April 17 – 10:30AM ET

Where Data Meets Decisions: An Overview of Our Free Jupyter Notebook Data Science Example Library

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GUROBI OPTIMIZATION

Where Data Meets Decisions: An Overview of Our Free Jupyter Notebook Data Science Example Library

GUROBI OPTIMIZATION

Agenda

WELCOME

ABOUT OPTIMIZATION

Why do data scientists care about optimization and how can they combine predictive and prescriptive analytics?

GUROBI'S EXAMPLE LIBRARY

More about our educational python notebooks

NOTEBOOK SPOTLIGHT

1. Planning for Airline Disruption
2. Avocado Price Optimization – Parts 1 and 2

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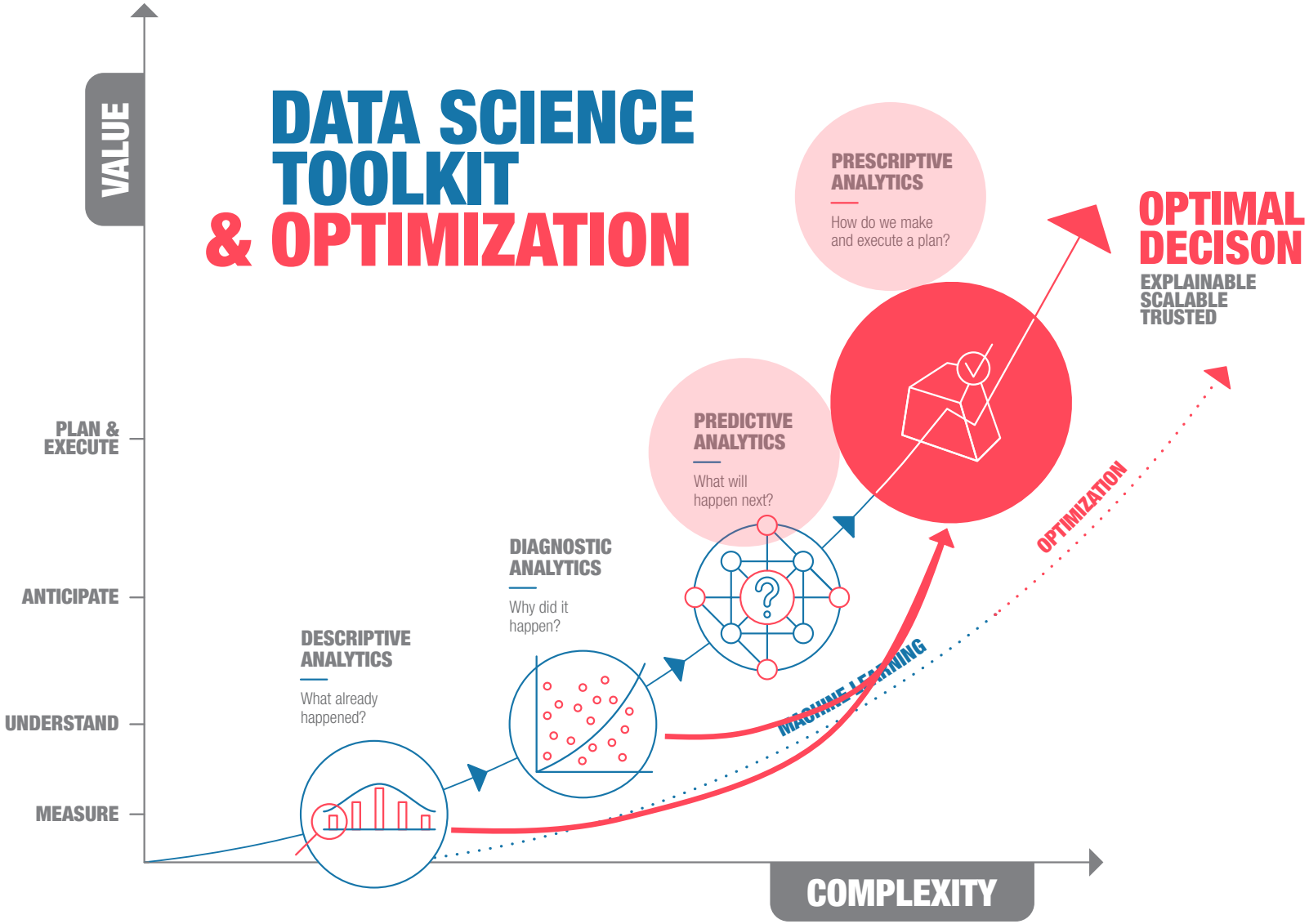
Predictive + Prescriptive Analytics



