

GOR-AG: Praxis der  
Mathematischen  
Optimierung  
Dr. Jens Schulz

Mail: [schulz-gor@gmx.net](mailto:schulz-gor@gmx.net)

Herewith, we invite you to the 106<sup>th</sup> meeting of the GOR working group “Practice of Mathematical Optimization” hosted by Zalando SE. This meeting is planned to be held in person (or virtually if circumstances so require) with the topic

## Applied Methods from Mathematical Optimization and Machine Learning for e-commerce

The workshop takes place in Berlin hosted by Zalando SE on **Thursday and Friday October 6-7**. The working language will be English to be inclusive for a non-German speaking audience.

Note that the participation in a GOR-AG-Workshop for non-members is subject to a registration fee, unless you are a speaker or a host. Given the uncertainty of Covid, travel restrictions, and company policies, we strongly advise you to book your stay and travel accordingly. Cancellation of the on-site event may occur on short notice, and the organizers will waive the registration fee but will not refund any other cost.

Please, register no later than September 30<sup>th</sup> via <https://redseat.de/pmo106>

The latest information on the meeting is available on the homepage of the GOR (<http://www.gor-ev.de/arbeitsgruppen/praxis-der-mathematischen-optimierung/real-world-optimization>).

Yours sincerely,

Jens Schulz, Julia Kallrath, Josef Kallrath  
(GOR AG)

Torsten Gellert  
(Zalando SE)

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**Vorstand**

Prof. Dr. Alf Kimms (Vorsitz)  
Prof. Dr. Alexander Martin (Arbeitsgruppen)  
Dr. Jens Schulz (Finanzen)  
Prof. Dr. Peter Letmathe (Tagungen)

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# Applied Methods from Mathematical Optimization and Machine Learning for e-commerce

## Specific aims

Methods from mathematical optimization have become key ingredients of modern digitalization, decision-making and automation initiatives across industry.

In recent years, the methods of artificial intelligence have improved a lot and have become a powerful addition to the more classical methods.

E-commerce by its nature has already made a shift into a digitized business model driven by advanced analytic methods and successfully applying hybrid algorithms that combine techniques of mathematical optimization with machine learning – with applications in network design, warehousing & storage, pricing & forecasting, to name only a few.

The underlying data and models are huge and steer two research directions:

Firstly, how to efficiently solve large models in strategic and real-time use case and secondly, how to make decisions and take actions from applying such methods. This is certainly an omnipresent theme in many industries. Hence, in this workshop we explicitly (though not exclusively) welcome to exchange on learnings across industry on solving large real-world problems based on hybrid methods from mathematical optimization and machine learning.

## About Zalando

Zalando connects customers, brands and partners in 23 countries. What started as a Berlin-based online shoe store in 2008 has transformed into a leading European online platform for fashion and lifestyle in just a few years. This achievement was enabled through great passion and the strong business sense of our team of more than 17,000 talents from 140 countries.

Complex business challenges arise in many areas of Zalando's operations. Engaging customers with inspiring recommendations and discounts, and handling logistics fast and efficiently to customers' satisfaction are just a few examples. With methods of machine learning integrated flawlessly with mathematical optimization, holistic decisions making across the company enable true customer centricity.

The core of this 1.5 day workshop will consist of an attractive schedule of talks covering a broad range of mathematical techniques and real world applications. As usually, we will reserve plenty of time for informal exchange and networking.

In talks of 15+5min, 25+5min or 40+5min duration, experts from practice and research will address problems and solutions.

If you are willing to contribute a talk, please feel free to contact any of the organizers.

