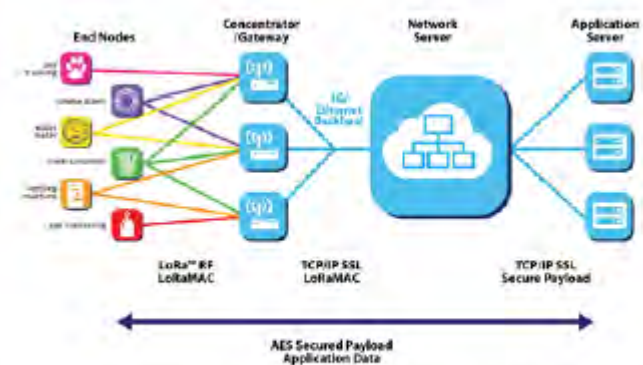


Figure 1. LoRaWAN topology (image taken from (Lora Alliance, 2015)).

Due to the prime requirement of long range data transmission, field tests for LoRaWAN are mainly concerned with assessing signal strength and quality in dependence of the distance between device and gateway. There, different quality measures are studied (cf. (Marais, Malekian, & Abu-Mahfouz, 2017))

1. The Receiver Signal Strength Indicator (RSSI) is the total signal power received in milliwatts. The RSSI is measured in the decibel-milliwatts (dBm).
2. The Signal-to-Noise ratio (SNR) is a ratio between the level of the signal and the level of noise.
3. The packet-loss refers to frames that are not received by the network server. Such frames can be either not received at all by the gateway or received by the gateway but with a bad CRC (Cyclic Redundancy Check) so they can not be decoded.

In this work we focus on the RSSI as quality measure of the network coverage. Under

ideal conditions, the RSSI value has a logarithmic dependence on the distance  $d$  of the device to the gateway, i.e.

$$RSSI = \frac{A}{65} - B \log_{10}(d)$$

for some constants  $A$  and  $B$ . In practice, however, the decay of signal strength also heavily depends on localized effects such as the surrounding elevation, environmental influences as well as buildings and vegetation that loom in the Fresnel zone of the device – gateway pair.

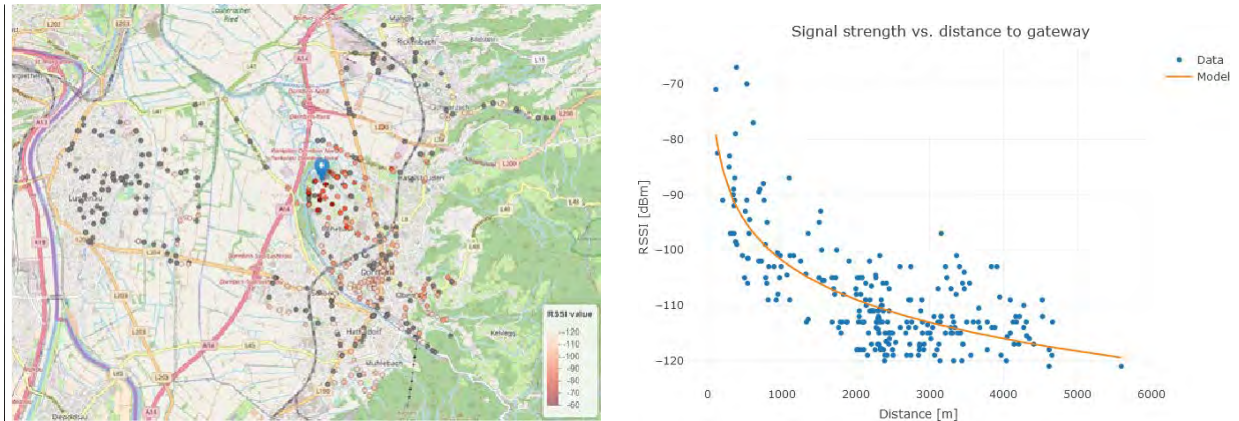


Figure 2. RSSI measurements in the Dornbirn area (Austria). Grey dots show measurement locations with packet-loss (left). Distance dependence of the RSSI value with logarithmic fit (right).

Figure 2 shows the distance dependence of RSSI (right) for a couple of measurements taken between November 2017 and March 2018 (left). The logarithmic fit results in a mediocre model.

In order to generate a reliable map that predicts the RSSI values between the measurement points, we employ techniques from geospatial statistics (cf. (Cressi, 1993)). In particular, we use kriging that allows for the spatial variance structure of the measurements and hence yields RSSI predictions that are sensitive to localized effects. In our situation, regression kriging amounts to update the predictions of the logarithmic regression model above with spatially interpolated residuals that take into account the covariance structure of the neighborhood of the spatial point under consideration. To this end, we estimate the *variogram* from the residuals of the regression model (see Figure 3 (left)) and predict the residual values at each point accordingly. This results in a heat map as in the right panel of Figure 3.

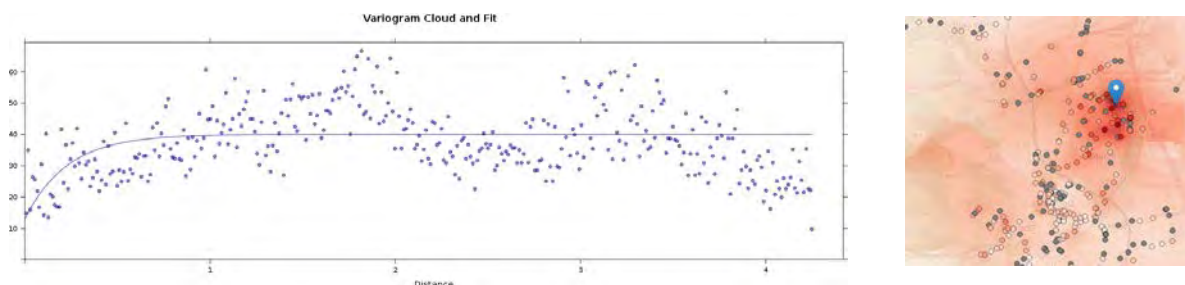


Figure 3. Variogram (left) and interpolated map (right). The blue sign indicates the position of the gateway.

The data handling, visualization and interpolation with the kriging approach were implemented in the R statistical software and visualized by means of a shiny app. The results of this project

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were achieved in a subject specialisation of the MSE program. We acknowledge the additional support of the Austrian Research Promotion Agency (FFG) and the Things Logic Network.

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## Energy and Environment

# Big Data system for pantropical land-cover change monitoring

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## Abstract

Land use change is a significant threat to protected areas, biodiversity and the continued provision of important ecosystem services to society. Yet deforestation continues at an alarming rate. Left unchecked, deforestation destroys natural ecosystems, endangers wildlife and wreaks havoc on the freshwater systems on which we depend for clean, safe drinking water<sup>1</sup>. In the face of climate change and the potential impact of forest conversion on human communities, scientists and world leaders are working to curb the continued loss of the world's tropical forest. Decision makers at multiple scales (local to national to regional) are hungry for information on land-cover change, requiring the information to be as accurate and recent as possible in order to prioritize interventions and act upon new land-cover change patterns in a timely manner. In this way, since 2012, "Terra-i: An eye on habitat change" (<http://www.terra-i.org>) has been a monitoring system that uses remote sensing and GIS technologies to provide land cover change data for Latin America and the Caribbean. This tool can generate predictive models supported by the use of neural networks and satellite data of vegetation indices (NDVI / MODIS) and precipitation (TRMM and GPM), as well as detect, from 2004 to the current year, the deviation from the normal natural cycle of vegetation over time that can be associated with anthropogenic impacts. The data generated by the tool enables the user to determine when, where, and how often the region is experiencing change<sup>2</sup>.



Figure 1. MODIS tiles used by the pantropical Terra-i

Since 2016, the scope of the tool has been extended to encompass the whole tropics, including Asia and Africa into the analysis. The new pantropical Terra-i analyses data from 54 MODIS<sup>3</sup> tiles of data, ranging from 2004 to the present<sup>4</sup>. The MODIS tiles used by Terra-i are distributed over the whole tropical area as it is shown in Figure 1. To cope with such a high volume of data, we created a data structure called the Rastercube. Rastercube was implemented as a python package, which stores large geographical raster collections on the Hadoop File System, and provides some facilities to process the data using Spark. Thus, the data is chunked in smaller cubes in which the two first dimensions are spatial dimensions and the third dimension is time.

Figure 2 shows an example.



Figure 2. Example of a Rastercube: stacked images on the left and chunks of data on the right

In the new version of Terra-i we hypothesize that, for a certain type of vegetation, the NDVI value of a (pixel, date) pair depends mostly on the date itself. Hence, we simplified the model by ignoring the effects of the rain in the vegetation index. We represent NDVI dynamics by computing the average and standard deviation of the NDVI values of some hand-selected groups of pixels belonging to the same vegetation type<sup>5</sup> and grouped by date. These pairs (average, standard deviation) represent the distribution of NDVI values of a given vegetation type for a given date.

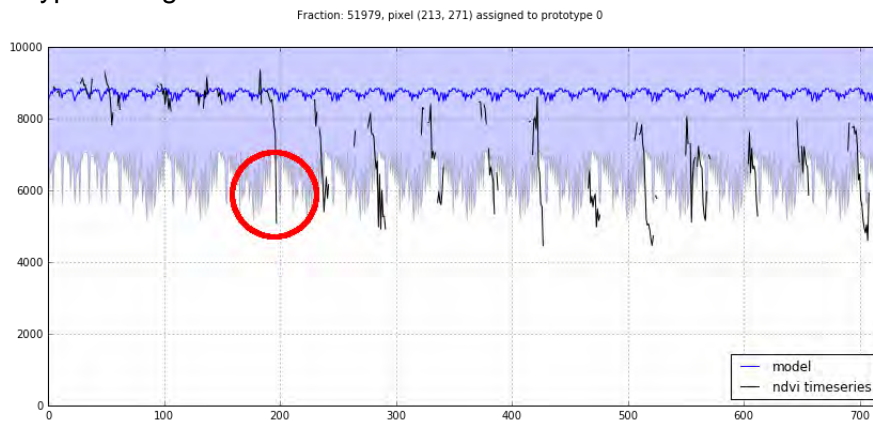


Figure 3. Example of a Terra-i detection. The model (average, standard deviation) in blue, and the incoming data in black

In order to detect deforestation events, the new version of Terra-i compares the NDVI value of a new date to the expected NDVI value at that moment of the year for the type of vegetation in the pixel. This computation has been parallelized using a Spark cluster. Figure 3 shows the example of a single detection for a random pixel. The curve in blue is the model of NDVI over time. Therefore, the values of NDVI for this particular pixel must remain inside the distribution (i.e., inside the blue shadowed area) otherwise, the NDVI value is considered as an anomaly, and may be interpreted as a deforestation event.

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- [2] Reymondin, Louis, et al. "A methodology for near real-time monitoring of habitat change at continental scales using MODIS-NDVI and TRMM." Submitted to *Remote Sensing of Environment*.
- [3] Each MODIS tile covers 10° at a resolution of 250 m. Which corresponds to a squared matrix of 4440 \* 4440 pixels approximately.
- [4] New images are available every 8 days if both satellites : Terra and Aqua are used
- [5] We used data from the Global Land Cover Facility (GLCF) <http://www.landcover.org/>

Industry, Production and Logistics

# Machine Learning on Accelerometer Data for Detection of Fence Violations

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## Abstract

We detect when people climb over a chain-link fence by using accelerometer data streams from multiple sensors mounted on the fence itself. A machine-learning based algorithm trained on hundreds of samples can differentiate between violations and non-violations (e.g. objects or people leaning on the fence, wind, collisions, etc...) with a 97% accuracy and 99% Area Under the ROC Curve.

## Introduction

Passive and active security systems are widespread to protect sensible areas, such as homes or factories. However, the costs of installation and use of such systems can become prohibitive. Within the SABIK KTI project, we propose a system based on inexpensive low-consumption wireless sensors attached to the chain-link fence, which produce accelerometer data that is processed by Machine Learning algorithms in order to detect hostile events, i.e. people climbing over the fence; the algorithms learn to ignore other events that generate vibrations on the fence, such as wind, people leaning over and objects hitting the fence.