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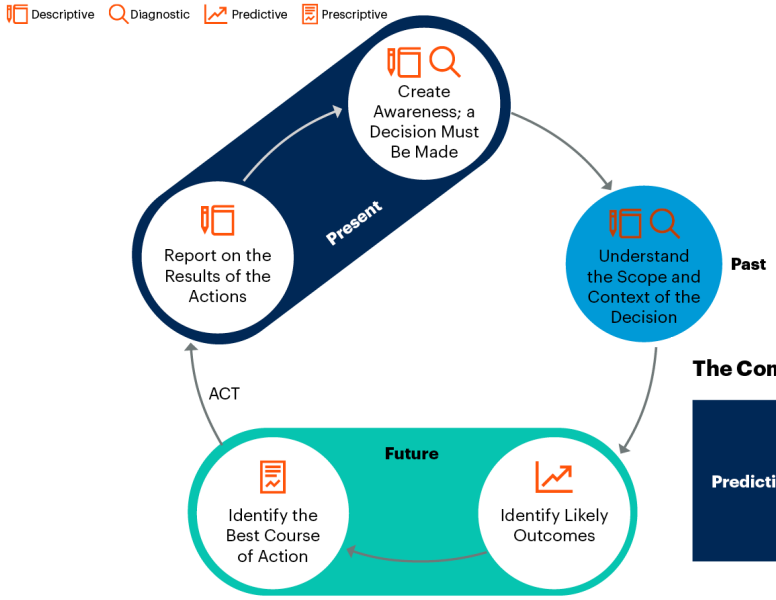
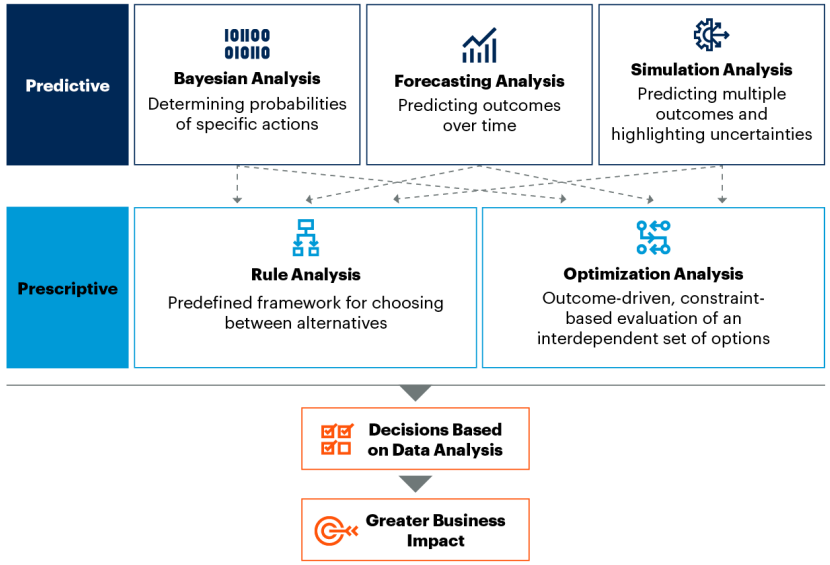
More on Predictive + Prescriptive Analytics