Jens Schulz ([schulz-gor 'at' gmx.net](mailto:schulz-gor@at.gmx.net))

Julia Kallrath ([julia.kallrath 'at' h-da.de](mailto:julia.kallrath@at.h-da.de))

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## The following speakers are confirmed:

**Pirmin Fontaine (Catholic University of Eichstätt-Ingolstadt)**

A Branch-and-Repair Method for 3D Bin Selection and Packing in E-Commerce

**Torsten Gellert (Zalando)**

Challenges in Large Scale Article Discounting

**Jasmin Classen and Sander van Aken (Flix SE)**

Matching demand and supply at Flix – a combined ML and OR approach to support network planning

**Meinolf Selman (CTO, InsideOpt)**

Modern Hybrids

**Andreas Söhlke (Deutsche Bahn)**

AI/OR Combinations for Solving Railway Dispatch Problems

**Alexander Tornede (Uni Hannover)**

Layers of AutoML

**David Winkelmann and Jakob Schulte (University of Bielefeld)**

Capacitated Vehicle Routing with Stochastic Loading Constraints

**Jonas Witt (Deutsche Post DHL)**

Courier-oriented route optimization for last-mile delivery at Deutsche Post

**Stephanie Ziegenhagen, Francisco Madaleno, Amin Jorati (Zalando)**

Mathematical Optimization Meets Machine Learning to Optimize Stock Distribution at Zalando

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## The venue & accommodation

### Venue

The meeting is hosted by Zalando SE. It takes place at

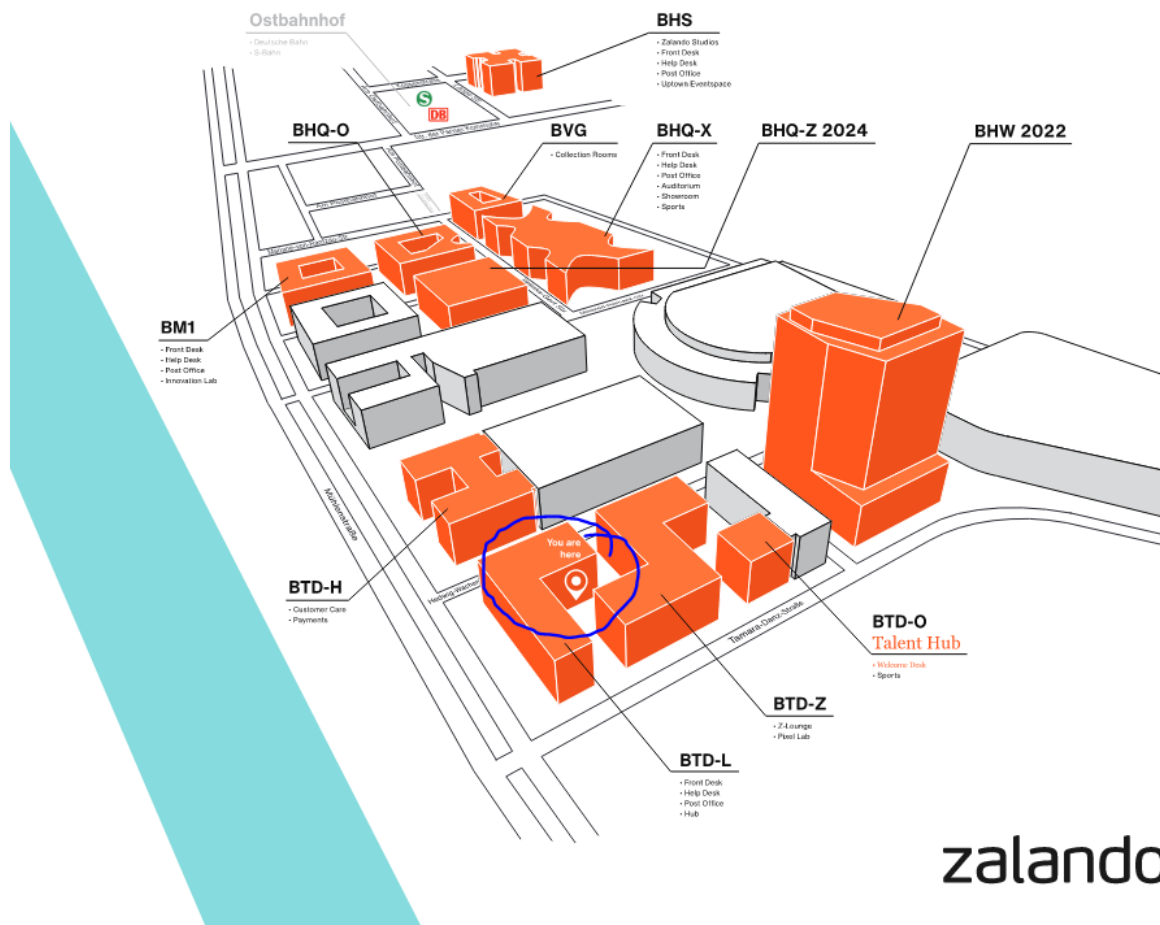
BTD-L Hub  
Tamara-Danz-Straße 1  
10243 Berlin  
Germany