This is achieved by means of a supervised classification approach; to train the classifier, we recorded a set of sessions in which an actor interacts with a sensed fence, either climbing over it (intrusion) or causing other kinds of turbulences which do not represent a threat for the perimeter. In a second phase we crossed the sessions' data with a journal file, building a consistent set of examples labelled as 'intrusion: yes/no'; this label is used as a target variable when training a supervised classifier. We finally tested this classifier using the Area Under the ROC Curve (AUC) metric and 4 new sessions as demonstrations.

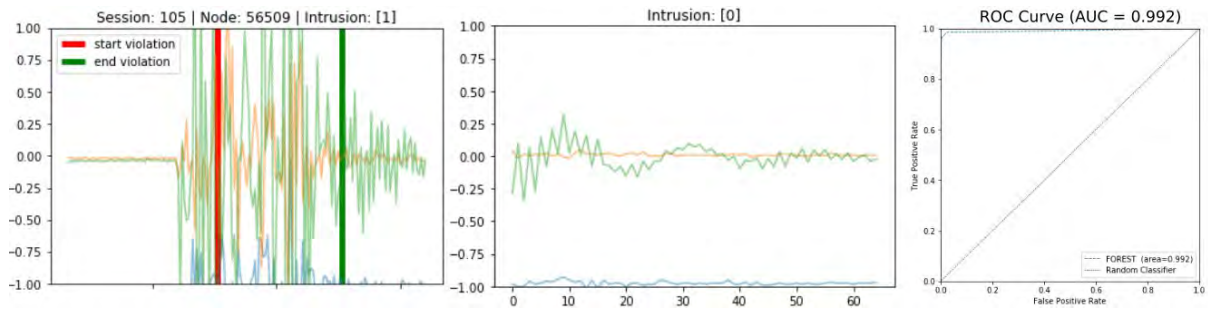
## Acquiring data



The data is acquired in an indoor prototype fence installation, 12 meters long, on which 6 sensors are installed. Each sensor can stream samples of the instant accelerations on 3 axes at a frequency of 13 Hz. A session is a set of time series containing the samples

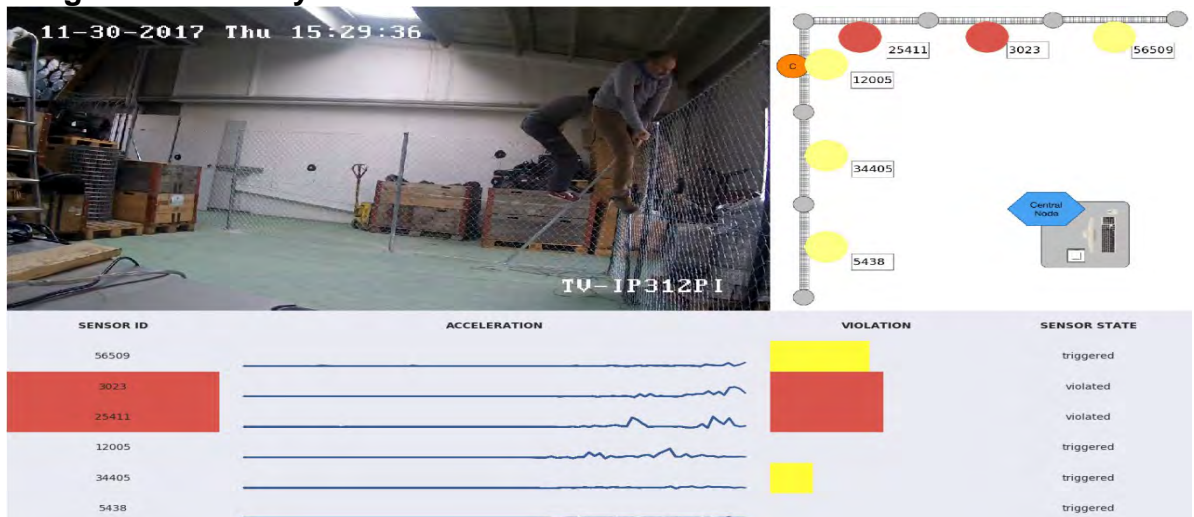
streamed by each sensor. We recorded 96 sessions where a person held different behaviours (see image above), reporting these on a journal. In a second phase we enriched the journal of the sessions containing an intrusion, by adding the information of the relative second in which the person started the intrusion and the second in which the intrusion ended (next image, left).

### Dataset, Training and Testing



Given a set of sessions, we implement a sliding window algorithm that collects the observations for the dataset. An observation is defined as a time series of 65 consecutive samples of a single sensor, that represents thus 5 seconds of data stream (image above, center). Each one of these observations is associated to a label (1 if the observation contains an intrusion, otherwise 0). The label is defined exploiting the information contained in the journal, since with it we know whether the current window contains (or is contained by) the bounds of intrusions. Once the dataset is ready, we use a Random Forest classifier [1]; the input to such classifier is the mean, standard deviation, maximum and minimum values of the acceleration recorded for each of the three axis within the window (12 features). We randomly sampled 30% of the sessions for validation and 70% for training; on the validation set, the classifier’s AUC [2] is 0.992 (image above, right).

### Integration in the system



Given a trained classifier, we developed a system that receives in real time the streams from the sensors, extracting new observations and submitting them to the classifier for a prediction. The system is tested using unseen sessions (image above).

### Conclusions

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We reached the goal of developing a pipeline based on machine learning for the detection of intrusions in a low-power sensed perimeter. We collected real data, created a dataset with which we can train any supervised learning algorithm and validated the approach using unseen data and the ROC metrics.

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Industry, Production and Logistics

# Reinforcement Learning in an Industrial Robotics Application

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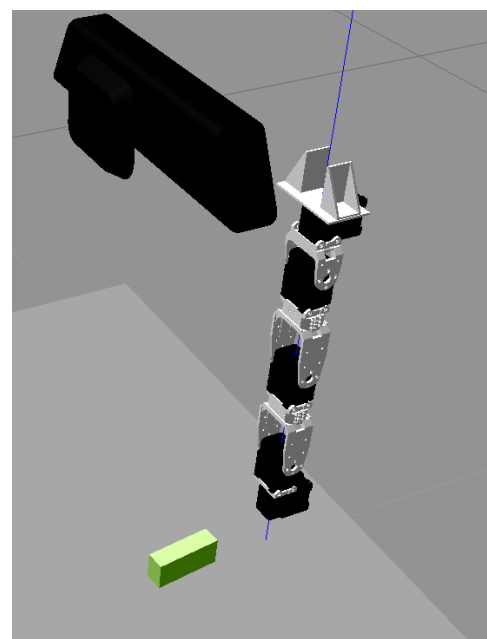
## Abstract

Robotics has ever since been an active research area for artificial intelligence. Smart drones, high-capable walking robots or autonomous cars are but some examples. A promising and fast-growing technology for AI in robotics is reinforcement learning (RL). Briefly explained, an RL-algorithm (agent) interacts with its environment by means of actions. The agent has an internal state, which is its representation of the environment. The environment reacts and returns a new state to the agent, along with a reward. This single scalar number indicates how “good” the new state is for the agent. The agent wants to maximise the overall cumulative reward, and so it values its chosen actions while interacting with the environment, eventually learning which actions in which state he has to choose.

This technique can naturally be used for robotics applications, as recent research shows (see e.g. [1]). The goal of this project is to develop a demonstrator for a typical industrial robotics task which is solved with Reinforcement Learning. We focus on a problem that can not be solved by simple inverse kinematics (IK) of the robot arm in a straightforward way: A well-known problem in the field of robotics is picking objects, which may lie unordered in a box. Even though many sophisticated and well-working solutions for this exist, reinforcement learning may help improving or extending this task, especially when the objects are not exactly alike [1].

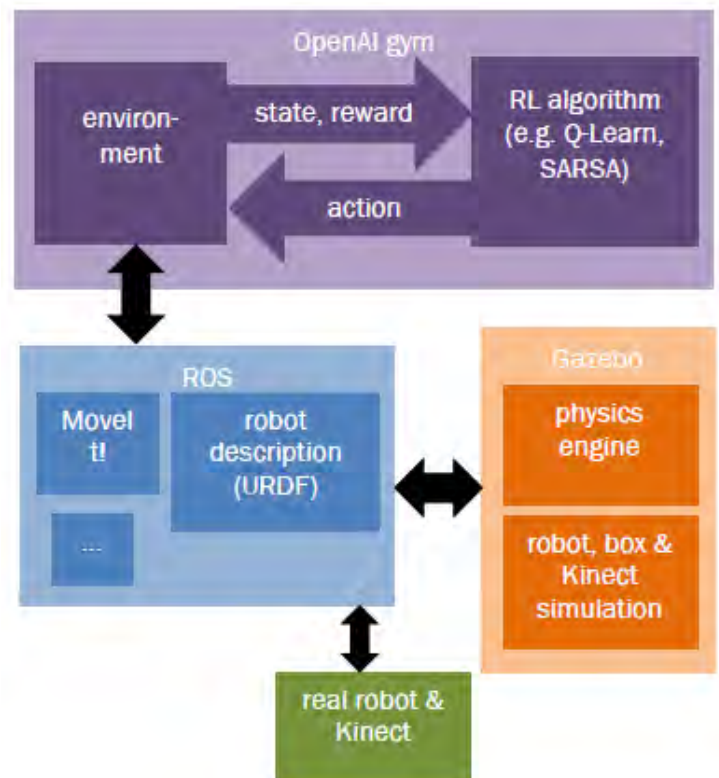
Therefore, the task for our robot to be learned is picking up a box, based on a depth image from a sensor mounted above the box. The box lies randomly placed on a plane, on which the robot arm is mounted. The figure to the right shows the setup in the Gazebo robotics simulator.

Combining robotics with RL is a promising field, although some challenges have to be considered. Since the robot has to interact with its environment for many training episodes, moving a real robot would cause wear on the mechanical parts and also be potentially dangerous, depending on the robot and its task. Simulating the robot and its environment is therefore a necessary requirement.



Not only does simulation increase the flexibility, learning can additionally be made faster and carried out over longer periods of time, compared to a real setup. The reward can also be calculated via the API of the simulator, which is an additional benefit.

Therefore, the setup for this project consists of three main parts: OpenAI gym, ROS and Gazebo, as seen in the figure to the right. **OpenAI gym** is a toolkit to develop RL algorithms in Python and proposes a unified interface between the environment, the agent and the RL algorithm. **ROS** is a modular open source framework for robotics which is widely used. It serves as a middleware between the different components (nodes), using well-defined messages over TCP/IP connections. **Gazebo** is a robot simulator with sophisticated integration of ROS and many predefined robots and sensors models. The RL algorithm in OpenAI gym uses ROS messages to start, stop and modify the simulation and also extract information from it. This architecture is also known as gym-gazebo [2].



Thanks to the modularity of ROS, it is possible to have the same interface for the simulation in Gazebo and for the real robot. The hardware used in this project consists of the PhantomX Pincher Arm, a small 4-DOF robot arm, and a Microsoft Kinect for Xbox 360 camera for generating the depth image. Both can be easily connected to the PC via USB and can be simulated in Gazebo. The whole architecture runs on Ubuntu 16.04 in a virtual machine.

In this project we implement the complete tool-chain outlined above. This includes creating a Gazebo simulation of the pincher arm as well as an OpenAI gym environment. The latter controls the simulation, calculates the reward and returns it to the RL algorithm, along with the current state. The action, which has to be chosen by the algorithm, consist of the desired point & orientation in space for the end effector (the gripper) of the robot arm, hence a 6-dimensional vector ( $x, y, z, \text{roll}, \text{pitch}, \text{yaw}$ ). Because of this, the learning task is to a certain extend independent of the specific robot used for picking the object. The algorithm knows where to move the gripper in order to get the most cumulative reward (i.e. grasping the box), the robot-specific IK solver takes care of positioning the gripper.

The results of this project were achieved in a subject specialisation of the MSE program.

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Industry, Production and Logistics

# Predictive Quality Management with Bayesian Networks

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## Abstract

Traditionally, quality control in manufacturing systems is carried out relying on the tools of Statistical Process Control (SPC) (Montgomery, 2009). In SPC, samples of size  $n$  are examined at fixed time intervals and the resulting statistics (e.g., sample mean and sample standard deviation) are checked against the statistically estimated control limits (UCL / LCL). At each sample inspection, the process is declared in control or out of control. A shortcoming of SPC is hence its reactive rather than preventive nature.

