FINANCIAL MATHEMATICS

Financial mathematics issues arise in the sales and risk management of vehicle financing and leasing offers, which we deal with in our department for various industrial customers, such as BMW AG Munich. For example, we develop models for the probability of closing a financing application and forecasts for the residual values of used cars.

DR. ANDREAS WAGNER
HEAD OF DEPARTMENT

EXPERTISE IN CLASSICAL FINANCIAL MATHEMATICS, DATA SCIENCE, AND THE ENERGY INDUSTRY

Our applied research provides solutions for problems in development, analysis, and implementation of mathematical models. We rely on the latest findings of financial mathematics and statistical research. At the same time, we draw on a portfolio of successfully completed projects with banks, insurance companies, and energy suppliers.

We cover all relevant areas of practical financial mathematics – from modeling to the development of valuation algorithms and their implementation – and maintain our own software libraries. Frequently, projects result in software systems for operational deployment in companies.

We assist our customers to validate their data using mathematical modeling and to discover insights from the data using classical and modern statistical methods. The applications include the most diverse areas of controlling – from the valuation of company-specific assets such as leasing vehicles, to the detection of anomalies. Our work involves a combination of classic statistical methods such as regression models and cluster analysis and current machine learning methods.

Financial mathematical methods play an increasingly important role in the energy sector. We have experience in various models; we use current research results to implement algorithms for the efficient solution of valuation problems; and, we know the specific problems and characteristics of the energy markets. In addition, we also provide finished software packages for the management of portfolio risk.

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MAIN TOPICS

- Financial Economy
- Data Science for Controlling
- Energy Industry

1

CREDIT RISK MANAGEMENT FOR GOVERNMENT AND CORPORATE BONDS BASED ON NEWS RELEASES

1 *Machine learning methods are used to index news from different media and divide it into specific categories.*

The aim of the SenRisk project is to develop a credit risk management system in cooperation with one domestic and two foreign industry partners. Project funding is provided through Eurostars, a program for SME driven research of EUREKA and the European Commission. In addition to market data and macroeconomic information, current news reports (press, tickers, blogs, etc.) are also assessed to improve forecasting quality.

Machine learning classifies messages

Data providers specializing in data processing provide preprocessed, enriched, and machine-processed messages. Specifically, this means messages are given a classification using the techniques of machine learning, for example, auto-encoding methods. These classifications

- by reference (e. g., country, industry, company, etc.)
- by topic (e. g., management decisions, product market launch, profit warnings, etc.)
- by the assessed severity or relevance
- allow the user to filter out or limit the relevant news about a particular bond.

We use non-linear regressions and time series approaches as well as neural networks to combine these recently provided explanatory variables to forecast future price changes (spread changes) or, at a minimum, to develop better risk indicators. These are integrated into an information system to assist traders and portfolio managers.

The methods are applicable to government and corporate bonds. Due to different maturities, there is a maturity structure, which is not the case with equities. In addition, large parts of the market are less liquid than the equities or derivatives markets and price movements are driven by a complex combination of currency, interest rate and economic momentum.

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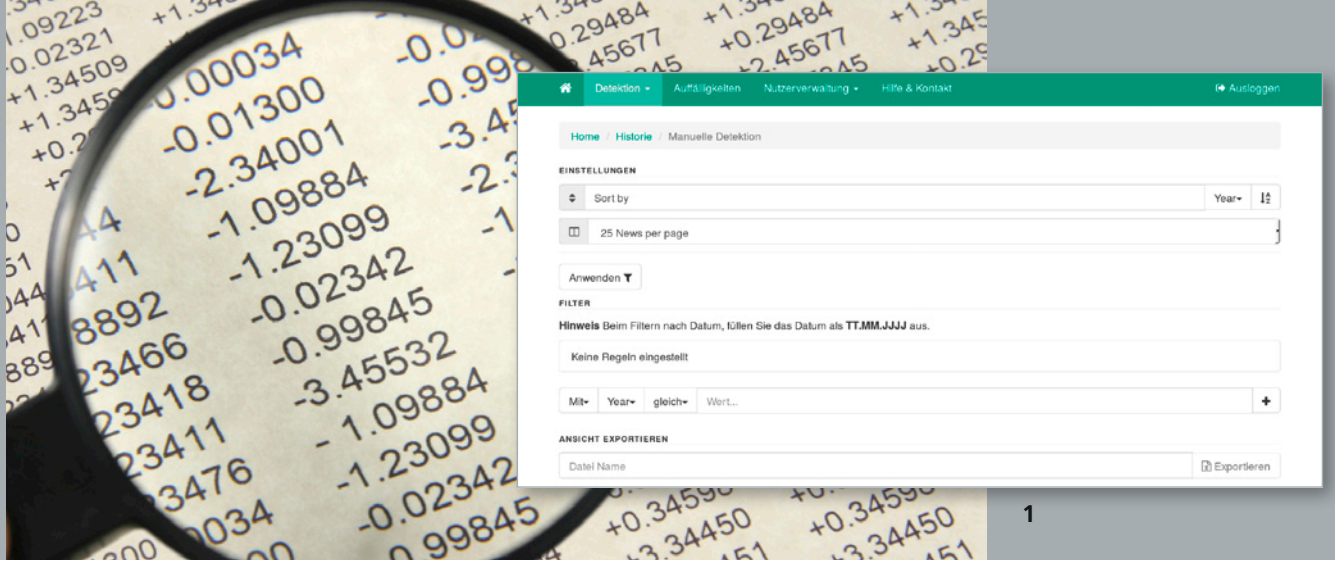
EUREKA

