GUROBI OPTIMIZATION

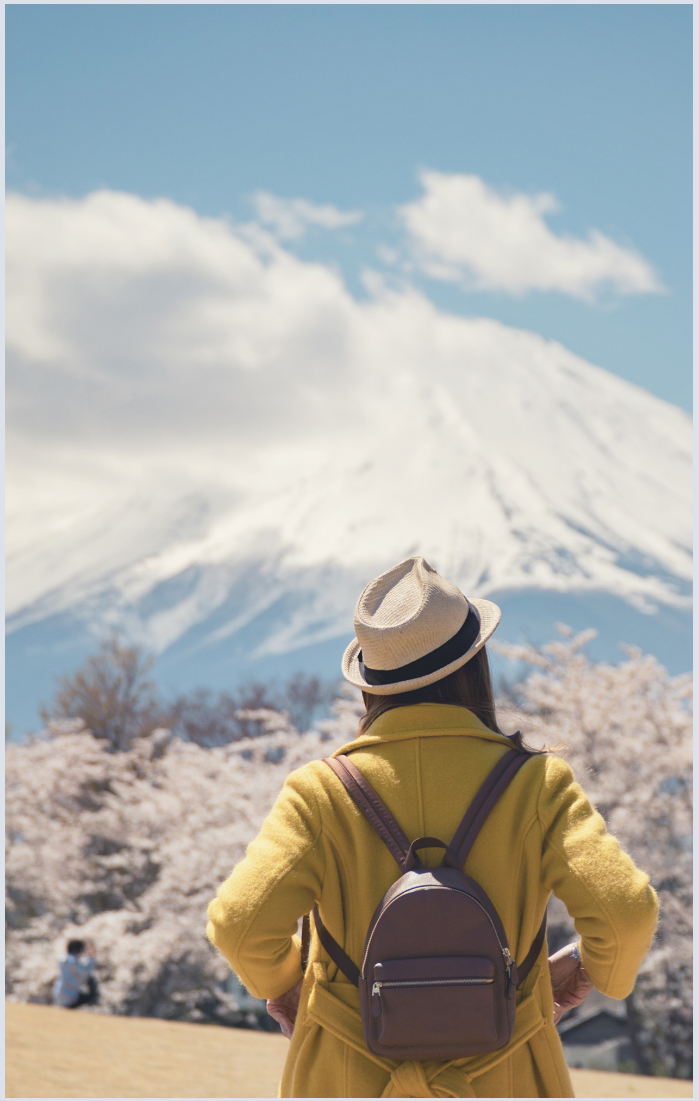
Aimpoint Digital

Add Decision Making to Your Databricks Toolkit with Mathematical Optimization

Thursday, October 12th

Dr. Yash Puranik
Principal Data Scientist,
Aimpoint Digital

Jerry Yurchisin
Data Science Strategist,
Gurobi Optimization



Webinar Topics

- Introduction to mathematical optimization (MO), what it is, the problems it solves, and its relation to other problem-solving approaches
- The power of Databricks in handling vast datasets and its seamless integration with machine learning, setting the foundation for optimization
- A use case that shows the synergy of mathematical optimization and machine learning
- A couple important notes on using Gurobi in Databricks
- Resources to learn more on mathematical optimization

Intro to Mathematical Optimization

What is it? Who uses it? How does it compare to other approaches?

Optimization Across Industries

A few examples of the business problems solved

GUROBI OPTIMIZATION

Who uses math optimization?

Google, Microsoft, AIRFRANCE, Marriott HOTELS · RESORTS · SUITES, NFL, Uber, Walmart, hp, NASA, Apple, Coca-Cola, The Walt Disney Company, TESLA, citigroup, Starbucks, SAP, BOEING, CISCO, Audi

This is just a small sample of the 2,600+ companies who are harnessing the power of optimization with Gurobi.

What problems does it solve?

Tackling the Hardest & Most Scrutinized Problem in Scheduling: How the NFL Uses Gurobi to Create its Schedule Each Season