The aim of our approach is to develop a predictive statistical model of the process of the production of Electronic Discharge Manufacturing (EDM) machines. The production of each machine involves the measurement of 160 control variables in four different stages (10 control variables are measured at the first stage, 20 are measured at the second stage, 4 are measured at the third stage and 130 are measured at the fourth stage). We aim at predicting early in the assembly problems that might become apparent only at a later stage, due to problematic joint configurations of several variables. The approach is hence predictive and aims at modelling the correlations existing between several variables, rather than independently analysing whether each variable is in control (as it is typically done with SPC).

To this end we developed a statistical model of the process based on Bayesian networks (Darwiche, 2010). Bayesian networks learn from data the *joint* distribution of a set of variables. For this reason, they are very flexible models. For instance, consider a process characterized by variables  $A$ ,  $B$ ,  $C$ , collected in this order. A Bayesian network can answer both the *predictive* query  $P(C|a,b)$  and the *diagnostic* query  $P(A|b,c)$ .

The considered manufacturing process is characterized by *interventions*. An intervention is necessary when a measure falls outside the specification limits; in this case the intervention brings it within the limits (and generally close to the target value). Moreover, interventions are also carried out when the operator suspects that the measure, though within the specification limit, is likely to result in the need for an intervention at a later stage (interventions in the later stages have to be minimized, as they require more time to be carried out than the intervention in the earlier stages of the process).

Yet learning from interventional data is challenging: the intervention alters the state of the machine, preventing any statistical relation between what is observed after and before the intervention. Indeed, the vast majority of statistical machine learning deals with learning from observational data set, where the measures are taken without interventions. The need for

techniques specialized on interventional data is however very clear in our case, since the application of the standard machine learning algorithms (such as random forest or neural networks, whose algorithm assume observational data) yields very poor predictions.

Learning Bayesian networks from interventional data set has been studied by (Cooper et al., 1999), which proposed a score for measuring the fit of a the structure of a Bayesian network to a set of interventional data. We learn the Bayesian network model by identifying the structure that maximizes such score; for the maximization task we adopt a state-of-the-art solver (Scanagatta et al., 2016). We learn the model from the measures regarding about 300 machines.

We validate the model by assessing its prediction on 50 machines whose data have been not used for training the model. The resulting model shows a promising accuracy in detecting the interventions in the last stage. For instance the estimated probability of an intervention occurring is estimated at about 8% for the machine in which no interventions occurs, and at about 25% (a three-fold increase) for the machines in which instead the intervention is necessary.

Further developments include a decision making stage (what shall we do, given a certain probability of intervention?) and a more refined model of interventions.

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Industry, Production and Logistics

# BBData, a Big Data platform for Smart Buildings

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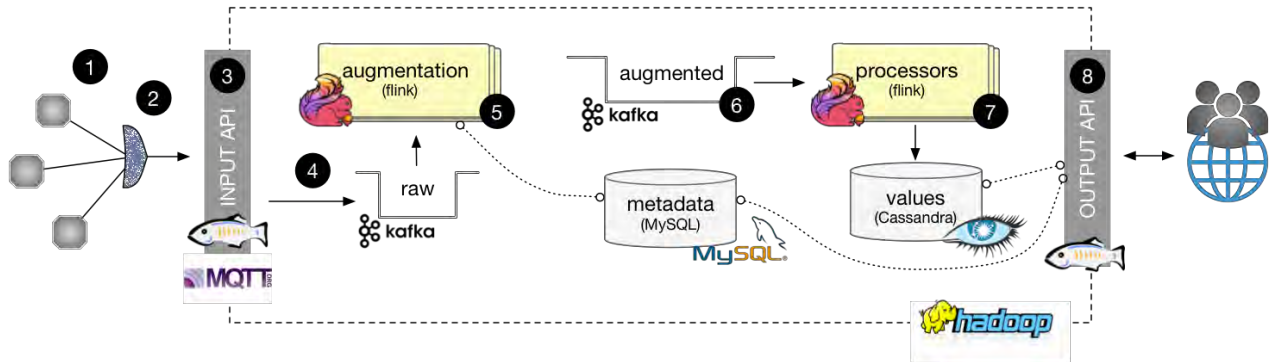
HES-SO, HEIA-FR, iCoSys - Institute of Complex Systems

## Abstract

The handling of Smart Building data in a Big Data perspective is challenging in many ways. First, the building automation domain has a long history with diverse systems and technologies creating interoperability issues [1] [2]. Second, the models behind current advanced controls systems become more and more complex, triggering the need for a constant source of data, both historical and in real time, as well as increasing computing power and storage capabilities [3]. Finally, efficiently applying Big Data technologies is a challenge in itself [4], added to the fact that there are few comprehensive approaches to support the collection of data from building sensors and to allow their exploitation.

The BBData – Big Building Data – project [5], is an attempt to answer those challenges by providing a full-featured data processing platform for Big Building Data. Still in its early stages of development, it has been running continuously for one year to gather data from more than two thousand sensors installed in the Blue Hall of the blueFACTORY innovation site in Fribourg. The platform is designed following four major principles: genericity, open- source technologies, scalability and performance. It serves two major purposes: a centralised and safe storage for building data and a highly efficient platform for real time, think-ahead data processing.

The journey of a measure inside BBData is shown in the Figure below. In (1), different kind of sensors produce measures. Those sensors might come from different providers and use various data encodings. To ensure the compatibility of the platform with any kind of equipment, BBData uses the concept of *virtual objects*. A virtual object has metadata, such as name, unit and type, and can be mapped to a real sensor through an ID. This mapping is handled by *collectors* (2). A collector creates a bbdata record for each measure and sends it to the input api in a structured JSON format. In case some sensors lack an internal clock, the collector can also produce a timestamp. The *input api* (3) is the entry point to the system. Available in two flavors, a standard REST API or an MQTT broker, it validates the incoming measure and ensure its authenticity using the object's ID and a secure token. If the check succeeds, the security information is dropped and the resulting JSON is added to an Apache Kafka *message queue* (4). Before processing, the measure is first *augmented* with the virtual object's metadata pulled from a MySQL database (5), such as its unit and type. The result is stored in a second message queue using a compressed format (6).



In BBDData, *processing* covers a wide area of tasks, from the saving of raw values into a persistent store to the detection of anomalies or the computation of time aggregations. Each of these tasks is handled by a specific processor. Processors are independent streaming applications running in a hadoop cluster. They subscribe to the augmented Kafka topic, carry their task and save their output, if any, in a Cassandra database. This design makes it possible to add or remove processors without any impact on the system. We have currently two kinds of processors: the first saves the raw records as is, the second computes live time aggregates (mean, max, last measure, standard deviation) with a granularity of fifteen minutes and one hour.

Users and building automation applications can access the data and manage virtual objects through a standard REST interface called the *output api* (7) or via HTML5 web applications [6]. Those applications also offer graphing and visualisations technologies, allowing users to monitor their building easily and build flexible dashboards in minutes.

Our future works include the development of more complex processors such as machine learning predictive systems and the inclusion of a MQTT broker at the output API.

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Industry, Production and Logistics

# Lessons learned from 16 applied data science (meta) case studies

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## Abstract

Recently data science gained considerable traction in business, industry and academia. Success stories of specific applications and respective technology transfer endeavours are prominently placed at conferences to underline the importance and the impact of data science. However, how meaningful and applicable are the often very specific and domain-centric results in other settings?

In this talk, we report on a careful analysis of 16 selected case studies that were conducted since 2014 by our colleagues, our collaborators, speakers in the “Swiss Conference on Data Science” series of events (Braschler et al., 2018) and us. While each individual case study highlights distilled lessons from a specific scenario (that itself summarizes up to dozens of specific projects), we bring these individual lessons in context of each other to derive best practices for applied data science across different methods, tools and domains. We provide insights into these case studies based on similar methodology, correlations in findings and different perspectives for identical use cases. Some of the major lessons learned come from the following areas:

- Data warehousing is key for effective market monitoring in e-commerce, in particular, and for a large part of big data projects, in general. Additionally, taking measures to comply with specific ethical standards and privacy laws is a prerequisite for attracting customers and for building sustainable customer relationships based on mutual trust.
- Deep learning does not only work effectively for analyzing large sets of image data, but is also practically applicable for visual media analysis based on small image data sets. When coupling learning systems and simulation for data creation in a closed loop, deep learning can even operate on almost “no data” from a data collection point of view, and be effective for production complexity analysis.
- Certain visualization methods give insights into the spread of infectious diseases based on call record data; other visualization methods are helpful for storytelling.
- Big data stream processing architectures are necessary for online anomaly detection or large-scale financial risk assessment. However, it is small data that poses big challenges to enterprise search engines due to the lack of data redundancy.

The talk will thus aggregate field-tested lessons learned over a wide variety of application domains and from the viewpoint of different disciplines.

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Braschler, Stadelmann & Stockinger (Eds.) (2018). *Applied Data Science – Lessons Learned for the Data-Driven Business*. Springer (to appear).

Industry, Production and Logistics

# Image-based Measurement of Material Roughness

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## Abstract

We use a convolutional neural network (CNN) acting as a regressor to estimate the roughness of metal processed by Electrical Discharge Machining (EDM), using as input an image acquired by a standard industrial camera; the model has been trained on a large dataset of images representing surfaces with known characteristics, and yields promising performance when tested on unseen surfaces.

## Overview

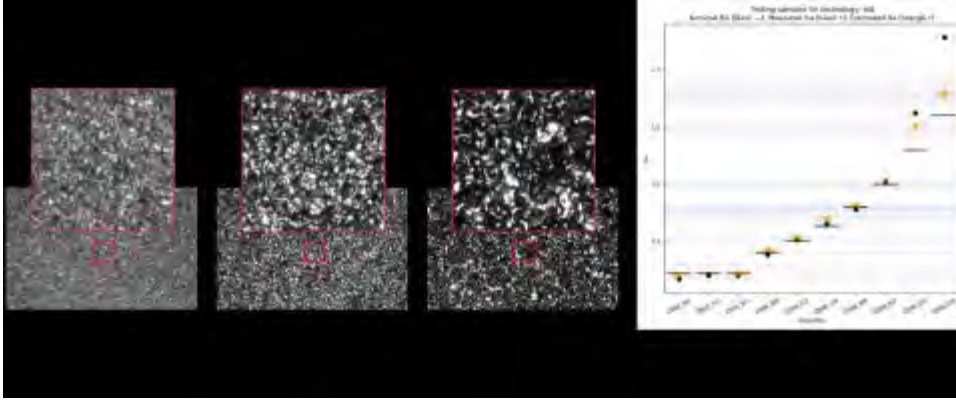
Electric Discharge Machining (EDM) is a complex process, and the surface characteristics (such as roughness) of the resulting workpieces are difficult to control. Measuring surface roughness while the workpiece is still clamped on the machine is currently difficult to be done and/or very expensive; in this project, we build a system that estimates the surface roughness value (as measured by the Ra value) using as input data from a standard machine-mounted camera, which is already used for other measurement tasks. This is an important innovation since it will allow the operator to continuously check the surface quality of the clamped workpiece and, if needed, plan additional machining steps in order to precisely achieve a desired Ra value.

Ra is related to the appearance of the surface on the image (see Figure 1 left); however, this relation is not trivial to capture and describe; for example, it can not be expressed as a function of a measurable characteristic (such as a length or an area) that can be extracted from the image using standard machine vision techniques. Instead, Ra is related to image texture, which is difficult to quantify.

In this project, we learn the link between image appearance and Ra value by means of Convolutional Neural Networks (CNNs). CNNs are a machine learning model specifically suited to work on 2D images. In most literature, CNNs are used as image classifiers, i.e. they estimate a categorical value (the “class”) given an image; recent examples are CNNs that classify an image depending on the object it represents [1]. However, CNNs can also be used as regressors, i.e. models that instead of predicting a categorical value, predict a continuous value. While classifiers are normally scored using accuracy or similar metrics, regressors are scored using metrics such as the Root Mean Squared Error (RMSE) or the Mean Average Percentage Error (MAPE); in this project we use the latter as a loss, i.e. as the value that our regressor should strive to minimize.

A regressor for a given problem is built by an automated procedure (training algorithm) that determines the regressor parameters in such a way that the loss is minimized on the training set; in case of a CNN, training is implemented by means of gradient descent.