The "SenRisk" project is part of the European "Eurostars" funding programme and the German partners are funded by the Federal Ministry of Education and Research.



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ANOMALY DETECTION FOR CONTROLLING

Researchers in the Financial Mathematics department, together with industry partners, have developed an anomaly detection software. The product enables users to find and assess various types of anomalies (outliers) in very large data sets – usually, in accounting data.

1 *Example of detection of suspicious messages*

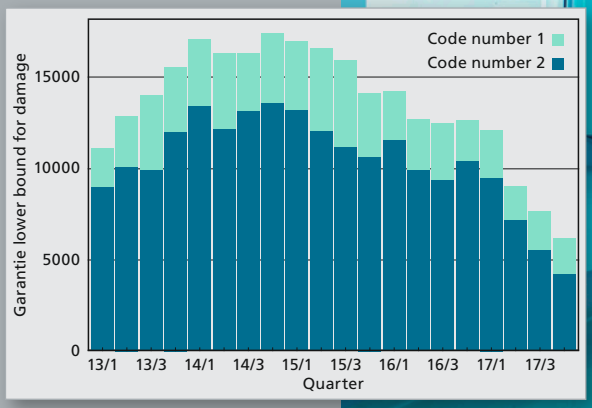
Identifying anomaly types – developing efficient algorithms

Our software lets us define various anomaly types tailored for the actual use case. In almost all projects, we detect mathematically simple anomalies, such as duplicate statements. However, deviations from the Benford distribution are also found and examined. Furthermore, we implemented a number of clustering methods that find, for example, highly deviating invoices in a large set. We also apply machine learning methods to define detection algorithms. In all cases, the development of efficient algorithms is an essential research task in the associated projects.

Software provides optimal support of workflows

The software we develop is optimally adapted for workflows encountered in controlling. Multiple users such as administrators, employees, and team leaders can work at the same time. The anomalies detected by the software can be viewed by all users who, if required, can check the underlying files or procedures to classify the anomaly according to severity or amount of damage. The users comment on or classify each stage of an anomaly, while a revision proof history of all work on an anomaly is maintained.

Lastly, our software approach permits a structured assessment of the data, for example, sorting and filtering as well as supporting an Excel export of all data and results.



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DAMAGE EXTRAPOLATION AND SAMPLE SIZE DETERMINATION IN THE HEALTHCARE SECTOR

1 *Example of a calculated warranty loss over an observation period of 20 quarters, based on two performance figures considered*

Investigating authorities and health insurance companies note time and again incorrect or implausible invoices for nursing services and contract physicians. We use statistical extrapolation to assist them in reaching a more efficient settlement.

The common phenomenon of fraud has recently received more attention in the media, especially, in the healthcare sector. Furthermore, there even appear to be connections to organized crime for some eastern European care services. Since May 30, 2016, a law to combat corruption (StGB § 299a, § 299b, SGB V § 197a), has made bribery and corruption illegal in the health services industry.

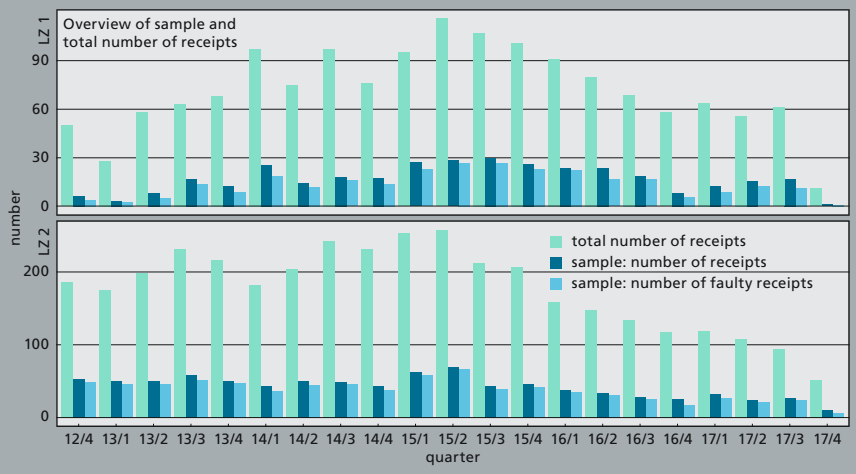
Example: Home care billing fraud

At the same time, the public insurance and law enforcement agencies experience great difficulties in investigating conspicuous cases. This is especially true in suspected fraud cases concerning home care. It is very costly to check all of the individually billed services for correctness while, at the same time, difficult to undoubtedly prove the faultiness of a single bill. This is due to the special situations in outpatient care (possibly demented patients, many "small" services).