How to get there?

600m walking distance from U+S Bahn Station Warschauer Straße  
alternatively

via S Bahn Station Ostbahnhof either 1,100m walking distance or Bus 300 till Tamara-Danz-Str., right in front of the venue

## Welcome to our Campus



zalando

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## Conference dinner

About one month before the event and according to the number of registrants, we will arrange a nice venue in the vicinity to the conference location for the conference dinner.

## Accommodation

Berlin offers a variety of hotels, pensions and b&b's. Overall room availability per hotel looks rather low. Hence, we will not organize any special rates nor reserve locations. Bear in mind that due to external circumstances, the organizers may decide to cancel the event, or switch to an online format. We cannot refund any cost incurred. Please, arrange your bookings accordingly.

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106<sup>th</sup> meeting of the GOR working group "Real World Optimization" at Zalando SE

## **Applied Methods from Mathematical Optimization and Machine Learning for e-commerce**

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Thursday, October 6, 2022: 09:00 – 18:00

- 08:30-09:00 *Feel free to join and grab your badge*
- 09:00-09:30 **Opening and Welcome** (Jens Schulz & Torsten Gellert)
- 09:30-10:15 **Torsten Gellert (Zalando)**  
Large Scale Discount Optimization with Business Targets
- 10:15-10:45 ----- Coffee Break -----
- 10:45-11:30 **Andreas Söhlke (Deutsche Bahn)**  
AI/OR Combinations for Solving Railway Dispatch Problems
- 11:30-12:00 **David Winkelmann and Jakob Schulte (University of Bielefeld)**  
Capacitated Vehicle Routing with Stochastic Loading Constraints
- 12:00-13:00 ----- Lunch Break -----
- 13:00-13:45 **Pirmin Fontaine (Catholic University of Eichstätt-Ingolstadt)**  
A Branch-and-Repair Method for 3D Bin Selection and Packing in E-Commerce
- 13:45-14:30 **Jasmin Classen and Sander van Aken (Flix SE)**  
Matching demand and supply at Flix – a combined ML and OR approach to support network planning
- 14:30-15:00 ----- coffee break -----  
----- Taking a Group Photo for the OR News and Press -----
- 15:00-15:45 **Peio Lahirigoyen (FICO)**  
Order picking in e-Commerce warehouses: Practical challenges and lessons learned
- 15:45-16:30 **Meinolf Selman (CTO, InsideOpt – virtual presentation)**  
Modern Hybrids
- 16:30-19:00 ----- Excursion -----
- 19:00-21:00 **Conference Dinner**

*All timings are still subject to change!  
They will be finalized 2 weeks before workshop*

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**Friday, October 7, 2022: 09:30 – 12:30**

- 07:30-09:00 ----- Breakfast at hotels -----
- 09:00-09:15 Welcome second day
- 09:15-10:00 **Alexander Tornede (Uni Hannover – virtual presentation)**  
Layers of AutoML
- 10:00-10:45 **Stephanie Ziegenhagen, Francisco Madaleno, Amin Jorati (Zalando)**  
Mathematical Optimization Meets Machine Learning to Optimize Stock  
Distribution at Zalando
- 10:45-11:15 -----coffee break -----
- 11:15-12:00 **Jonas Witt (Deutsche Post DHL)**  
Courier-oriented route optimization for last-mile delivery at Deutsche Post
- 12:00-13:00 ----- Lunch -----
- 13:00-13:45 **Round Table**
- 13:45-14:00 **Final Discussion – End of the Workshop**