### Dataset

The dataset is acquired on a set of 66 cavities machined specifically for this task; each cavity is machined with different parameters, which yields a different Ra value. The true Ra value of each cavity is measured using a tactile surface profiler (Taylor Hobson Talysurf); the machine is then programmed to acquire a large number of nonoverlapping images for each cavity, which yields a large dataset composed by a total of 3044 752×480 grayscale images; for each of these images, the true Ra value is known. 56 cavities in the dataset is used for training; the remaining 10 cavities are used for testing.

### Regressor

The regressor operates on 50x50 pixel patches extracted at random positions from the source images. The CNN has a 50 × 50 1-channel input layer followed by two consecutive 5 × 5 convolutional layers with 15 maps, one avg-pooling layer, one 5 × 5 convolutional layer with 30 maps, one 2 × 2 avg-pooling layer, followed by a 50-neuron densely connected layer and a 1-neuron densely-connected output layer with linear activation which yields the estimated Ra value, for a total of 134,861 trainable parameters. When evaluating the roughness of the surface in a testing image, the regressor is applied to 100 patches extracted at random positions, and the results are averaged to yield an image-level estimate.

### Results

The performance of the system on each of the testing cavities is shown in Figure 1 right. Since multiple images have been acquired for each cavity, we, plot both the image-level estimates and the cavity-level results (obtained by averaging the estimates for all images of the cavity). The approach yields a MAPE of 9.92% with respect to the measured Ra value.

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Industry, Production and Logistics

# A Framework for Text Analytics with Visual Exploration and Machine Learning

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## Abstract

Understanding a text classification data set (corpus) takes time. First, the data has to be parsed, then the appropriate algorithm has to be determined and adapted to the corpus at hand, and lastly, a statistical analysis can be performed. Additionally, practitioners often want to train machine and deep learning classifiers on the data. Currently, there is no tool which combines these steps and also presents the output of such algorithms in a graphical user interface.

The framework presented here, called *texploration*, aims to solve these challenges by presenting the output of the statistical text analysis and classification in a graphical user interface, freeing the user from the task of interacting with command-line tools and analyze plain text output.

The first module, corpus analysis, analyses a text corpus using a robust method to parse data files and perform corpus analyses including statistics on topics, text lengths and relevant words for the whole corpus and itemized by labels. Additionally, multiple sentence splitters and word tokenizers are compared visually by highlighting the differences in their output (Figure 1), which in turn helps practitioners to select the appropriate preprocessing tools.

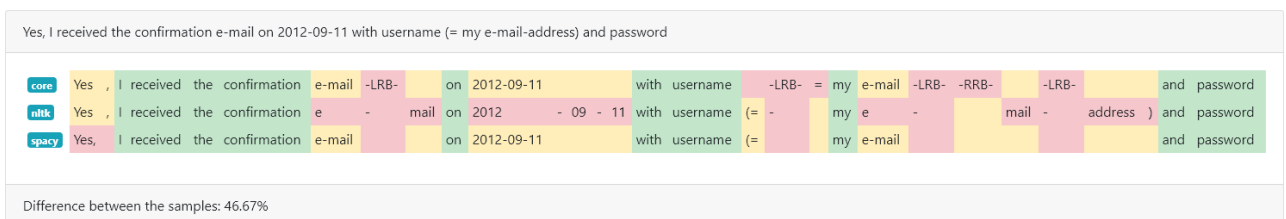


Figure 1: The sentence at the top of the grey box is tokenized by different algorithms (shown in blue on the left of each row) into tokens. The tokens are aligned by position and the result of the comparison at each position is highlighted in green, yellow, or red.

A good and thorough understanding of a corpus is integral to the quality of any further analysis or classification performed on it. In addition to comparing tokenizers, topic modeling is performed where terms that tend to appear together are placed in groups i.e. topics. These topics also include information on how many texts contributed to that topic and of which labels it consists.

The second module, classification, uses various algorithms to train machine and deep learning algorithms on the corpus. The results of training the algorithms, like the confusion matrices, are displayed to allow comparison and analysis of the different classifiers. Additionally, the generated models can be used to classify user-defined texts and further data files.

The third module adds a graphical comparison to the classification module. The classification results of the models are compared and filtered, for example, by complete agreement or all that have predicted the wrong label. From each filter, a few samples are presented in the user interface featuring an easy to read color coding for the predictions of the algorithms (Figure 2).

**Disagreement**  
Classifiers disagree on labels

Correct label	Support			Convolutional neural network: run	Stochastic Gradient Descent: run	Text
	Naive Bayes: run	Vector Machine: run	AdaBoost: run			
neutral	!	!	✓	!	!	Harper does
positive	✓	!	!	✓	!	#factsabout
neutral	!	!	✓	!	✓	Shaw would

Figure 2 : A text, displayed in the right-most column, has got a label, displayed in the left-most column. Different models predict different labels for a text. If the prediction is correct, a check mark is displayed, and an exclamation mark otherwise. Additionally, a color is automatically assigned to every label, indicating which label was predicted.

In order to validate the claim of *exploration* of being intuitive and user-friendly, two user tests were performed with researchers from the Institute of Applied Information Technology (InIT) at ZHAW. During both tests, the testers expressed enthusiasm and delight about the framework and suggested ways in which it could be further improved.

Industry, Production and Logistics

# Development of an inductive array Sensor for the Detection of Metallic Objects

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## Abstract

### Motivation

In the construction industry it is necessary to detect and classify metallic objects behind solid walls, for example armoring rebars, floor heating's and electric cables to avoid drilling hits or the check the quality of the construction (as planned - as built, minimum cover for corrosion protection).

In a CTI project we are developing a new sensor for this task based on the principle of electromagnetic pulse induction. The sensor consists of a coil transmitter and receiver array that is scanned over the surface of the building to image in 3D what is hidden. It should be able to detect and classify different materials (rebars, aluminium and copper pipes), detect the position of the object and in case of a ferromagnetic object, it should furthermore be able to detect the cover and diameter of the object with high accuracy. A part of this project is the development of a fast forward model of the whole sensor and the interaction between the sensor and the conductive materials for the design and optimization of the sensor. In a second step, a backward model is used to estimate the object parameters out of the measured signals.

### Electromagnetic Induction Modeling

Pulse induction is a technology where short broadband periodic current pulses are generated in the transmitter coil to generate induced eddy currents in conductive targets. The secondary magnetic field of these eddy currents is delayed in time and can be picked up by one or multiple receiving coils. The response of the targets depends on their conductivity, permeability, size, shape, orientation and distance. In order to simulate, optimize the sensor design and in order to estimate the target parameters, a fast forward model of this response is necessary. The calculation of the response of a standard grid area of 1.20m x 1.20m using standard FEM methods would take weeks even on a high performance cluster. A reduced model of the full sensor and the targets in the quasi-static regime based on a dipolar approximation of the scattered fields was developed to calculate the sensor response in the frequency domain, which is then transformed by an inverse numerical Laplace transform into the time domain.

In the dipolar approximation, the induced voltage in the receiver coil at a radial frequency can be written as a tensor product of the magnetic polarizability tensor with and, the magnetic field intensity of the transmitter (TX) and the receiver (RX) at the dipole position [2].  $I$  is the transmitter, current,  $R$  is a rotation matrix,  $A$  is a constant that takes into account the gain transfer function of the amplifiers, and is the magnetic flux constant.

Exact magnetic axial and transverse polarizabilities are available for simple shapes in frequency domain [4] for a homogenous or for a dipolar primary excitation field. The transverse polarizability is the diagonal components of the polarizability tensor. It is a complex function of one single parameter that contains all relevant material properties for discrimination. In the actual case, the realistic targets are cylinders of *finite* length that are modelled in this work using a linear chain of infinitely small dipoles as described in [3].

### Optimization / Backward Modell

After scanning a wall with the new developed scanner, the objects in the wall have to be estimated out of the measured signal. The measured signal can be written as a linear superposition of all signals from all objects with parameters close to the measurement point.

In the backward model, the parameters of all targets are estimated out of the measured signal. The optimization parameters are object type, distance, size and position. Using a gradient based optimization, the measured signal is compared with precalculated and/or measured forward responses for different object parameters such as sizes and positions. These forward responses are stored in a database for fast calculation. The Jacobi matrix is calculated explicitly for faster calculation speed especially in optimization runs with more than 100 parameters.

The optimization model is written in a high level language. Using automatic code generation, the high level code is translated into C-code, which can be directly implemented in the framework of the new sensor.

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Industry, Production and Logistics

# Endowing humanoid robots with the capability of reading and reacting to human body language

Andres Perez-Uribe, Hector Fabio Satizabal-Mejia, Francisco Gonzales Lopez

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## Abstract

Autonomous mobile robots are increasingly getting their place among us. Successful examples include the robotic vacuum cleaners in our houses and robot mowers in our gardens, but many more applications are expected soon. The use of autonomous indoor robots in commercial spaces is already a fast-growing domain of application. A clear example is the humanoid robot Pepper [1], which has been meeting customers at Renault dealerships all over France. Other pilot projects are placing Pepper inside airports (e.g., at the Oakland International Airport), cruise lines (e.g., the Costa Diadema), hospitals (e.g., Belgian hospitals in Ostend and Liege), shopping malls, and railway stations (e.g., Mount Rigi in Switzerland). Indeed, targeting commercial spaces allows for a clear value proposition that goes beyond entertainment, because humanoid robots can be programmed to interact with visitors to provide them with useful product and service information. Moreover, commercial spaces are supposed to comply to security regulations (e.g., doorways, thresholds, ramps) that facilitate the robot programming, and last but not least, they offer reliable communications infrastructure (e.g., Wi-Fi and cellular connectivity) that allows the robot to keep in touch with an external command center.

In Switzerland, Avatarion AG commercializes these robots and has programmed them to work in real indoor environments like the EMS Primeroché at Prilly, a school in Basel and is currently partnering with the Luzerner Kantonsspital, Migros, Rigi Bahnen, etc. Thanks to Innosuisse support, we are currently collaborating with Avatarion and the Ecole Hotelière de Lausanne (EHL) with the aim of developing a telepresence application that will allow remote concierges to interact with people by means of such humanoid robots. However, telepresence is just a niche application. Indeed, it would be desirable to have those robots working autonomously most of the time, but the truth is that they are generally stationed at a given location and are accompanied by human users, because they find it difficult to understand human behavior. Moreover, even if they successfully rises curiosity among people, they rarely exhibit appropriate body language coordinated with the human in front of them [2]. A robot like Pepper is already capable of recognizing facial expressions, but not body language.

This abstract presents preliminary work regarding the idea of endowing humanoid robots with the capability of reading and reacting to human body language to enhance human-humanoid interaction. To read human body language, we captured a total of 230 postures from a single user, corresponding to six different moods: happy, sad, angry, surprised, reflexive and neutral, using a Kinect 2.0 camera. Each posture is characterized by 23 Euler angles, computed from the human skeleton joints provided by the Kinect SDK. We then trained a Multi-layer Perceptron Neural Network of 2-hidden layers (having 17 and 6 hidden neurons in the first and second hidden layer), ReLu function activations in the hidden layers

and a Sigmoid activation function in the output layer. We used stochastic gradient descent as optimizer (learning rate = 0.025, decay = 1e-5, momentum=0.15) and the loss function was the categorical crossentropy. The model achieved a precision of 95%.

In order to react to human body language using human-like gestures, we trained a Deep Convolutional Generative Adversarial Network (DCGAN) [3] with sequences of joint Euler angles corresponding to human body gestures. A sequence was composed of 40 sets of 16 Euler angles, which were selected such that the humanoid robot was able to play the synthesized gestures. The generative network used a vector of 100 random inputs and four deconvolutional and upsampling layers to synthesize a matrix motion sequence of 40x16 Euler angles. The discriminative network processed the training matrix motion sequences using 5 convolutional layers and a single fully connected layer to distinguish real from fake movements. The database consisted of only 32 motion sequences, but by randomly modifying the angle values we performed data augmentation to come up with a database do 3200 motion sequences. We trained the DCGAN using RMSprop. We are conscious that the database sizes are too small for such a large networks, but the result was surprisingly promising. In figure 1, you can see a synthesized motion sequence of a shaky “hello” gesture, performed by Pepper in simulation. This work was performed by Francisco Gonzales, an exchange student from Universidad Autonoma de Cali [4], supervised by Prof. Andres Perez-Uribe and Dr. Hector Satizabal at HEIG-VD / HES-SO.