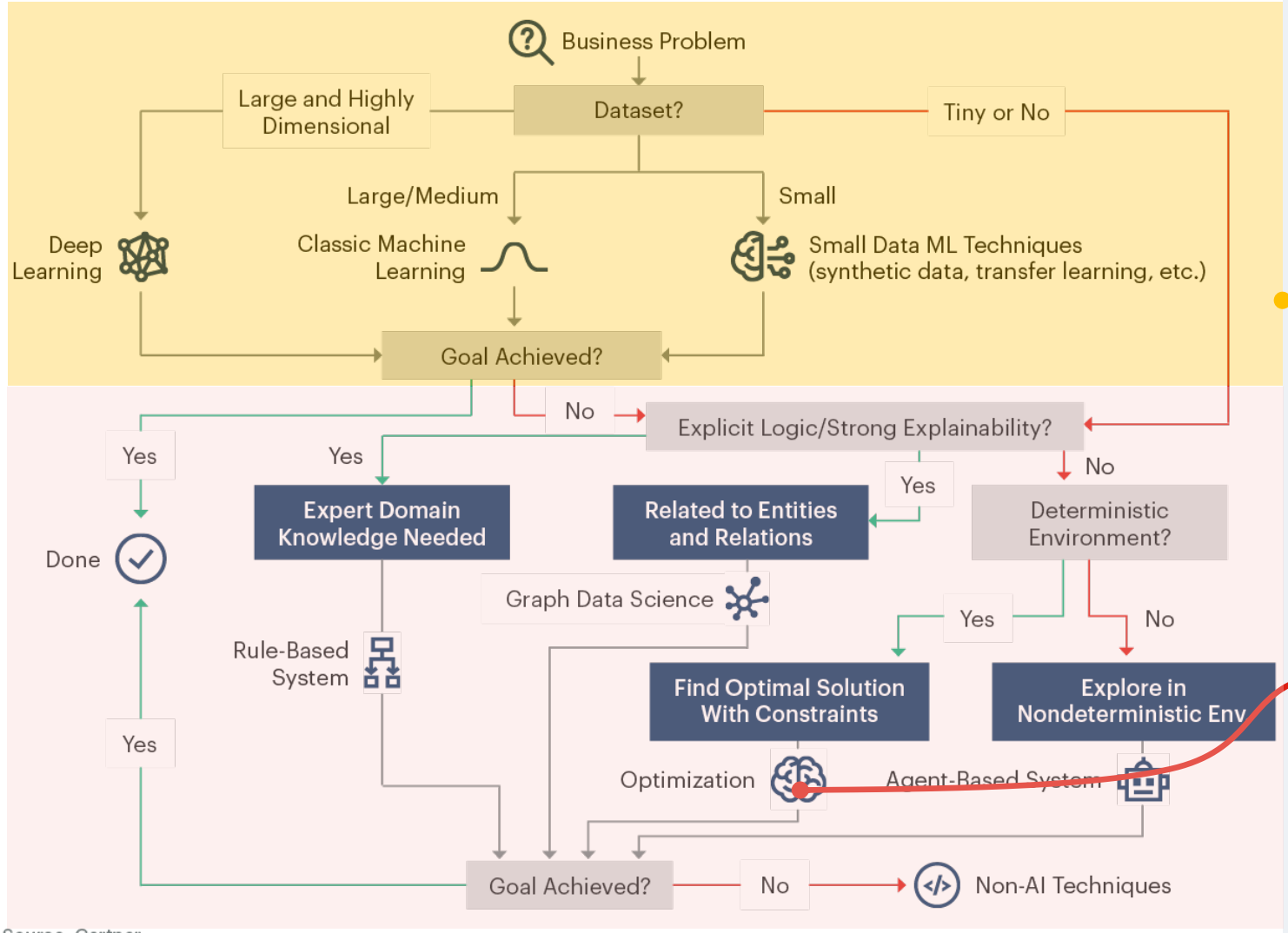
CONSULTING

Decision Lab: Optimizing Scarce Water Resources

CONSUMER PRODUCTS

Birchbox: Subscription Box Service Optimization

Possible AI Techniques Cheat Sheet



Source: Gartner

Note: If a single approach cannot solve the problem, a combination of techniques as in composite AI is a good option.

762946_C

Image from: *Go Beyond Machine Learning and Leverage Other AI Approaches*

Published 26 September 2023

Gartner

GUROBI OPTIMIZATION

Optimization in AI

Predictive analytics lives here

Decision making: Mathematical Optimization lives here

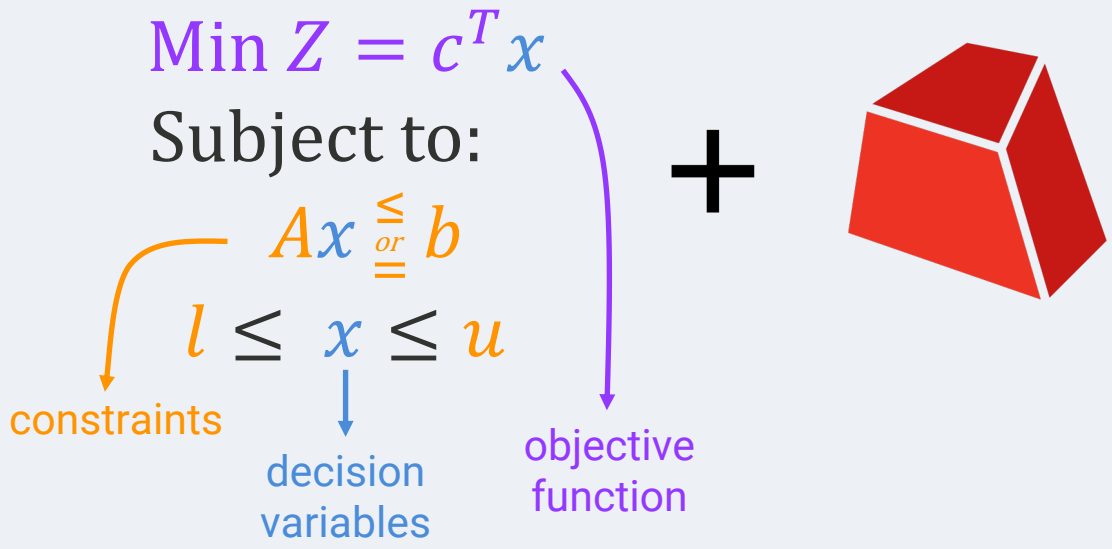
When is Math Optimization the Right Tool?