How Gartner's Analytics Continuum Relates to the Decision-Making Process



Source: Gartner
753925_C

The Combined Strength of Predictive and Prescriptive Analytics



Source: Gartner
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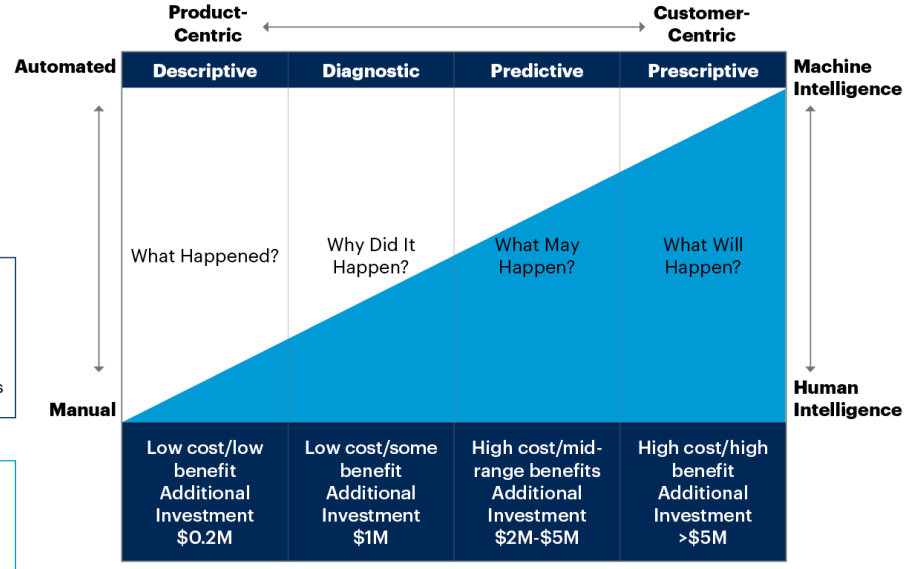
Gartner

The Journey From Descriptive to Prescriptive Analytics



Gartner

- Use Multistructured Analytics for Complex Business Decisions
- Combine Predictive and Prescriptive Analytics for Better Decision Making
- Market Guide for Consumer Goods Trade Promotion Solutions

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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
6. Guarantee the solution is **feasible** and **optimal**!

Quantities
- Continuous (Ex: setting the price of produce)
- Integer (Ex: manufacturing cars)

Alternatives
- Binary (Ex: yes/no decision to use and aircraft for a given flight)

Decision problems to optimization models

$$\text{Max } c_1 x_1 + c_2 x_2$$
$$\text{Subject to:}$$
$$a_{1,1} x_1 + a_{1,2} x_2 \leq b_1$$
$$a_{2,1} x_1 + a_{2,2} x_2 = b_2$$
$$l_1 \leq x_1 \leq u_1$$
$$l_2 \leq x_2 \leq u_2$$

objective function

decision variables

constraints

+

Your favorite programming language

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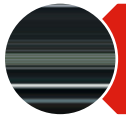
Gurobi's Example Notebook Library

Introductory to advanced examples



Key features of Gurobi and the Python API

Covers numerous industries

Experiment and learn with mathematical optimization

Find inspiration for your projects

NEW: DS EXAMPLE LIBRARY

- Fantasy Basketball
- Price Optimization
- Music Recommendations
- Renewable Scheduling
- Airline Disruption
- Text Similarity

FULL EXAMPLE LIBRARY

- Telecommunications
- Logistics
- Financial Services
- Energy and Utilities
- Healthcare
- Food and Agriculture
- Research, Analytics, and Optimization
- Manufacturing
- Metals and Mining
- Oil and Gas
- Transportation
- Services
- Government
- Professional Services
- Airlines