To avoid a review of all services, we determine on behalf of the investigating authorities a so-called "guaranteed damage" as a lower limit for the total damage due to the billing fraud. For this, we take a statistical sample from the whole set of billed services. Only this much smaller number of claims is evaluated by the investigating authorities.

On this basis of a few claims, taking into account the resulting statistical uncertainty, we determine a lower bound to extend to the whole population. Only with a very low probability of error will the true total damage lie below this predetermined bound. Our procedure is legally established in court for cases of medical billing fraud. Usually, a confidence interval of 99.5 percent is used. Then on average, only one in 200 cases is below the calculated guaranteed damage.

The greater the statistical uncertainty (quantified by the safety margin) is, the lower the guaranteed bound for the damage becomes. This margin significantly depends, among other things, on the size of the survey sample. At the same time, sample size is one of the few factors that can be directly influenced by the investigative authorities prior to conducting the survey.



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Consequently, we often perform a sample size determination before conducting the survey. A minimum sample size is determined in such a way that a meaningful guaranteed damage can be calculated for the vast majority of possible realizations of the sample.

New method enables faster billing review

We always take into account the specific structure of the invoices. Nurse and physician cases differ in the choice of a meaningful sample unit. A new method, developed in close cooperation with the investigating authorities, makes it possible to check invoices dealing with nursing care much faster. The period for which services are billed is important for the legal proceedings. Our method also covers this necessary periodization of the claim.

The approach can be used both in home care cases (SGB V and SGB XI) and in medical billing fraud cases (in-patient and out-patient). In particular cases, we specifically adapt the statistical methodology, for example, for very small rates of faulty claims, for cases of clearly observable varying rates, or for smaller but more expensive billing populations.

Our calculation of a guaranteed damage gives investigative agencies the ability to track cases involving a number of small individual claims that cannot be fully investigated simply because of the lack of time and staff. Because of our additional optimization of the number of cases prior to the sample survey, we are able to provide substantial relief to the investigative resources of the authorities. In some cases, an investigator only works one month on a review that used to take up to twelve months to complete.

2 *Example of a settlement profile for a population and the number of claims for a sample that has actually been checked; in light blue, the receipts objected to in this sample.*

NEWS

NEW FACES AND NEW PRODUCTS

The Financial Mathematics department continued to expand in 2017. Four new employees were hired to meet the growing demands of our project work.

This year again the main task of our department was the classification of pension rates for the Pension Product Information Center (PIA). In addition, we successfully marketed two new software packages: the ALMSim Path Generator and the redesigned anomaly detection software. A marketable software product is now available in all three of the department's priority research areas.

The Fraunhofer internal WISA for "Risk management for Insurance Companies" was also successfully completed. Several new customers were acquired, for example, BMW Bank with a project aimed at forecasting the residual value of leased vehicles.

TALENTA PROGRAM – FINANCIAL AID FOR RESEARCH CAREERS

Two staff members, Ria Grindel and Dr. Elisabeth Leoff, were accepted into the Fraunhofer-Gesellschaft TALENTA program. Both appreciate this support at the start of the careers and to further their career planning in applied research. Our department's mathematical competence was also emphasized by several scientific publications and completed doctorates in 2017.

OUTLOOK 2018

Our proposals for major research projects for 2018 in the priority areas of data science and the energy economy were successful. We plan to develop new methods for forecasting time series and to introduce our expertise in the field of machine learning in "ML4P" (Machine Learning for Production), a Fraunhofer showcase project.

The "ENets" project (Stochastic modeling and control of the power grids of the future) combines innovative models for the energy market with the modeling of electrical and gas grids. This project is sponsored by the German Federal Ministry of Education and Research (BMBF).

Front, left to right: Ria Grindel, Franziska Diez, Simon Schnürch, Dr. Andreas Wagner, Philipp Mahler, Prilly Oktoviany, Dr. Elisabeth Leoff, Wieger Hinderks, Christian Laudagé, Prof. Dr. Ralf Korn, Dr. Büşra Temoçin, Dr. Robert Knobloch, Robert Sicks, Dr. Jörg Wenzel, Dr. Johannes Leitner, Dr. Roman Horsky