What is mathematical optimization?

An approach to solving complex decision problems where you want to…

1. Find the best course of action
2. Among *many* possibilities
3. That the decision maker can set
4. Given specified limitations
5. With some particular objective(s) in mind

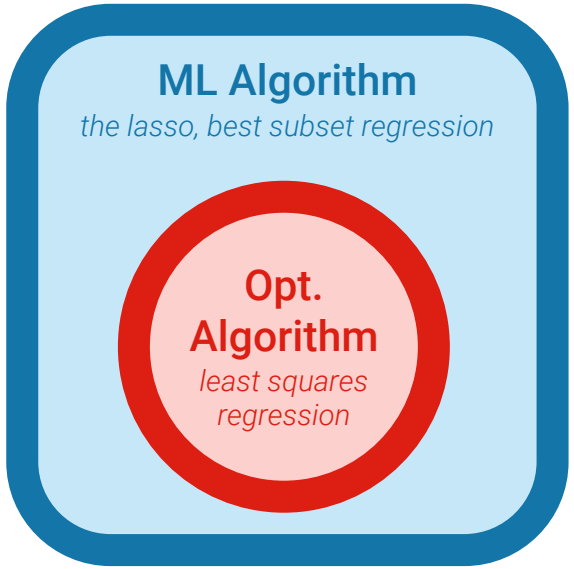
Decision problems to optimization models



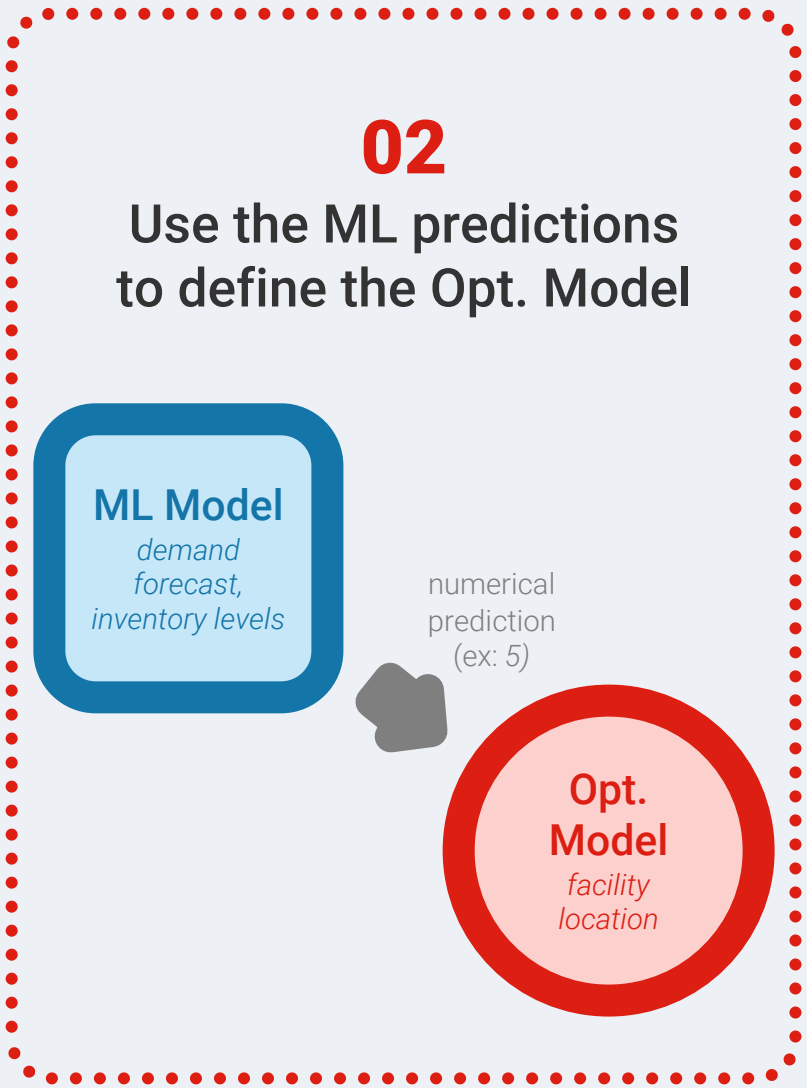
Combining Machine Learning and Optimization