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**Location: Zalando SE -- BTD-L Hub  
Tamara-Danz-Straße 1  
10243 Berlin; Germany**

*All timings are still subject to change!  
They will be finalized 2 weeks before workshop  
Friday may get extended if new talks are registered – due to Covid, some speakers have  
signaled interest but cannot yet commit.*

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## Abstracts

### **Pirmin Fontaine (Catholic University of Eichstätt-Ingolstadt)**

#### **A Branch-and-Repair Method for 3D Bin Selection and Packing in E-Commerce**

Since one challenge in parcel distribution is the high amount of unused space, finding the best-fitting parcel type and the associated packing pattern is important. In the literature, this problem is known as the three-dimensional bin packing problem with rotation. Knowing the right parcel type raises the question of the right parcel type portfolio. We address this by introducing the three-dimensional bin selection problem (3D-BSP). To solve the 3D-BSP, we introduce a decomposition method called branch-and-repair. We show that due to the relaxation a majority of binary decision variables in the master problem can be relaxed and weak combinatorial cuts are avoided without further lifting. Problem-specific acceleration techniques further improve the performance of branch-and-repair. In the numerical study, we show that branch-and-repair reduces the run time by more than two orders of magnitude compared to the mixed-integer programming formulation and instances with millions of binary decision variables and constraints are solved efficiently. The sensitivity analysis shows the trade-off between the costs of variety (depending on the number of parcel types) and costs for unused space. Compared to minimizing unused space, minimizing total costs increases unused space by 6 to 27 percent depending on the portfolio size.

### **Peio Lahirigoyen (FICO)**

#### **Order picking in e-Commerce warehouses: Practical challenges and lessons learned**

In various projects, we have been helping clients to improve eCommerce warehouse operations by leveraging applied mathematics to improve efficiency of several processes, from put away, picking, sorting, and packaging to shipping.

The business is driven by 2 main goals: maximizing delivery velocity and minimizing costs, while restricted by many (business, legal, and physical) constraints. In this talk, we will present several problems where machine learning, and mathematical optimization are combined using FICO's Xpress Suite, with special focus on practical challenges that require custom solutions. The talk will also address how the increasing development of automation in warehouses can be strengthened using such techniques.

### **Meinolf Selman (CTO, InsideOpt)**

#### **Modern Hybrids**

This talk summarizes our 15+ years of work on the use of Machine Learning for Search & Optimization. I review the four main approaches that we invented during this time. Since learning during search takes effort, it should not surprise that we designed three of these approaches for a particular target range of total function evaluations: from few tens of dozens, to thousands, to many hundreds of thousands of function evaluations. The last hybrid I review regards a surrogate-based approach for optimization under stochastic uncertainty. The wonder of this research area is that each of these four methods defines the state of the art in its respective area, giving significant empirical evidence that learning to optimize can be highly effective.

### **Speaker: Sander van Aken, Jasmin Classen (Flix SE)**

#### **Matching demand and supply at Flix – a combined ML and OR approach to support network planning**

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Flix is Europe's largest player in the long-distance bus market. Network planning enables unlocking Flix' vision of providing smart, sustainable and affordable travel for everyone. Matching supply and demand is key to ensure profitability for both Flix and its bus partners, who operate the network. Our network planners create timetable, bus and driver schedules, transporting tens of millions passengers in 40 different countries.

Within a complex operating environment, they balance demand for hundreds of thousands of possible connections and different travel patterns, with the cost of operating a high-quality network. Planning supply is subject to a wide variety of - often country-specific - constraints such as driver working rules, and station platform availability. Although they can rely on a wide range of high-quality data sources and supporting tools, it remains a very manual and experience-based process.

We believe that advanced analytics can aid users to plan customer-oriented and profitable schedules in a scalable way. During this presentation, we will give insights into how we connect machine learning methods for forecasting demand, with operations research algorithms to plan supply in a holistic way. We will dive into the inherent interdependency between supply and demand, and how this leads to unique challenges in terms of methodology, technology, and explainability.

