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4 Reasons Why Data Scientists Should Add Mathematical Optimization to Their Analytics Toolbox

Management Paper



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It has been said that “data is the new oil”—and it’s true that data is indeed a valuable commodity in today’s business world. Most companies have the capability to collect and process huge quantities of data, but few are actually able to utilize their data to generate insights and predictions and make decisions.

To extract the maximum business value out of their data (by leveraging it to make optimal decisions), companies must have the right advanced analytics technologies.

Today’s data scientists need to have a full analytics toolbox at their disposal. But which tools do they actually need?

In addition to machine learning, visualization, heuristics, and other common tools, mathematical optimization is becoming an essential technology for more and more data scientists.

Indeed, a growing number of data scientists are adding mathematical optimization into their analytics arsenals—as they are discovering that mathematical optimization is capable of rapidly tackling complex, real-world problems (that involve conflicting tradeoffs among various business objectives and an astronomical number of possible solutions) and delivering optimal solutions.

Mathematical optimization has been successfully applied by numerous companies across various industries—including finance, telecommunications, manufacturing, electrical power, aviation, and transportation—to optimize their operational efficiency, resource utilization, and profitability.

However, many data scientists are still reluctant to explore and embrace mathematical optimization technologies—and opt instead to use machine learning, deep learning, and heuristic techniques to solve their business problems and drive their decisions.

In this management paper, we will discuss four key reasons why every data scientist should add mathematical optimization into his or her analytics toolbox.



4 Reasons Why Data Scientists Should Add Mathematical Optimization to Their Analytics Toolbox



Reason #1: Mathematical optimization technologies are powerful, fast, and easy to use

In the past, many data scientists steered clear of mathematical optimization technologies as they had the perception that these technologies were too slow and that mathematical optimization models were too difficult to build and maintain. But this is simply not the case.

With advances in computing power, algorithms, and data availability and quality over the last few decades, it is now possible for mathematical optimization technologies to rapidly and effectively handle even the most complicated combinatorial optimization problems—and generate globally optimal solutions. Just consider this fact: A mathematical optimization problem that would have taken 55 years to solve in 1991 can be solved today (using a commercial solver) in one second!

And, with recent ease-of-use improvements to mathematical optimization technologies, data scientists with some basic mathematical programming skills can easily learn how to build, deploy, and maintain mathematical optimization applications.

Armed with these mathematical optimization technologies, data scientists can rapidly and automatically generate globally optimal solutions to their complex business problems—and use those solutions as the basis for optimal decisions that maximize their company's operational efficiency.

When facing a complex business problem, today's data scientists can choose which problem-solving approach they want to use: heuristics (which are useful in some situations where the problem cannot be defined mathematically, but are unable to guarantee globally optimal solutions) or mathematical optimization.



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Reason #2: Mathematical optimization and machine learning can be used in a complementary manner

More and more companies are developing applications that combine mathematical optimization and machine learning as these two technologies—when deployed together—form quite a dynamic duo.

Simply put, machine learning enables you to generate predictions, while mathematical optimization empowers you to make decisions. In today's highly complex and constantly changing business environment, companies must have the capability to:

- Predict what is going to happen in the future.
- Use those predictions to help decide on the best courses of action.

Mathematical optimization and machine learning—when they are utilized in a complementary manner—can give you this capability. With mathematical optimization and machine learning working in concert, you can look into the future and foresee likely business conditions and outcomes, and then utilize those predictions to help you make optimal decisions.

Mathematical optimization technologies can leverage machine learning-based predictions by using them as input (i.e. decision constraints) for mathematical optimization-generated solutions and decisions.



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Let's take a look at some real-world examples that illustrate the power of this mathematical optimization and machine learning combination:

Logistics

- Machine learning enables logistics providers to predict future supply chain issues that may arise.
- Using those machine learning-based predictions as constraints, mathematical optimization enables logistics providers to decide on the most cost-effective way to reroute shipments.

Cybersecurity

- Machine learning enables cybersecurity firms to predict when and where the next cyberattacks will occur before they happen.
- Using those machine learning-based predictions as constraints, mathematical optimization enables cybersecurity firms to decide which investigators to assign to potential threats based on skill sets, potential damage from an attack, and other factors.

Retail

- Machine learning enables retailers to predict customer demand for specific products on a daily basis.
- Using those machine learning-based predictions as constraints, mathematical optimization enables retailers to decide on how to dynamically, optimally adjust prices for those products to maximize profits and customer satisfaction.

Airlines

- Machine learning enables airlines to predict aircraft engine failures days before they happen.
- Using those machine learning-based predictions as constraints, mathematical optimization enables airlines to decide on the best time to schedule maintenance activities in order to minimize operating costs and aircraft downtime.

Financial Services

- Machine learning enables investment managers to predict fluctuations in securities prices and identify investment opportunities.
- Using those machine learning-based predictions as constraints, mathematical optimization enables investment managers to determine how to optimize the allocation of assets in a portfolio.

These are merely a few examples that show how, by combining machine learning and mathematical optimization in a single application, you can unlock the true value of your business data by using it to make optimal business decisions (based on your predictions and other constraints, as well as all relevant decision variables and business objectives).



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Reason #3: Mathematical optimization can be used to improve the accuracy of machine learning-based predictions

The relationship between mathematical optimization and machine learning is a symbiotic one: machine learning-based predictions (as we discussed above) can be used to improve mathematical optimization-generated solutions, while mathematical optimization-generated solutions can be used to improve the accuracy of machine learning-based predictions.

How does the latter process work? It's simple: Mathematical optimization-generated solutions can be fed back into machine learning models, and utilized as machine learning-model training features and machine learning-model scoring and inferencing inputs.

In this way, mathematical optimization-generated solutions can help shape, retrain, and improve machine learning models—which often decay over time.

Reason #4: Mathematical optimization can be used to solve classification and prediction problems

Leading researchers in the data science field have started using mathematical optimization to tackle classification and prediction problems—which have been traditionally addressed by using only machine learning algorithms.

There are several advantages of using mathematical optimization to solve classification and prediction problems:

- Mathematical optimization improves the interpretability of machine learning predictive models. Having an interpretable model that subject matter experts (SMEs) can understand and trust is critical—particularly in “life-or-death” classification problems like predicting cancer, heart disease, or criminal recidivism. In these and other instances, mathematical optimization models—which have feature weights that are associated with particular variables—are easier for SMEs to grasp and trust than their machine learning counterparts.
- With mathematical optimization, you can easily add constraints and preferences to your prediction or classification models and effectively control the tradeoff between accuracy and interpretability. The flexibility of mathematical optimization enables data scientists to fine tune their models based on the experience and expertise of each SME.



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Due to these factors, mathematical optimization is being used by leading researchers in the data science field today to build and train interpretable models for classification and prediction problems, and generate optimal solutions that they (and the SMEs they work with) can rely on to make decisions.



Conclusion

For the reasons highlighted in this management paper, a growing group of data scientists have added mathematical optimization into their analytics toolbox.

Mathematical optimization is being used by data scientists and leading researchers today in an ever-expanding range of applications—sometimes in combination with machine learning, and other times on its own to address classification and prediction problems.

With a full set of analytics tools including mathematical optimization, data scientists can maximize the business value of their data—by using it make accurate predictions and optimal decisions.