GUROBI OPTIMIZATION

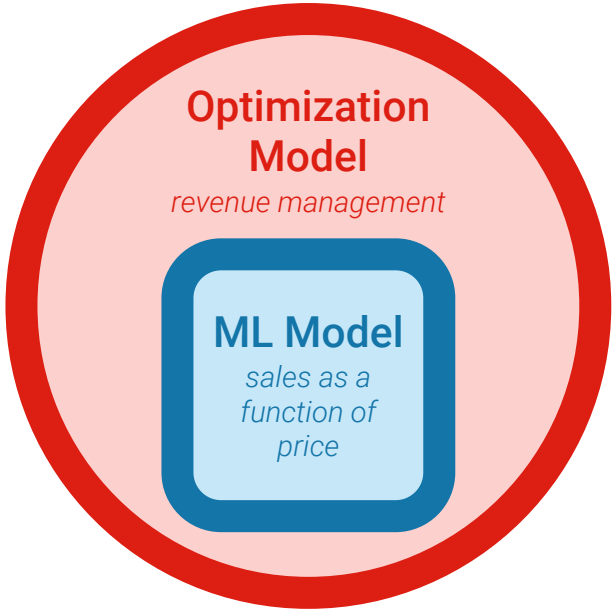
01
Training a ML model



02
Use the ML predictions to define the Opt. Model



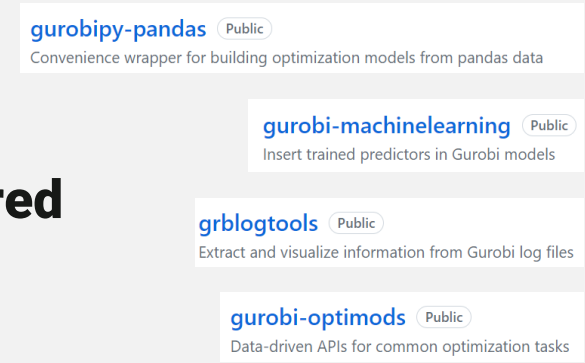
03
Embed a ML model inside the Opt. model



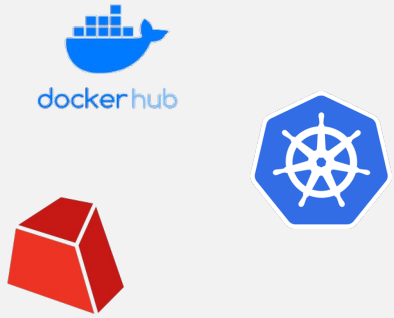
How do I Implement an Optimization Model?

Native Lightweight APIs

Most Popular: Python API & Gurobi sponsored packages



Flexibility in the Cloud



Open Source Modeling Packages

*not all Gurobi features are accessible from open source APIs, and model build time may vary.

Comparing Heuristics and Math Optimization

Heuristics		Math Optimization
Typically done very quickly, though complex approaches can take significant time	Development Time	Requires in-depth knowledge of the problem and detailed modeling of a complex system
Typically near instantaneous, but that depends on the "tool" created	Time to get Solution	Depends on size and structure of the problem – can be done in seconds
A "good" solution, but no guarantees of feasibility or known gap from optimal	Quality of Solution	A solution is guaranteed to be both feasible and globally optimal
Updating ranges from very little work to starting from scratch	Model Adaptability	Updating a model typically requires adding variables/constraints to the current model