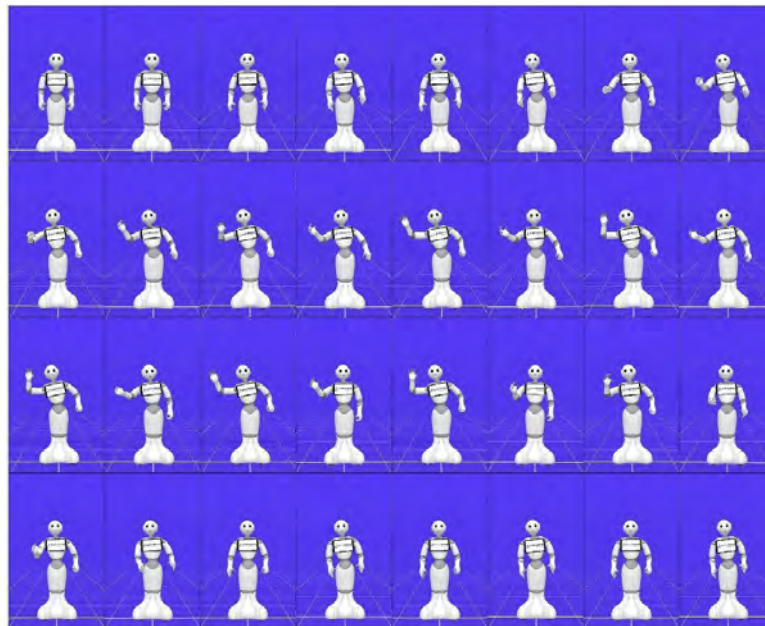


Figure 1. Synthesized motion to say “hello” waving one hand using a Generative Adversarial Network.

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Life Sciences and Healthcare

# AI-based prediction of virus-bacteria interactions as a contribution to fight against antibiotic resistance

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## Abstract

### Introduction

Antibiotic resistance and its rapid dissemination around the world threaten the efficacy of currently-used medical treatments and call for novel, innovative approaches to manage multi-drug resistant infections [1]. Phage-therapy is a re-emergent therapy and one of the most promising alternative therapies to antibiotics. It consists in the use of viruses, called bacteriophages (phages), to specifically infect and kill pathogenic bacteria along their life cycle with the aim of curing the infections they cause [2]. These viruses have cohabited and coevolved with bacteria for billions of years contributing to control bacterial populations, as in epidemics, and contributed also to bacterial genetic exchanges. They have the advantage of being extremely strain-specific and, thus, not having a major impact on the commensal flora. Phage therapy is based on the correct matching between a target pathogenic bacterium and the therapeutic phage. Nevertheless, such a matching is a major challenge as there is no systematic method to efficiently predict if a given phage-bacterium interaction would exist and they must be empirically tested in laboratory. The host range of a phage is determined by means of infection tests [3] usually based on spot assays or, more recently, on methods such as microfluidic-PCR or PhageFish [4,5]. All these methods, depending on the number of bacterial hosts tested, may require several days of laboratory work. Herein, we present our approach for developing a computational model able to predict whether a given phage-bacterium pair can interact based on their genome.

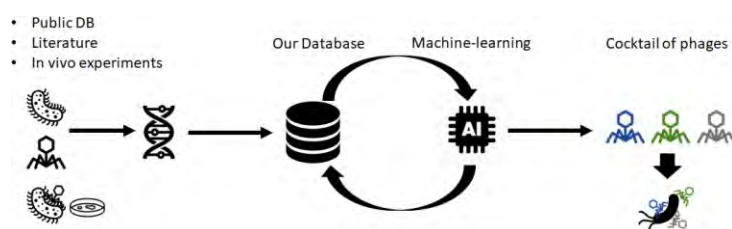
### Highlights

We are conceiving, implementing, and investigating an original approach, based on supervised machine-learning, intended to predict if a given pair of phage-bacterium would interact using only their genomic information. This approach is illustrated in the Figure below. As a first step, we extract annotated phage-bacterium pairs from public databases such as NCBI [6] and PhageDB [7]. In addition, other pairs are provided directly by our partner at UNIL, who sequences the organisms and performs *in-vitro* tests. Up to now, we have created a database with more than 20'000 interactions and 6'000 different organisms. As a second step, we extract meaningful and informative features from the genomes, a crucial task, knowing that the predictive models are trained on the resulting information. We created more than 20 datasets using two different kinds of features: (1) domain-based



scoring of protein-protein interactions and (2) statistics from the protein primary structures. As a third step, we build our predictive models we explore several, radically different, and complementary approaches: (1) Ensemble learning, which combines several different supervised machine-learning models through a voting method;

(2) One-class learning, based solely on positive (i.e., interacting) pairs, as they are the most often reported in the literature, and (3) a deep-learning approach intended to use mainly the organism's whole genomes. Current results that show high predictive power (ranging from 80 to 90%), encourage us to continue exploring these approaches. Finally, we will include in our AI system a selection of the best models that will be used to produce, for instance, a list of candidates therapeutic phages able to infect a given bacterium. These phages might then be tested in laboratory to confirm their efficacy. All along our project we have published two peer-reviewed articles [8] and [9].



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Life Sciences and Healthcare

# D-REX: Improving Deep Neural Networks Understanding via Rule Extraction

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## Abstract

### Introduction

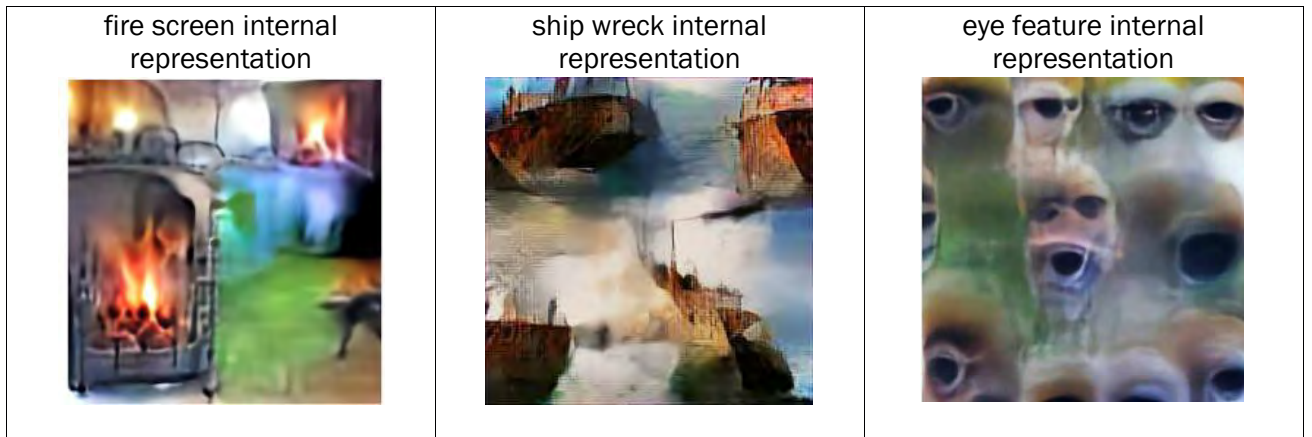
The growing amount of data available to researchers and companies coupled with the increasing computational power allows for the development of complex machine learning systems. In this context, artificial deep neural networks are a powerful tool, able to extract information from large datasets and, using this acquired knowledge, make accurate predictions on previously unseen data. As a result, deep neural networks are being applied in a wide variety of domains ranging from genomics to autonomous driving, from speech recognition to gaming [1]. Many areas, where neural network-based solutions can be applied, require a validation, or at least some explanation, of how the system makes its decisions. This is especially true in the medical domain where such decisions can contribute to the survival or death of a patient.

Unfortunately, the very large number of parameters required by deep neural networks is extremely challenging to cope with for explanation methods, and these networks remain for the most part black boxes. This demonstrates the real need for accurate explanation methods able to scale with this large quantity of parameters and to provide useful information to a potential user. In this context, our project D-REX (Deep Rule EXtraction) supported by the Hasler Foundation aims at providing the tools and methods to improve the interpretability of deep neural networks.

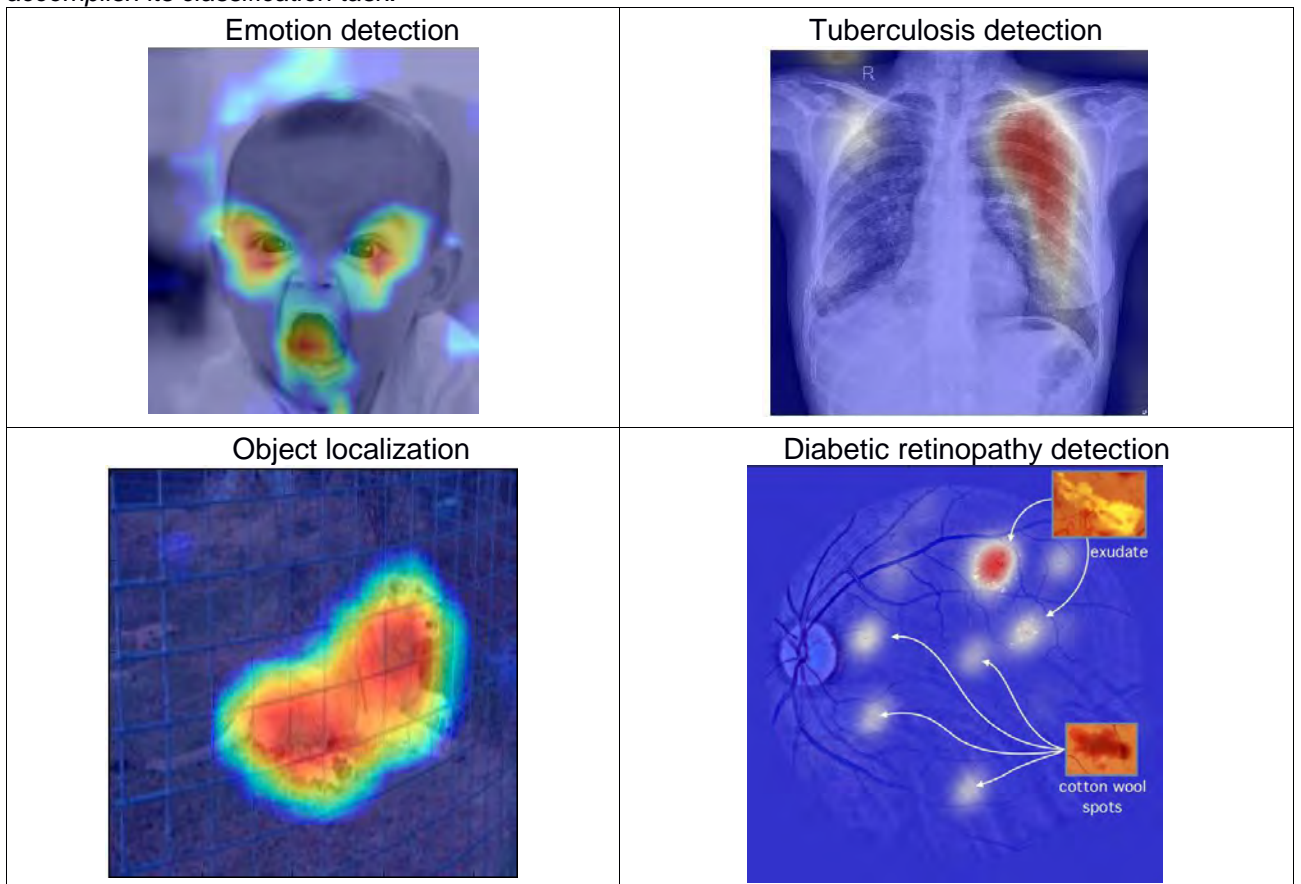
### Highlights

Within the framework of D-REX, we developed a method [2] allowing a user to interrogate a trained neural network and reproduce internal representations, at various depths within the network, as depicted in Figure 1. This allows for the discovery of biases that might have been overlooked in the training dataset and enable the user to verify and potentially discover new features that have been captured from the data by the network.

Another tool, based on rule extraction, is a method that emphasizes the regions of an image that are relevant to a certain class, through a local approximation of a neural net. Some results are presented in Figure 2. This method is of particular interest when the detection of a certain feature or characteristic is particularly complex, and where artificial neural nets exceed human performance. This is especially the case in some medical diagnosis tasks.