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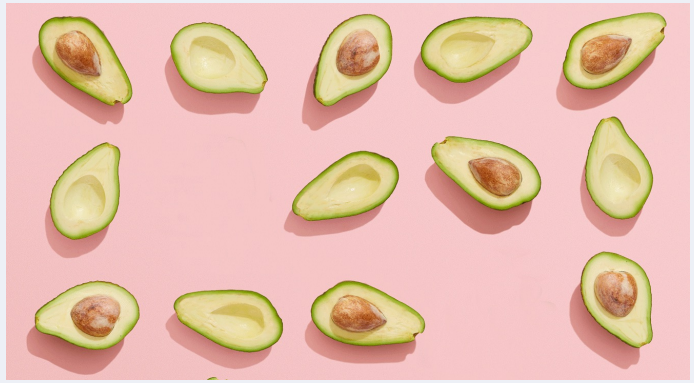
Notebook Spotlight

1. **Flight Planning After Disruption**

2. **Avocado Price Optimization**



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I. Flight Planning After Disruption

More than 1,700 flights canceled as winter storm hits US

WEATHER

Dozens of flights delayed at San Diego airport amid storm

EUROPE

German airport strikes force hundreds of flight cancellations

2022 was a bad year for flight cancellations and delays. Here's why

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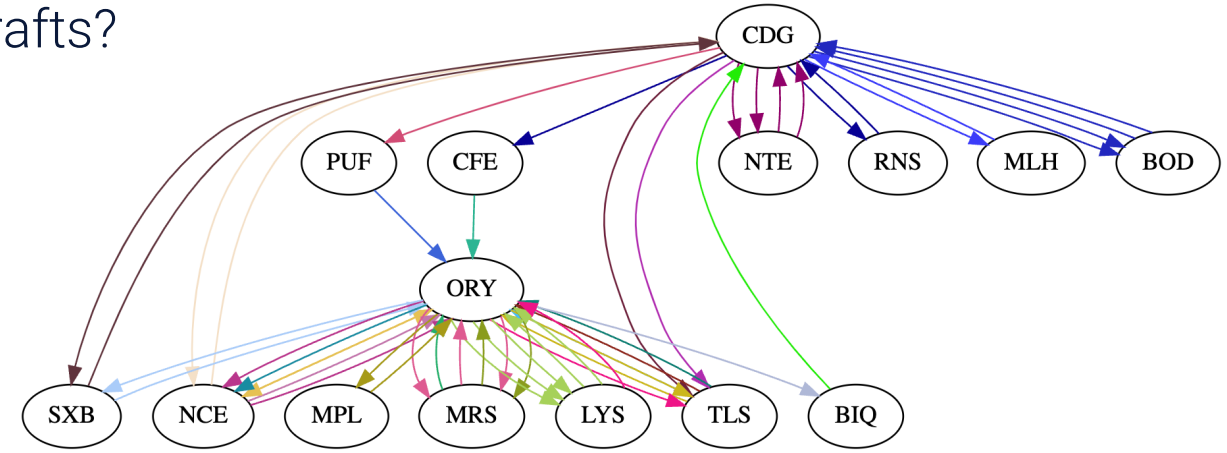
I. Flight Planning After Disruption

- During a weather event, airport **capacities** are diminished
- Let's say you are running airline operations (how fun!)
- You have made **flight plans** for all your aircrafts for 24 hours
- Goals: **Re-optimize** the flight plan during the disruption day
  - Which flights to **cancel**?
  - What are the **new routes** for the aircrafts?
- Real data from AMADEUS (France)



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II. Integrating ML into an MIP model

Part 1: Price Optimization with Avocado Sales

EXAMPLE PART 1 OVERVIEW

- You supply avocados to the US and need to:
  - Decide avocado **price**
  - **Amount** to supply to each region
  - Maximize **profit**
- Use data available from Hass Avocado Board
  - Ordinary **Least Squares model** (OLS) to predict demand
- Formulate an optimization model to find the best price and allocation for each region

Image courtesy: **DALL·E**

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II. Integrating ML into an MIP model

Part 2: Price Optimization with Avocado Sales

WHAT'S NEW IN PART 2

- Two open-source, experimental packages from Gurobi:

1. **Gurobi Machine Learning**
   - Replaces the OLS model with a trained Scikit Learn object directly as a constraint
   - `add_predictor_constr`

2. **Gurobipy Pandas**
   - Easily create decision variables using a pandas data frame and corresponding constraints
   - `add_vars, add_constrs`
   - Offers a small glimpse of functionality

- See github.com/Gurobi for more on our open-source work

Image courtesy: DALL·E

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II. Integrating ML into an MIP model

Part 2: Price Optimization with Avocado Sales

GUROBI OPTIMIZATION

```
pred_constr = add_predictor_constr(m, reg, m_feats, d)
pred_constr.print_stats()
print(m)
```

```
Model for pipe1:
88 variables
24 constraints
Input has shape (8, 4)
Output has shape (8, 1)

Pipeline has 2 steps:

--------------------------------------------------------------------------
Step            Output Shape    Variables            Constraints
                                                Linear    Quadratic      General
==========================================================================
col_trans1          (8, 10)           24            16            0            0

lin_reg1             (8, 1)           64             8            0            0

--------------------------------------------------------------------------
```

Linear predictor model added 64 variables and 8 constraints to the optimization model

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II. Integrating ML into an MIP model

Part 2: Price Optimization with Avocado Sales

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```
from sklearn.ensemble import GradientBoostingRegressor
```

```
reg = make_pipeline(feat_transform, GradientBoostingRegressor(n_estimators=100, max_leaf_nodes = 20,
                                                              loss = 'absolute_error', random_state = 123))
scores = cross_val_score(reg, X_train, y_train, cv=5)
print("%0.4f R^2 with a standard deviation of %0.4f" % (scores.mean(), scores.std()))
# Fit to entire training data
reg.fit(X_train, y_train)
y_pred = reg.predict(X_test)
print(f"The R^2 value in the test set is {np.round(r2_score(y_test, y_pred),5)}")
reg.fit(X, y)
y_pred_full = reg.predict(X)
print(f"The R^2 value in the full dataset is {np.round(r2_score(y, y_pred_full),5)}")
```

```
0.9399 R^2 with a standard deviation of 0.0057
The R^2 value in the test set is 0.94608
The R^2 value in the full dataset is 0.94706
```

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II. Integrating ML into an MIP model

Part 2: Price Optimization with Avocado Sales

```
pred_constr.remove()
pred_constr = add_predictor_constr(m, reg, m_feats, d)
pred_constr.print_stats()
m.update()
```

```
Model for pipe4:
6688 variables
824 constraints
6372 general constraints
Input has shape (8, 4)
Output has shape (8, 1)

Pipeline has 2 steps:

--------------------------------------------------------------------------------
Step            Output Shape    Variables            Constraints
                                                 Linear    Quadratic      General
================================================================================
col_trans            (8, 10)           24          16            0            0

gbtree_reg            (8, 1)         6664         808            0         6372

--------------------------------------------------------------------------------
```

Gradient boosting added **many more** variables and constraints to the optimization model

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gurobi-machinelearning Public

Insert trained predictors in Gurobi models

Python 111 22

Gurobi Machine Learning:

Incorporate your Machine Learning Models into Optimization

Zed Dean
Technical Account Manager

Alison Cozad
Gurobi Expert Team NA Manager

Tuesday, April 18 | 9:10-10am | Cottonwood 11

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MARCH 14 – SEPT 1, 2023 | ON-DEMAND TRAINING

Optimization 101 for Data Scientists:

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LEAD INSTRUCTOR

Jerry Yurchisin

Data Science Strategist, Gurobi & Former Instructor of Mathematics and Statistics

WITH GUEST INSTRUCTOR/PARTNER

Ehsan Khodabandeh

Principal OR Scientist, Decision Spot & Lecturer, Northwestern University: MS in Analytics

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Decision Spot

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QUESTIONS?

Thank You

For more information: gurobi.com

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