Aimpoint

Digital

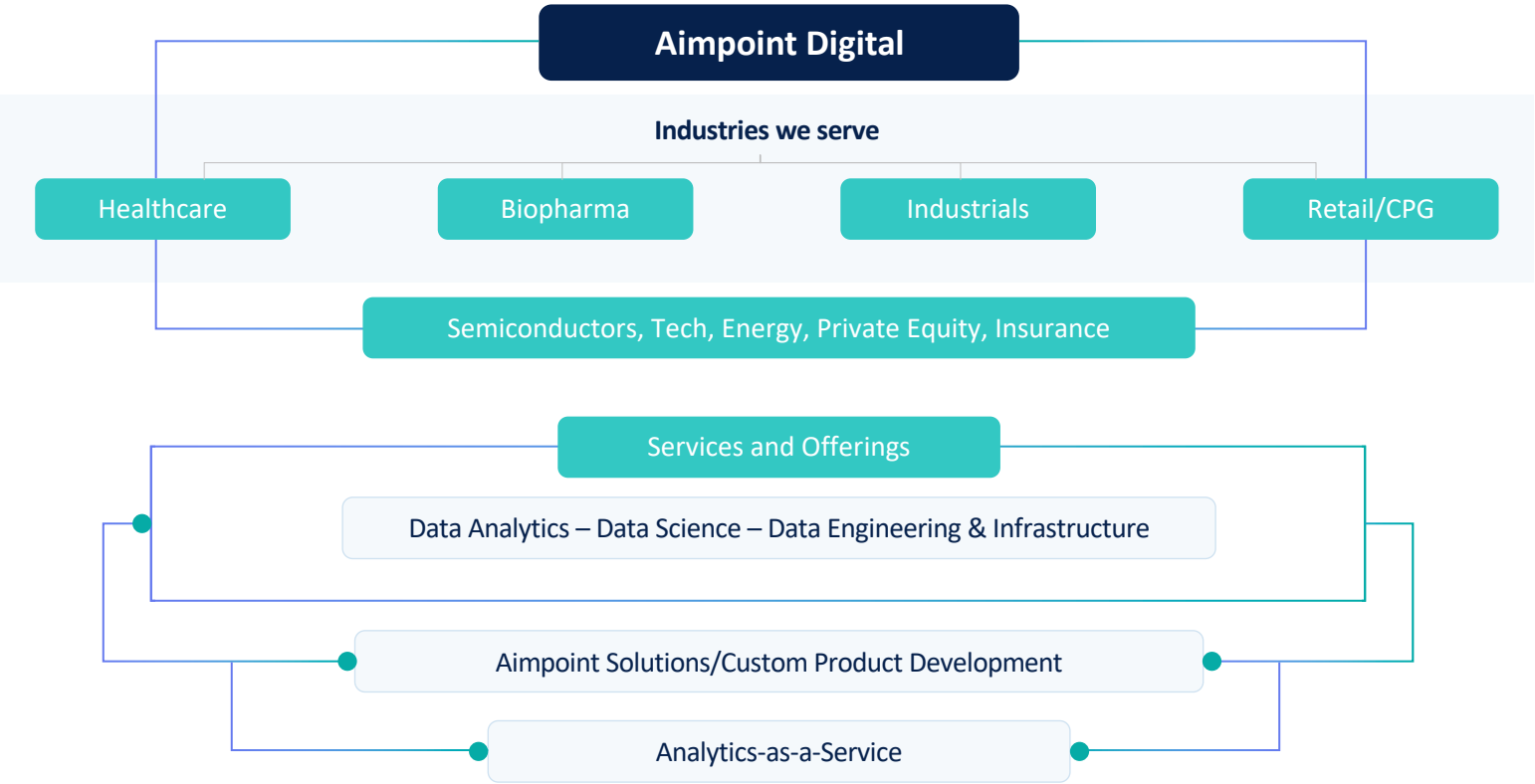
Aimpoint Digital

01

Aimpoint Digital

Aimpoint Digital

Our team consists of top-tier analytics experts, digital consultants, data scientists, and engineers who collaborate with our clients to drive sustainable economic growth from digital, data, and analytic capability development



Our Firm

Extensive track record delivering data and analytic engagements across the project continuum; from large scale enterprise transformations to advanced use case solutioning and continuous support

Three key elements of differentiation:

01 Level of Expertise

02 Client First Mentality

03 Service Economics

Our team has worked for some of the top management consulting & analytics firms in the world (e.g., BCG, Deloitte, PwC, The Information Lab, Accenture)

Aimpoint Digital

Our Areas of Expertise

Advisory + Enablement + Execution

Data Analytics

- Self-Service Analytics
- Data Visualization
- Tableau / Power BI Training
- Digital Process Automation
- API/Connector Development
- Custom Tools/Macro
- Spatial Analytics

Data Science

- Dataiku Training & Enablement
- Predictive Modeling
- Machine Learning Engineering
- AI Systems
- Mathematical Optimization
- Simulation

Data Engineering and Infrastructure

- Systems and Process Analysis
- Data Modeling
- ETL / ELT Pipeline Dev
- MLOps
- Data Architecture
- Infrastructure Modernization
- DataOps & FinOps

Analytics Strategy

- Digital Strategy & Roadmap
- Enablement
- Strategy
- Platform
- Operating Model
- Governance

Our Partners

alteryx · data iku · tableau · databricks · dbt · snowflake · GUROBI OPTIMIZATION