**Figure 1:** Illustration of our method generating preferred inputs reflecting a trained neural network internal representations based on the knowledge acquired from the data during training. These images can represent classes representations (e.g. fire screen or wreck) as well as features (e.g. eyes) that the network has been trained to detect in order to accomplish its classification task.



**Figure 2:** Illustration of our method highlighting regions of interest in an image. This result is achieved by extracting rules that locally approximate the outcome of a trained artificial neural network. The method can be applied to various problems such as emotion detection in human faces, object localization, and pathology detection in medical images.

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Life Sciences and Healthcare

# Real-Time Detection of Micro-Expressions through New Features Selection for Helping Doctors to Know Their Patients

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## Abstract

Through time, face, facial expressions and micro expressions detection has been evolving. Many studies have been made to reach a high accuracy software where people can rely on. Still until now we do not have a proper tool that can help this detection. In this paper, we show a new way for feature extraction in the aim of improving the emotional state where we take the difference between the points detecting the face and the difference between the frames over the time. A neural network has been used for the machine learning to detect the emotion.

### 1. Introduction

Nowadays with the technology evolving and the world moving towards the usage of machines and electronic devices, the mentality of the people is changing. Many doctors tried to understand their patients while working with them. Specifically speaking with psychologists, they might have the hardest problems with the communication with their patients. Even though humans can recognise what others are trying to express, yet some hidden emotions can be so hard to understand. Yet these hidden emotions create some involuntary facial micro expressions; but these micro expressions have major issues. Micro expressions are short and fast. Many studies and papers introduced many ways to detect micro expressions but not so many have studied the feature extraction. In this paper, we propose a feature selection that will help to achieve promising results.

### 2. Related work

In this section, we present already existing micro expression detection and feature selection systems. The most used approach is the local binary pattern from three orthogonal planes (LBP-TOP) where the usage of a threshold for neighbourhood of each pixel transformed into binary as in Guo in 2014 [1],Huang 2015[2]. We have other studies where they use the division of the face into regions of interest ROI, where some of them used the 3D gradient descriptor as Polikovsky did in 2009[3] or the Spatio Temporal Local Texture Descriptors SLTD, with Multiple Kernel Learning MKL classification, Pfister 2011[4]. All these studies been made but micro expressions are involuntary and rapid, thus we are working with sensitive data, which means binary transformation can be delicate because it is sensitive to noise thus a small change or a bad calculation can lead to high error rates. As well for the region division where while taking different part of the face some border can be important and not taken into consideration. Providing long histograms slows down the recognition speed especially on large-scale face database, which makes it hard to analyse and synthetize the result of the emotion felt or expressed during a 1/25 seconds.

### 3. Proposed Method

We need to be more realistic and efficient without losing any precision of the face. We need fast processing to make it a real-time application, thus the calculation of the changes in the face known as the action units AUs have to be fast. We use 68 points face detection algorithm [5] for each frame of a video, that detects the eyes, eyebrows, nose, mouth and jawline. Then for each AU difference between the points related to it is calculated over a single a frame and through the video flux frames, the calculation is a normal Euclidian distance over the x and y coordinates. On this point, we have calculated the difference we need to detect the emotions expressed. We are working with the CASME II database to do our tests. Afterwards after finding all the distances needed, a machine-learning algorithm implemented over the data we have, we are using Neural Network to cluster our data. Our contribution is reaching around 60-70% accuracy.

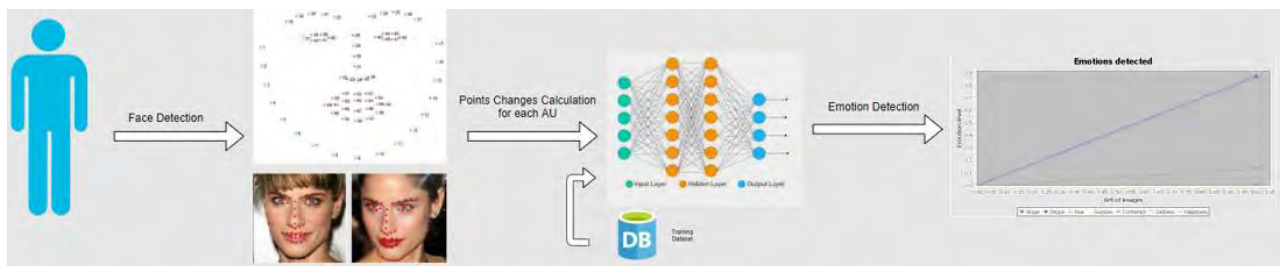


Figure 1 : Micro Expression System Contribution

### 4. Conclusion

In this paper, we have shown that the presented contribution shows a new way for feature selection. This feature selection have advantages as being fast to be processed, second it do not lose any face details since it takes the whole face into consideration. Moreover, we can see the changes happening in the hidden emotion of humans, which will be a solution for the doctors to be able to understand their patients. As for future work, on this algorithm we still have many concepts to add, by adding the number of points of the face detection. Trying different machine learning algorithms. Calculation of the changes over the curves instead of point that might be more accurate.

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Life Sciences and Healthcare

# Gamification Approach for Diabetes (T1DM) Management and co-morbidities prevention in Adolescents and Children

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SUPSI; DTI

## Abstract

We propose a novel methodology to identify, effectively implement, and scale-up a novel intervention methodology for Type 1 diabetes mellitus (T1DM) in children and adolescents supported by gaming, starting from the limitation of current practices. T1DM is one of the most common chronic illness in children and teenagers, affecting 1 in 400, and there is evidence that the incidence of childhood T1DM is rising worldwide. This generates a societal challenge and implies high direct and indirect costs for patients. Supportive care for T1DM in children is needed, to simplify children management of diabetes, to support parents' involvement with complete information while leaving freedom to their child, to act as adjunct to clinical care to meet the necessities to this high-risk population. If addressed from the early life, diabetes management can be more easily accepted by children as it becomes part of their life. This, clearly, requires both a correct education to such management as well as a personalization of the management, in order to adapt it as much as possible to their life, instead of being forced to radically change their life to the treatment.

Our novel methodology combines multiple disciplines ranging from network and data science; gamification; paediatric diabetes and endocrinology medicine; psychology. This is the basis for designing and building a system for effective and scalable intervention. The key elements of innovation of the methodology reside on the use of *gamification* as mean to involve children in the management and prevention, and to encourage them to maintain a correct life-style. The gamification interventions will include (hide) medical guidelines for the T1DM treatment, healthcare practice and evidence-based strategies, as well as prevention of T1DM co-morbidities, from previous research on diabetes and healthy habits in order to integrate scientific knowledge and effective interventions into everyday use by means of the game. The disease self-management includes: (i) drug monitoring, nutrition education, and monitoring of dietary habits, physical activity and sleep quality; as well as (ii) personalized feedbacks provided by a virtual coaching platform.

The gamification approach will be included in a *mHealth game*: a game that promotes health and wellness or seeks to improve care management or clinical outcomes, mostly with mobile phone technology. We complement the traditional mHealth approach with a virtual coaching platform, monitoring and strong communications features among peers (also related to distributed gaming functions) and with the family, to contrast with the loneliness and isolation feelings that can arise while continuously using and playing on smartphones independently. More importantly, our system allows to *collect automatic, objective, unconditioned and seamless data* on the patient mobile phone. This conversely to traditional studies (e.g. questionnaire and survey based data collections), which can be performed only periodically and in conditioning context (e.g. medical labs), and that are resulting mainly in subjective evaluations. Such systematic data gathering allows an unprecedented breakthrough.

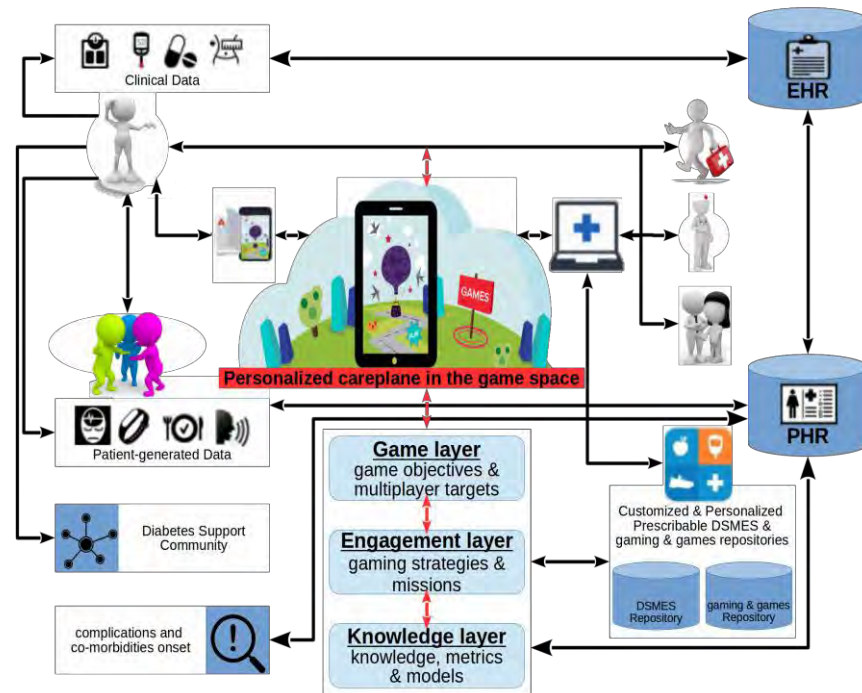


Figure 1: the proposed methodology scheme

With *network and data science* it will be possible to build an analytical approach for the performance, effectiveness and scalability intervention assessment, and even provide projections for that.

As a specific medical innovation with respect to T1DM, we introduce also a *sleep quality monitoring feature*, since it has been recently proved that disturbed sleep patterns (i.e., restriction, deprivation, and fragmentation) in healthy young adults produce alterations in both metabolism and cardiovascular disease risk markers, and sleep disruption in people with T1DM may negatively affect disease progression and the development of complications. Gaming further ease the *natural and free communication with peers and adults*, and children and adolescents naturally act as multipliers, to spread and scale-up interventions. This will easy therapy adherence, nutrition education and monitoring of dietary habits, and give appropriate stimuli to maintain a correct physical activity.

The proposed methodology represents a transformational innovation that promise to change the intervention for chronic diseases. We will also be able to assess guidelines and policies for T1DM management at regional, national and EU levels. The proposed methodology will be seamlessly included in current interventions and policies to the local and regional levels, with the perspective of scaling-up to other regions, countries or very large regions. We expect to decrease direct and indirect costs of diabetes for patients. Behavioural change studies for diabetes patients have delivered direct cost reductions ranging between €250 and €900 per patient per year; although the cost of medication and treatment device expenditures increases, clinical care costs decreases to a much larger extent. In addition to that, self-care also reduces the indirect costs for patients by increasing productivity, decreasing absenteeism from work and decreasing the cost of home care provided by another family member or a specialist.

Life Sciences and Healthcare

# Detection of Skin Affliction using Fully Convolutional Neural Networks

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## Abstract

### Background

Hand eczema (HE) is the third most frequent work-related disease. It occurs in about 10% of the working population. Immense loss of productivity results due to sick leave, which on average has a duration of 12 weeks. HE produces well-defined visible clinical skin changes. Early detection of hand eczema by the presence of such lesions could allow treatment before the disease becomes clinically relevant. Here we have constructed a machine learning approach to achieve this goal.

### Methods

Two data sets of images are used. The first set consists of 48 images of hand eczema taken at the University Hospital of Zurich (USZ) using a digital camera, but no standard light conditions or settings. 30 dermatologists were asked to each mark the lesions using a java-based web platform ('SkinAppWeb'). Regions, where at least 50% of the dermatologists agreed on eczematous skin, were labelled as such. The second set consists of images that were taken at the USZ using a 'photobox' containing fixed light sources and a digital camera controlled by an application. A green background was employed to facilitate background segmentation. The images were labelled by Dr. Lilian Kaufmann and have a higher resolution (3456x2304) than the previous data set. An initial set of 76 images was used for training and cross validation and additional sets of images were used for evaluation.

Both data sets were used to train Fully Convolutional Neural Networks (FCN) that can discriminate between background, healthy skin and eczema. In order to optimize the performance of the used GPUs and to train from multiple images in one mini-batch, the images were divided into overlapping tiles and then shuffled into mini batches.