### **Andreas Söhlke (Deutsche Bahn) AI/OR Combinations for Solving Railway Dispatch Problems**

The need for increased capacity in rail operations continues to grow. With a more powerful route network, the sector initiative "Digitale Schiene Deutschland" can make a significant contribution to reducing CO2 emissions and achieving the Federal Government's climate targets. However, frequent and dense traffic requires better tools for real-time control which are responsible to reduce delays after disturbances or disruptions and will provide punctual and reliable rail services.

In today's network operations, humans in operation centres make a large number of local dispatching decisions – about waiting times, train sequences, track changes, rerouting and more. Together, these dispersed decisions determine the traffic flow on the overall network. With our approaches, we want to solve the highly complex optimisation problem with thousands of automated decisions across the network, made in the shortest possible time. With classical, analytical methods alone, a problem of this size cannot be mastered in the short time required.

In this talk, we will give an overview of the approaches with Deep Reinforcement Learning, mathematical models, and their hybridization, that are being developed for the future Capacity and Traffic Management System CTMS of DB Netz. In particular, we outline the shortcomings of pure OR and AI approaches and suggest how the integration could cope with extremely large network sizes in short times.

### **Alexander Tornede (Uni Hannover) Layers of AutoML**

Automated machine learning (AutoML) is a key technology to enable efficient development of machine learning applications. By optimizing several design decisions of ML packages, it supports users and developers in deciding on well-performing hyperparameters, predictive algorithms, pre-processing techniques, neural architectures and entire pipelines for their application and dataset at hand. Over the last decade, AutoML researchers proposed different kinds of approaches for AutoML on different layers of the underlying ML algorithm; it

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started from a simple black-box view of the ML algorithm, went to exploiting certain characteristics of ML algorithms in a gray-box manner, and even achieved direct meta-learning of the ML training algorithm at hand. In my talk, I will summarize this development and highlight the different underlying optimization tasks being addressed by these different layers of AutoML.

**David Winkelmann and Jakob Schulte (University of Bielefeld)**  
**Capacitated Vehicle Routing with Stochastic Loading Constraints**

In times of rising transportation costs and increasing environmental pollution, for companies the efficient transport of goods is becoming more and more important. Companies must determine not only optimal truck routes, but also whether packages can be transported together within a vehicle.

However, the transport of goods is particularly challenging when the packages have very heterogeneous shapes. Due to complex loading constraints it is not clear how many packages can be loaded into a vehicle and a time consuming packing problem must be solved. However, if several thousand heterogeneous packages must be shipped every day, it is almost impossible to derive a good packing plan for each vehicle. To tackle this optimization problem, we use a binary regression model to estimate whether all packages assigned to a vehicle will fit, rather than compute a packing plan in a time consuming manner. We integrate a binary regression into a mixed integer programming model using Taylor series expansion and solve the resulting capacitated vehicle routing problem with stochastic loading constraints with Gurobi to optimality.

**Jonas Witt (Deutsche Post DHL)**  
**Courier-oriented route optimization for last-mile delivery at Deutsche Post**

Traditional last-mile delivery planning purely based on optimization methods often lacks important real-life aspects and thus does not satisfy relevant operational requirements. Only experienced couriers have tacit knowledge about the delivery area and its customers, forcing them to deviate from planned routes. They know where to find good parking spots, when to best approach certain business customers, and which neighbors to approach at what times when the actual recipient is not at home. This tacit knowledge is almost impossible to collect and maintain, let alone to incorporate in optimization algorithms.

Thus, we at Deutsche Post DHL developed an algorithm following a different approach: We aim at implicitly learning about this tacit knowledge from historical tours and combine this with optimization algorithms to plan routes that an experienced courier would choose. In this talk we will present details of our algorithm, which incorporates machine learning, statistics, and optimization in a novel way. Furthermore, we show how it impacted last-mile delivery planning at Deutsche Post after its rollout across Germany.