Aimpoint Digital

Aimpoint Digital

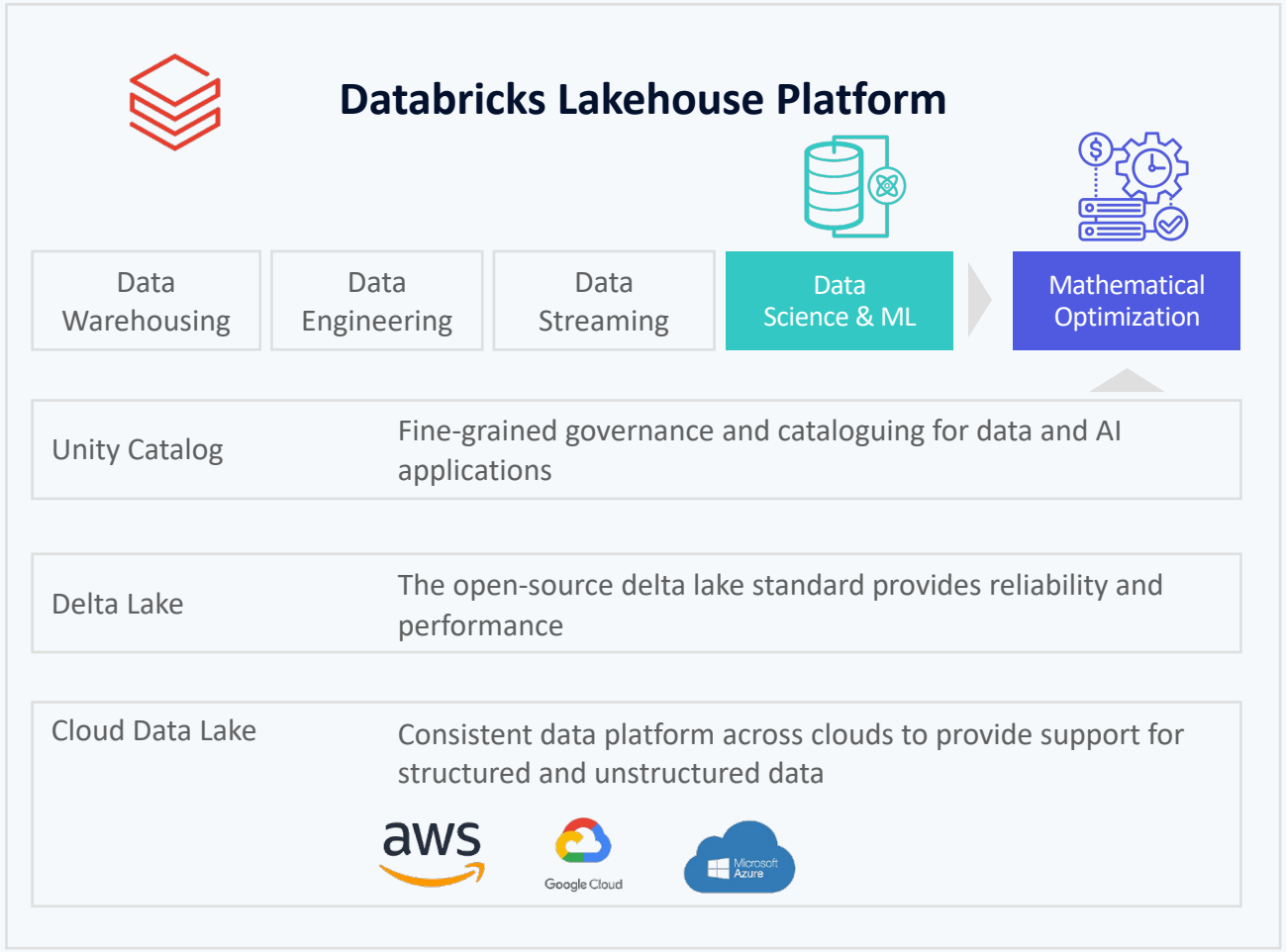
02

Lakehouse Platform

ML and optimization both rely on good understanding of the data and process to improve decision-making

	Optimization Science 	Data Science 
Value	Decision Intelligence/Decision Support	Inferences and Insights
Example	Production Scheduling	Predictive Maintenance
Techniques	Mathematical optimization, Simulation, Heuristics	Natural Language Processing, Computer Vision, Predictive Modelling, Gen AI
Tools	Python/Gurobi	SQL/Python, Spark, Tensorflow
Computation	Data needs are typically lower but compute needs are typically exponential	Large data needs and sophisticated storage/compute methods needed

Databricks is the pioneer Lakehouse Platform and it supports highly complex ML and OR workloads in a unified architecture



- Optimization models are consumers of processed data and ML models' output data
- Optimization models must be integrated into existing technological ecosystems
- Optimization techniques can enhance skills and value generated by the modern data scientist