Fully convolutional networks have been introduced in (Long et al., 2015). Whereas previous networks for image classification combined convolutional layers with pooling and fully connected layers in order to obtain a single classification for the whole image, fully convolutional networks calculate a result at every pixel. This is commonly referred to as semantic segmentation (Long et al., 2015). In difference to their approach, we employ only convolutional layers without any strides. Pooling layers have been explored in some configurations, but without shrinking the resulting images. Only 3x3 convolutions are used, but the different networks use a different width (or channels) in the layers. Table 1 gives an overview of the used network configurations, where the values in brackets indicate the width for each layer. All networks are followed by a 1x1 convolutional layer to the resulting depth



of 3, which corresponds to the number of classes.

Network	Layers	Variables	Remarks
<b>Net15</b>	6 conv (8-8-16-16-32-32); 1 max pool; 3 conv (16-32-16)	32'123	
<b>Net16</b>	1 conv (16) 5-res-blocks (16-16) 1 conv (32)	28'387	Residual network with skip connections (He et al. 2016)
<b>Net17</b>	11 conv (16), 1 conv (32)	28'387	Same as net 16, but without skip connections

Table 1: Used network configurations

The neural networks were trained for 10000 epochs using AdaGrad optimization, L2 regularization, 0.8 dropout keep probability with a batch size of 512 image tiles of size 64x64 using tensorflow. In order to compare the results, a support vector machine (SVM) approach as described in (Schnürle 2016) was trained on the same data sets.

### Results and discussion

A fivefold cross validation was calculated on each of the data sets and accuracy, precision, recall and the F1 score were computed for each of the validation sets of the folds. The best performing neural network, as measured by the F1 score, was Net16, copying the ResNet architecture (He et al. 2016), but it outperformed Net17 only slightly. The SVM was on average better on the first data set, but with greater variety, but performed worse on the second data set.

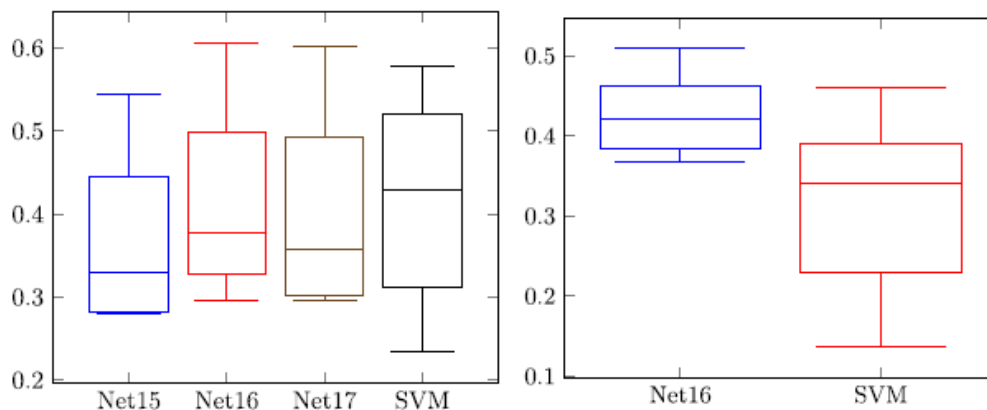


Figure 1: Boxplots of the F1 scores of the 3 networks and the SVM on the 5 folds of the first data set (left) and of Net16 and SVM on the folds of the second data set (right).

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Life Sciences and Healthcare

# Deep Learning for Recognizing Sleep Stages from Mobile Sensor Data

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## Abstract

### 1. Introduction

Sleep quality is closely associated with health, wellbeing and quality of life. Sleep disorders, however, are wide-spread and often coincide with chronic health problems such as diabetes, hypertension as well as cardiovascular and psychiatric diseases.

Traditionally, sleep disorders are investigated in sleep laboratories by means of polysomnography (PSG). But not only is such sleep monitoring costly, it also removes people from their normal sleeping environment and prevents repeated or longitudinal studies. Recently, smart watches, fitness trackers as well as sensors built into a smartphone offer new opportunities for continuous monitoring in everyday settings.

However, the tracking devices and sleep screening apps currently available cannot compete with the accuracy of clinical sleep laboratories. At best, they are able to distinguish between waking time and sleep time. Given the shortcomings of existing solutions for monitoring sleep architecture in a home setting, the SmartSleep project set out to develop a low-cost monitoring solution for *capturing sleep architecture at home* over a longer period of time with an *accuracy approximating a clinical polysomnography* [4].

### 2. Approach

We gave several wearable sensors to 15 healthy volunteers in addition to the usual PSG sensors in the sleep lab of the clinical project partner Barmelweid. For each person the sleep stages ('Wake', 'REM', 'N1', 'N2', 'N3') were labelled by experts according to the gold standard of the AASM classification. This resulted in sensor data streams segmented into labelled sleep stages of 30 seconds each, from which sleep stage classifiers were subsequently learned.

As sensors we used a Zephyr BioHarness chest strap and two MSR 145B4 accelerometers, one at the wrist and one at the ankle. It turned out that the chest strap had too many missed readings and artefacts so that we used the data from the MSR sensors only.

The quality of a classifier not only depends on the chosen algorithm and its parameter settings but above all on the features being used. Especially in the case of learning from sensor data, identifying significant features is a critical and difficult task. We experimented with handcrafted features as well as with *unsupervised feature learning* based on the deep learning paradigm. In [3] it was already shown

that unsupervised feature learning with deep learning is promising for learning sleep stage classifiers. From the features we generated a Random Forest classifier.

For the feature learning we applied a deep belief network built from stacked Restricted Boltzmann Machines (RBM) [2]. The resulting higher-order features reflect significant patterns in the underlying raw data and are therefore expected to be better suited than ad hoc handcrafted features. Besides using RBMs we also experimented with a stack of two autoencoders [1].

### 3. Results

Several sleep stage classifiers were learned from the sensor data streams of the two MSR accelerometers. The classifier based on handcrafted features gave an accuracy of 84% over all sleep stages. The features learned with the RBMs resulted in 80% overall accuracy. The autoencoders fared slightly better and reached an overall accuracy of 82.5%.

In all cases the recognition rate for N1 is very low and often confused with N2. When we combine both stages into one we achieve an overall accuracy of 90% for handcrafted and 88.5% for learned features.

### 4. Outlook

We are currently applying for a follow-up project where we can create more learning data and experiment primarily with recurrent neural networks that are better suited for dealing with sensor data. We expect deep learning to become superior to handcrafted features once we have considerably more data available from which to learn.

Moreover, to utilize the transition probabilities between sleep stages as an additional information source we plan to combine the classifier with a Markov model to increase the overall accuracy.

### Acknowledgements:

The SmartSleep project was funded by the Internationale Bodensee Hochschule.

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## Energy and Environment

# Accurate transport mode detection in Smartphone-based mobility tracking for sustainable mobility

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## Abstract

Due to the current diffusion of Smartphones and the always increasing quality and availability of sensors, travel data collected by Smartphones have become a fundamental source of information about mobility choices and transport usage.<sup>1</sup> The little effort required to users in the data collection process, makes automatic Smartphone-based mobility tracking a preferable solution compared to traditional, very time consuming, travel surveys. In the field of sustainable mobility, the data thus recorded are of great interest as they allow assessing citizens' mobility. Also, fully automatic tracking is, indeed, a necessary requirement for large scale interventions aimed at data collection and monitoring, as confirmed also in two recent field experiments (GoEco!<sup>2</sup> and Bellidea<sup>3</sup>) we have carried out in Ticino and Zurich areas. These projects focused on the use of persuasive Smartphone apps to induce citizens to more sustainable mobility choices, by exploiting gamification techniques, social interactions and tangible prizes. It clearly appeared that, on one hand, users tend to leave the project if it requires too big an effort in data collection; on the other hand, any interaction with the user could influence her behaviour.

Currently, depending on the quality of the device, automatic location tracking can be very accurate. It has already been implemented in several tracking apps freely available on the market (e.g., fitness apps). However, most of these apps cannot accurately identify all transport modes that are relevant for a correct quantification of the ecological impact of mobility patterns. For instance, the commercial app Moves®,<sup>4</sup> used as tracker by both GoEco! and Bellidea apps, can only distinguish between foot, bike and motorized transport. Therefore, the general framework of the persuasive GoEco! and Bellidea apps, has been to collect pre-processed position data using Moves® app and, then, infer from these data, by a purposely developed algorithm, a more refined classification of the transport mode, including car, bus and train besides foot and bike. We have assessed the performance of different classification approaches based on the data collected in the GoEco! project (around 200 users tracked for at least two weeks) and in an internal testing phase of Bellidea (around 15 users tracked for four weeks). Results have shown that learning different classifiers for each user improves the classification accuracy as it allows learning user-specific routines. On the other side, matching the trajectories recorded by Moves® with the transport network has no relevant effects,

probably due to the inaccuracies in the segmentation of the recorded location data performed by Moves®. Moves®, in fact, does not provide the original GPS coordinates of all the tracked positions, but aggregates them into trajectory segments called activities. This feature is quite common in commercial apps.

In GoEco!, training data for the classifier were collected by asking users to confirm the correctness of all identified transport modes and to manually modify them when the classification was wrong. Having identified a relevant cause of dropout from GoEco! in the conspicuous effort required by this validation procedure, in Bellidea the number of validations requested has been reduced: validation of all recorded activities was only asked in a first *warm up* phase of about two weeks; after that, validation was requested only for the activities with low classification confidence, that is, those for which the probabilities of the two most probable transport modes were too close. Thresholds on the number of validations initially required and on the acceptable classification confidence have been set by measuring the effects of these two parameters based on the data collected along GoEco! and Bellidea projects. Due to the limited number of validated data for each user, a single classifier, common to all users, was created. Besides reducing the number of validations required to achieve a reasonable accuracy, this approach makes the classifier more robust to cheating, compared to having different classifiers for each user. To limit the negative effects of a common classifier on classification performances, a user identifier was passed as input to the classification algorithm to allow for a certain degree of specialization. Overall, we managed to obtain an accuracy of 87% asking the validation of the first 80 activities in the *warm up* phase and of about 15% of the activities during ordinary monitoring. The precision varies between 73% and 93% across transport modes, whereas the recall is between 58% and 97%.

This work has shown that, although a classification accuracy acceptable for smartphone applications can be achieved, there are good margins of improvement, especially concerning the number of validations required and the classification accuracy of public transport modes. The accuracy that could be achieved is limited also by the lack of low level sensor data, such as accelerometer and gyroscope measurements, which have proven to be effective in distinguishing between different motorized transport modes.<sup>5</sup> Also, the sometimes low quality of the GPS measures and, more often, the inaccurate segmentation of the recorded positions performed by Moves®, represent a limit to the classification performance. Future research will be devoted to the improvement of such segmentation either starting from Moves® records, or directly from low level sensor data.

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## Energy and Environment

# Detailed data collection and usage allow unprecedented understanding of energy supply and demand dynamics in future smart cities

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### Abstract

Nowadays, energy supply networks in cities – natural gas, electricity, heating/cooling - are almost always planned and operated separately from each other. Indeed, these infrastructures are either belonging to different companies not connected to each other or managed within distinct departments within the same energy utility.

This “silo-like” approach prevents energy utilities and city planners from:

- identifying synergies opportunities among the networks, as to increase reliability and robustness of energy supply;
- optimally planning heavy infrastructure investments and taking into account future energy demand evolutions while avoiding oversizing.

Concomitantly, energy supply and demand data rarely are comprehensively available at territorial level, thus rendering the computation of relevant decision-oriented indicators approximate at best in most cases.

The EU project IntegrCiTy (<http://iese.heig-vd.ch/projets/integracity>), coordinated by HEIG- VD aims at providing a first answer to the lack of systemic vision for urban energy networks, by fostering energy networks interoperability in existing or future urban infrastructures and by developing so-called co-simulation frameworks, in which the dynamics of different networks are simultaneously taken into account. Within a co-simulation approach, planning scenarios for a given urban zone must be precisely defined for energy demand and supply, including control strategies. The scenarios can either be built ad hoc, i.e. based on a given local policy, or stem out of an optimization process.