**Stephanie Ziegenhagen, Amin Jorati, Francisco Madaleno**  
**Mathematical Optimization Meets Machine Learning to Optimize Stock Distribution at Zalando**

Zalando has a network of 13 warehouses and 26 return centers serving more than 49M customers in 25 European countries. The scale at which we operate gives rise to a variety of optimization problems, which in turn require a deep understanding of customer behavior. In this talk, we present two stock distribution problems and the demand forecasting used to solve them.

Demand Prediction is modeled as a time series forecasting problem at the individual article level. We present our machine learning model for the demand forecasting problem. The

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model consists of a deep Recurrent Neural Network and produces probabilistic forecasts. We give an overview of the features, architecture, and the loss function of this model. We then focus on two optimization problems that use this forecast, namely the network item distribution problem and the in-warehouse item relocation problem.

In the item network distribution problem, items are moved between warehouses: We need to ensure that for each country, the warehouses serving that country have the article assortment and stock quantities that best fulfill the country's expected demand. Our objectives are to maximize sales and minimize delivery times and costs. We discuss the algorithm currently used to make distribution decisions and present some results.

The in-warehouse item relocation problem is defined at the warehouse level. A warehouse contains various storage areas with different capacities and speed for collecting one item. Given a constant stream of incoming and outgoing item flows, we can relocate items between storage areas to achieve a distribution that is optimal for the demand reduced to a warehouse. We present a formalization of the problem and prospective approaches to solve it.

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# CVs

**Jasmin Classen** is a Data Scientist in Flix' network planning domain. Her team builds analytics, data science and software products to enable data-driven decision making and intelligent automation for network planners. Outside work she hosts the podcast CorrelTalk presenting projects that apply Data Science for the social good.

**Pirmin Fontaine** is an Assistant Professor of Operations Management at the Catholic University of Eichstätt-Ingolstadt, Ingolstadt School of Management. His main research interests are in large-scale optimization and decomposition techniques with applications in logistics, transportation, mobility systems, and supply chain management. He is a recipient of the German Operations Research (GOR) Doctoral Dissertation Prize.

**Johann Hartleb** works as an Operations Research expert within the "Digitale Schiene Deutschland" team that is responsible to develop the future traffic management system of DB Netz. Prior to his work at DB, Johann researched at Erasmus University Rotterdam and University of Stuttgart how passenger demand models can efficiently be integrated into public transport optimization.

**Andreas Söhle** has a role as product owner and optimization expert within the "Digitale Schiene Deutschland" team that is responsible to develop the future traffic management system of DB Netz. He is dedicated to use his experience in optimization and software development to create solutions for complex real-world problems.

**Sander Van Aken** is Senior Operations Research Engineer within Flix' network planning optimization team. The team develops OR algorithms, which are embedded in software products, to support network planners in their daily work. Before Flix, Sander worked a couple of years as simulations and data science consultant for various players in the public transportation sector.

**David Winkelmann** is Research Assistant at Bielefeld University, Department of Management Science and Business Analytics, Chair of Management Accounting and Operations Management. He holds a Bachelor's and Master's degree in Business Administration and Economics earned from Bielefeld University. His research topics of the PhD thesis focus on combining Operations Research and Data Science with applications in economics, especially in logistics operations. His research bears a strong practical background, collaborations with companies, also in the project presented.

**Jonas Witt** is working as Operations Research Scientist in Deutsche Post DHL Group's Data Analytics Center of Excellence working on last-mile delivery and network design projects. He holds a doctoral degree in Mathematics from RWTH Aachen University on decomposition methods for mixed-integer linear programming. Before joining Deutsche Post DHL he worked as Data Analytics Consultant.

**Stephanie Ziegenhagen** is part of the team handling network stock distribution. She has a background in mathematics and has been working as an Applied Scientist for Zalando for close to 3 years now. **Amin Jorati** is working on time series forecasting as part of a dedicated team in logistics algorithms at Zalando, where he's been working as an applied scientist for the past two years. His academic background is in theoretical computer science. **Francisco Madaleno** is part of team handling in-warehouse item distribution within the logistics and

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algorithms department. His background is in aerospace engineering and joined Zalando 1 year and half ago as an applied scientist for the pricing and forecasting department.

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