Aimpoint Digital

03

Databricks Demo

Aimpoint Digital

04

Takeaways

Takeaways

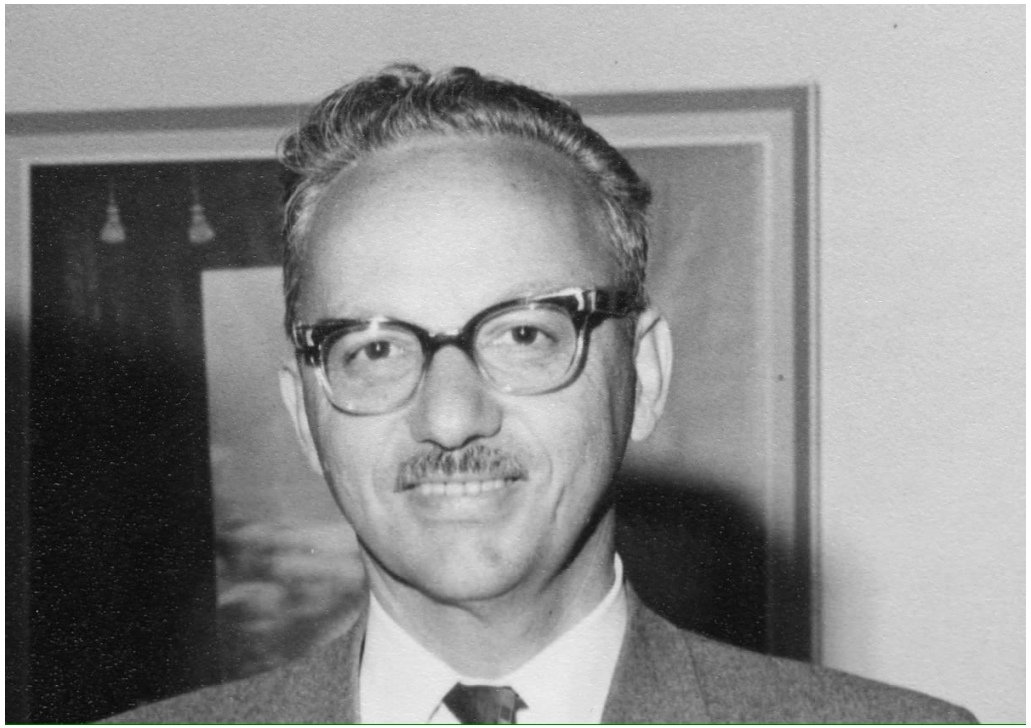
Data Scientist

Optimization is a powerful technology for a wide range of problems, with the goal of improving decision-making.

Optimization opportunities are likely when the business questions include:

- What is the best..?
- How much? How many?
- When?
- Which?

Optimization problems can be solved with many approaches including heuristics, reinforcement learning, dynamic programming and mathematical optimization.



"Linear programming is viewed as a revolutionary development giving man the ability to state general objectives and to find, … optimal policy decisions for a broad class of practical decision problems of great complexity." — George Dantzig

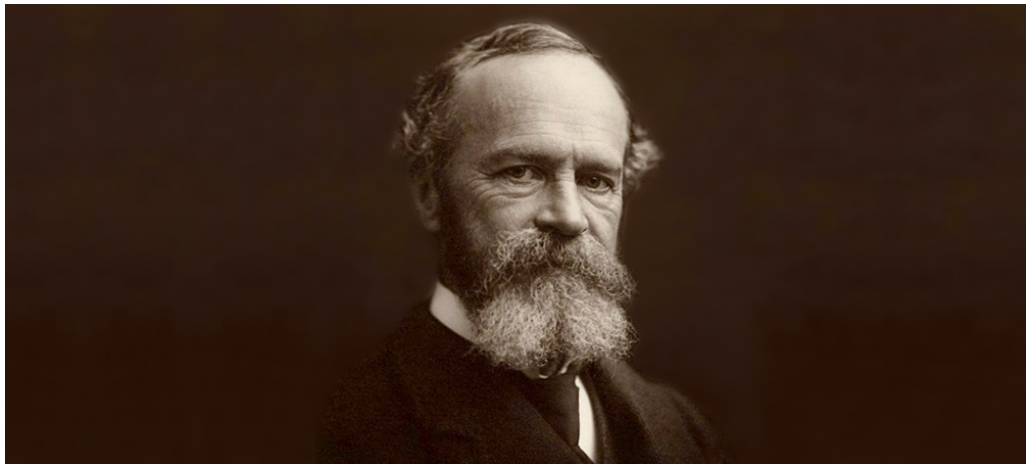
Aimpoint Digital

Takeaways

Optimization solutions are integrated into larger workflows including data pipelines, visualization/dashboarding, predictive models and prescriptive models

The deployment, long-term monitoring and maintenance of optimization solutions is critical to ensure long-term value is driven by optimization solutions

Keeping up-to-date with the technological trends and modern platforms like Databricks will ensure an OR Analyst's work finds widespread adoption



"We are like islands in the sea, separate on the surface but connected in the deep. "- William James

Aimpoint Digital

Aimpoint

Digital

Important Info on Using Gurobi in Databricks

A couple key items from our experts

Important Info on Using Gurobi in Databricks

GUROBI OPTIMIZATION

Gurobi's technical experts stay up to date on all the platform and development options available to optimization modelers, and Databricks in no different.