In a second project led by HEIG-VD, namely Networks\_in\_City (NIC), an optimization process for the existing urban energy networks will be developed and tested on a real Swiss territory. Indeed, in this urban zone existing natural gas and electricity networks will be impacted by the deployment of a third energy network,

an energy grid, used as heating/cooling network. This new resource will have an impact of both the usage and operational management of the energy networks already present in a given urban zone: the basic question is thus to use optimization techniques to continue exploiting the existing networks, with the constraints given by an additional resource and in synergy with the latter, albeit with a modified strategy and role in the overall energy supply mix. NIC project aims at using selected optimization approaches, within the overall co-simulation framework developed in IntegrCiTy, in order to integrate low-carbon mobility (fed by electricity and natural gas) in a given urban zone. The new energy demand locally created by low-carbon mobility would be supplied by existing networks, on one hand – e.g. by leveraging on demand decrease due to implementation of a new network fed by a different energy vector - and additional renewable generation capacities (e.g. PV).

Hence, the interplay between optimization techniques, used to generate future scenarios, and a co-simulation framework providing the necessary validation of the optimized network design will be exploited to tackle concrete projects on the ground.

The central and crucial role of data precisely characterizing both energy supply and demand complex fabric in urban zones is highlighted, since it provides the indispensable source for understanding the current situation and thereafter proposing solutions to attain increased energy efficiency in future smart cities.

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## Energy and Environment

# Machine learning and optimization for the design of photovoltaic installations

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## Abstract

We consider the Photovoltaic Installation Design Problem (PIDP) where photovoltaic modules must be organized in strings and wired to a set of electronic devices. The aim is to minimize installation costs and maximize power production considering “mismatch losses” caused by non-uniform irradiation (shading) and directly related to design decisions. We relate the problem to the known class of location routing problems and thanks to the existing knowledge on the problem, we design a route-first cluster-second heuristic. We propose an efficient machine learning approach to evaluate PV string performances accounting for mismatch losses. We prove that our approach is effective on real-world instances provided by our industrial partner.

## Introduction

Photovoltaic technology has progressed in the last decades, in particular for what concerns rising efficiencies and falling prices of components [2]. Anyway, the system design process still represents a bottleneck for the realization and capitalization of efficient PV installations [1]. Modern design support tools are still lacking of methods for a comprehensive evaluation of alternatives. One of the disregarded aspects concern the electrical performance (voltage and current) of PV installations where mismatch losses effects, due to different level of irradiation between cells and modules, can have a significant impact on energy yield up to 25% with respect to the optimal configuration [4]. In the context of an applied project, we collaborate with an industrial partner: InSun SA, an IT company based in Lugano, which provides a platform of services to the players of the photovoltaic value chain. The goal of the project is to enrich the inSun’s platform with AI and Optimization components.

## Machine Learning and Optimization

For each PV configuration, composed by a different number of PV strings  $s$ , we build a synthetic data set by simulating a physical model in a range of different conditions and we train a statistical predictor aimed at approximating the mismatch loss. We use as inputs the ratio between diffuse irradiance and global irradiation and the proportion of shadow referring to each string, which thus yield  $s + 1$  independent variables.

For each different number of string  $s$ , we train a random forest model as a statistical predictor. We obtained very good approximation in all data sets, with an absolute error smaller by at least one order of magnitude than the mismatch loss to be predicted and correlations larger than .99 between the values produced by the physical model.

The photovoltaic installation design problem (PIDP) is described as follows: given a set  $M$  of homogeneous PV modules, a set  $I$  of inverters, a set  $S$  of irradiance samples, determine



the inverter configuration and string configuration so that both installation costs and mismatch losses are minimized.

We observe that the PIDP can be conveniently cast to a multi-depot location routing problem (CLRP) with some problem specific additional constraints. Analysing the CLRP literature, we focused on methods based on the route first cluster second principle introduced by Beasley [3] where the computational effort related to routing is concentrated on computing one or few “giant” TSP tours once and the clustering component is able to produce a population of non-dominated solutions.

## Computational results

We performed experiments on real-world instances proposed by our industrial partner. We have at hand 9 real-world instances. The smallest instance has 60 modules and an average of 10 modules per tracker, the largest instance has 1218 modules and an average of 305 modules per tracker. For the largest instance, the method converged in 192 seconds of computation. For all instances the method proposes different solutions in short computational time.

Savings related to installation costs can be up to 31.76% in the largest instance and mismatch losses are reduced up to 45.20%. In some cases, the best solution with respect to one objective has a worse performance on the corresponding value of the other objective and this is expected. For example, in a 631 modules instance the best mismatch loss performance of 5.95 corresponds to a worsening of cable length by 3.27%. Anyway, for all instances, we were able to provide solutions improving both cabling and mismatch loss objectives. Finally, we remark that for the largest instance, the proposed method is able to connect all 1218 modules, while the reference solution connected one module less and still the overall cabling and mismatch loss are largely reduced.

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## Energy and Environment

# The world's first underground AA-CAES pilot plant: modelling and validation

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## Abstract

In the field of large-scale electrical energy storage, a valid alternative to pumped hydro systems is represented by compressed-air energy storage (CAES), thanks to the foreseen advantages of limited environmental impact and lower estimated capital costs [1]. Two industrial-scale CAES plants are successfully in operation nowadays: the 321 MW Huntorf plant (Germany), and the 110 MW McIntosh plant (USA). In both these plants the large amount of thermal energy produced during the air compression phase is wasted, limiting therefore the round-trip efficiency to 42% and 54%, respectively. To improve the performance and to overcome the need of fossil fuels, a thermal energy storage (TES) system can be exploited to store the thermal energy produced during compression to be recovered prior expansion. This idea led to the concept of advanced adiabatic CAES (AA-CAES) whose expected round-trip efficiency is in the order of 70% [2]. At the end of 2016, the Swiss company ALACAES SA built and tested the world-first underground AA-CAES pilot plant in the Swiss Alps, near Biasca (TI), to evaluate the feasibility of exploiting existing rock caverns and a packed bed of rocks as TES system [3]. Figure 1 depicts the 4.9 m diameter and 120 m long section of a presently dismissed transportation tunnel, which was exploited as air reservoir of the pilot plant including the TES engineered to fit the tunnel cross section, as illustrated on the r.h.s. of Figure 1.

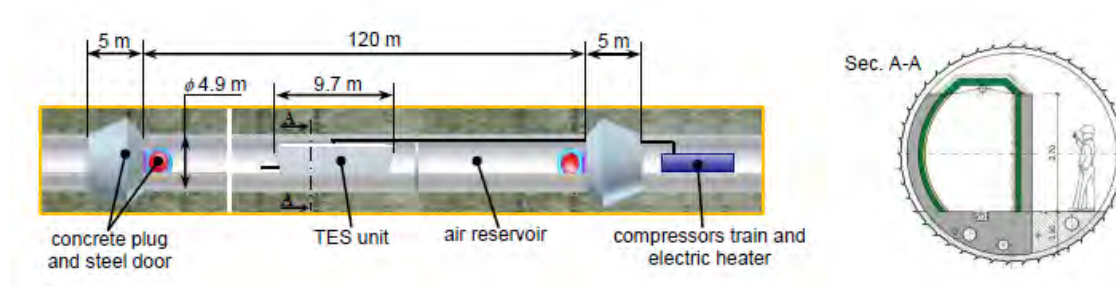


Figure 1: Schematic layout of the world's first underground AA-CAES pilot-plant (l.h.s) and cross section of the integrated packed bed TES unit (r.h.s.). Courtesy of ALACAES SA.

A computational fluid dynamics (CFD) approach was pursued with the twofold aim of designing the air flow distributors and characterizing its thermo-fluid dynamics behaviour. A representative experimental campaign, characterized by a 42 h pre-charging followed by 5 partial charge/discharge cycles, was selected to validate the numerical model developed.

Figure 2 shows the comparison between simulation results and experimental data gathered from some thermocouples located, at different heights, into the packed bed.

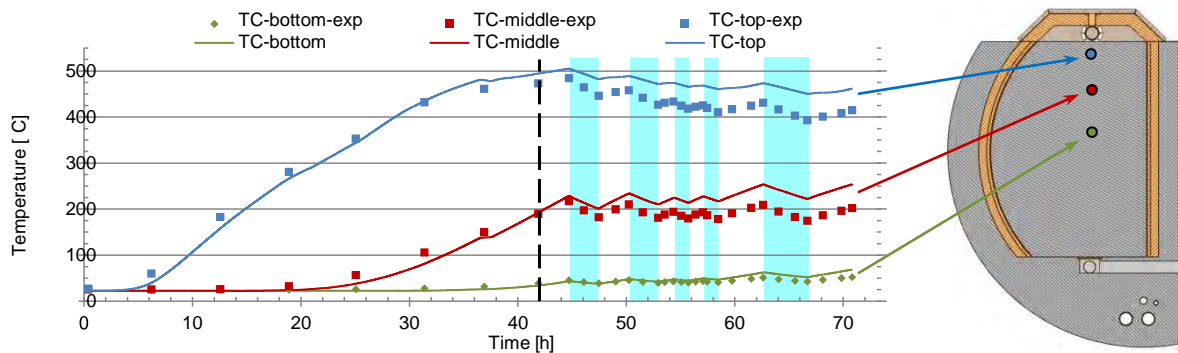


Figure 2: Comparison between CFD simulation results (solid lines) and experimental data (markers).

A physical model of the pilot plant was also developed in Simscape, accounting for temperature dependent properties of air, the cavern dynamics and the detailed TES geometry thanks to the embedded 1d code provided by ETH Zurich. Figure 3 summarizes the main results: the evolution of air temperature and pressure within the cavern follow the experimental data with a fairly good agreement. A disagreement between simulation and experiments can be observed looking at the TES air outflow temperature during discharging, where the model gives higher temperatures than expected. The cause of this was found in a partial by-pass of the air flow rates during discharges that reduces the overall temperature of the air at the outlet. The estimated efficiency of the pilot plant ranged amid  $0.63 \div 0.74$  and the TES thermal efficiency was between  $0.77 \div 0.91$  [3].

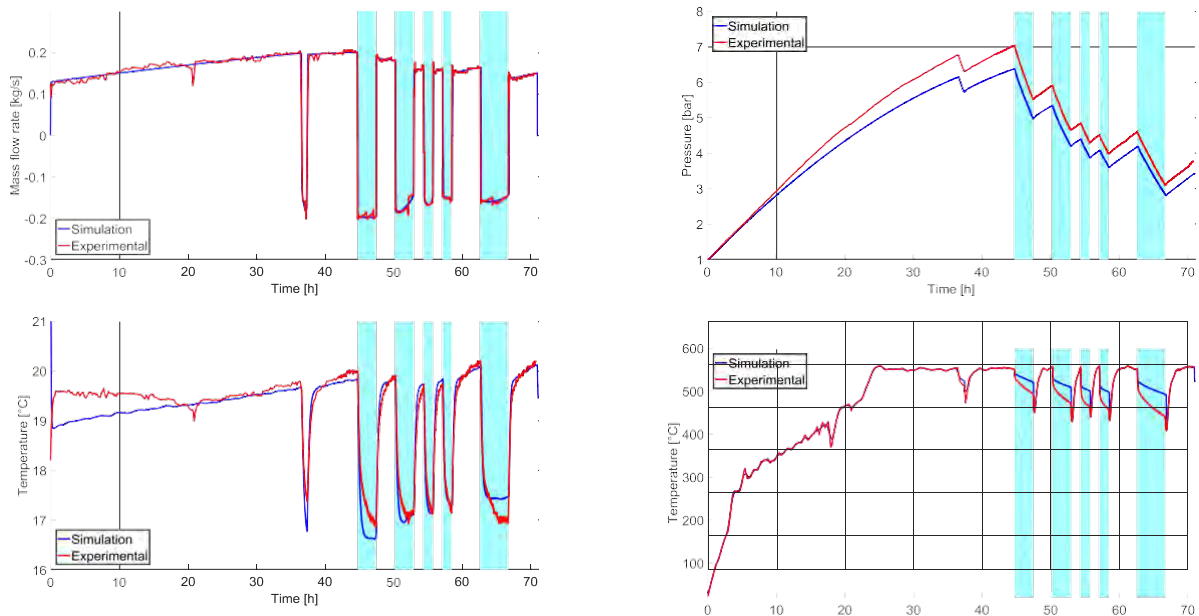


Figure 3: Simulation results (blue lines) against experimental data (red lines) Left-right, top-bottom: mass flow rates, cavern pressure and temperature, temperatures at the TES top.

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