The computations needed for MO are different than ML

- **Gurobi supports only single node Databricks clusters**
  - Databricks is known for increasing performance by increasing **nodes**
  - Gurobi has researched parallelization and distributed computing for MO
    - Gurobi parallelizes well – typically adding **cores** will increase performance
    - Gurobi Distributed Add-On was developed to best utilize distributed computing for MO
- **GPUs are not supported by Gurobi**
  - Our R&D team has diligently researched using GPUs for MO
  - At this time, they are not yet they best way to run Gurobi's algorithms
- For more: www.gurobi.com/solutions/distributed-optimization/

Gurobi Resources to Learn More on Mathematical Optimization

Resources you need to start your optimization journey

Resources to Learn More

Notebook Examples

Repository of examples from various industries, with a set created specifically for data scientists

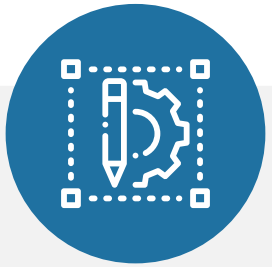
Webinars

Watch the Gurobi team show how to integrate ML and MO. Learn more about optimization and Gurobi's features

Burrito Game

This game illustrates the complexity of even the (seemingly) easiest of decision problems and is a great way to show the power of MO

burritooptimizationgame.com/

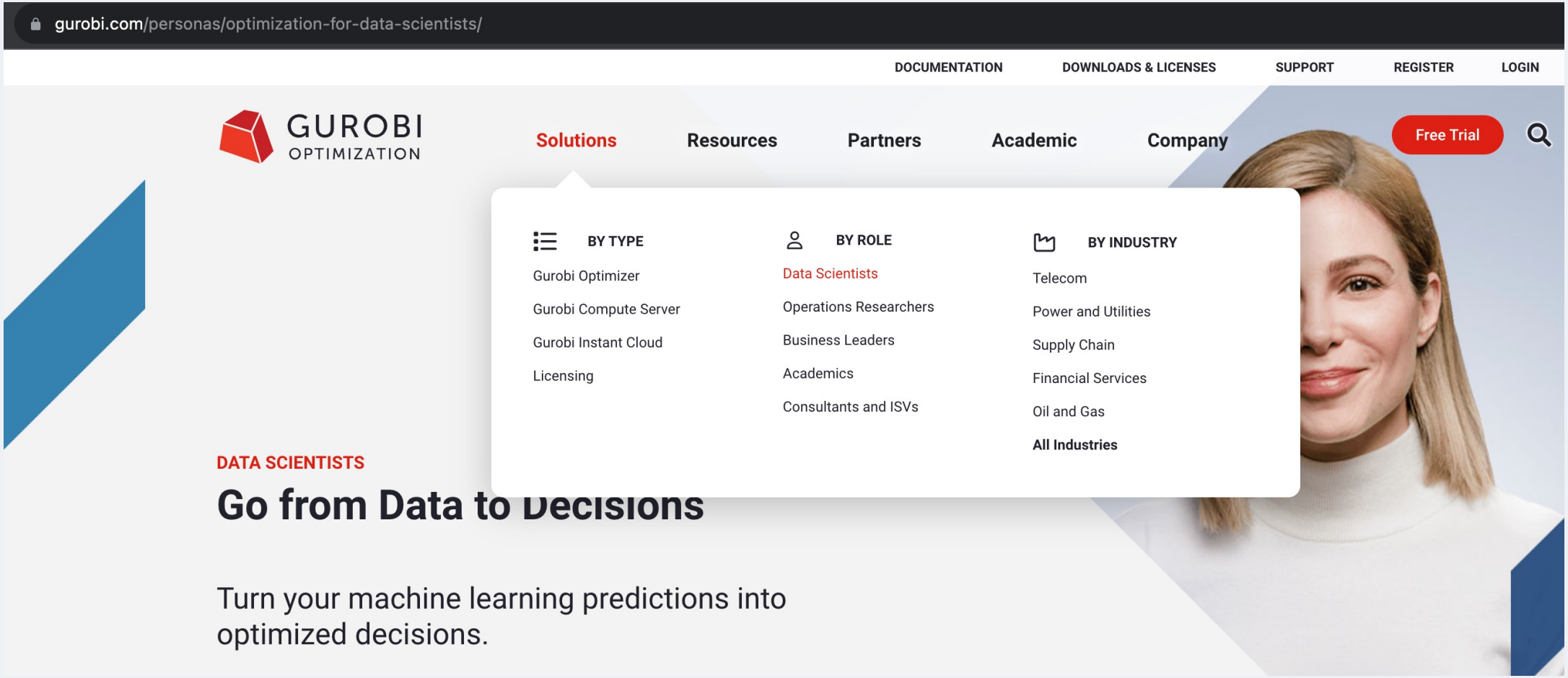


Open-Source Tools

Gurobi sponsored Python packages that make combining ML and MO easier than ever

Gurobipy Pandas
Gurobi Machine Learning
Gurobi OptiMods

How do I get to all this great stuff?



GUROBI OPTIMIZATION

Q&A

Please use the Q&A feature!

Thank You

For more information:

yurchisin@gurobi.com

yash.puranik@aimpointdigital.com

