Teaching, Learning, and Applying Optimization: AMPL’s Intuitive Modeling Meets the Python Ecosystem

Part II

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Outline

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Part II (live demos):
- Quick introduction to amplpy (our Python API)
- AMPL on Google Colab
  - AMPL Model Colaboratory (https://colab.ampl.com)
- AMPL and solvers as python packages
- AMPL on Streamlit Cloud
- How to deploy large-scale optimization applications with AMPL
Quick introduction to amplpy!
What do you need to know to use amplpy?

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- Basic Python features (lists, dictionaries, etc.)

- Data manipulation with Pandas dataframes

- How to model in AMPL (or how to ask Chat GPT to write AMPL models for you!)
Example: Christmas model  (https://colab.ampl.com)
Example: N-Queens

How can \( n \) queens be placed on an \( n \times n \) chessboard so that no two of them attack each other?

Constraint \texttt{alldiff} enforces a set of integer variables to take distinct values. Using \texttt{alldiff}, we can model N-Queens as follows:

\begin{verbatim}
param n integer > 0; # N-queens
var Row {1..n} integer >= 1 <= n;
s.t. row_attacks: alldiff ({j in 1..n} Row[j]);
s.t. diag_attacks: alldiff ({j in 1..n} Row[j]+j);
s.t. rdiag_attacks: alldiff ({j in 1..n} Row[j]-j);
\end{verbatim}

\begin{itemize}
  \item Row[1] == Row[2]
  \item Row[1]+1 == Row[2]+2
  \item Row[1]-1 == Row[2]-2
\end{itemize}
Example: N-Queens ([https://colab.ampl.com](https://colab.ampl.com))
Example: Network design with redundancy ([https://colab.ampl.com](https://colab.ampl.com))
Global Optimization with Gurobi (https://colab.ampl.com)
Wait a minute. How are AMPL & solvers running on Google Colab integrated with Python?
AMPL and all Solvers are now available as Python Packages

AMPL and all solvers are now available as python packages for Windows, Linux (X86_64, aarch64, ppc64le), and macOS (Intel, Apple Silicon).

```bash
# Install Python API for AMPL
$ python -m pip install amplpy --upgrade

# Install solver modules (e.g., HiGHS, CBC, Gurobi)
$ python -m amplpy.modules install highs cbc gurobi

# Activate your license (e.g., free https://ampl.com/ce license)
$ python -m amplpy.modules activate <license-uuid>

# Import in Python
$ python
>>> from amplpy import AMPL

>>> ampl = AMPL()  # instantiate AMPL object

> https://ampl.com/python/
```
AMPL is Free on Google Colab

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> https://dev.ampl.com/ampl/python/colab.html

> https://try.ampl.com (quickly access to AMPL on Colab)

You can install AMPL on Google Colab (where it is free by default) as follows:

```python
# Install dependencies
%pip install -q amplpy

# Google Colab & Kaggle integration
from amplpy import AMPL, ampl_notebook
AMPL = ampl_notebook(
    modules=["gurobi", "coin", "highs", "gokestrel"],
    license_uuid="default")  # license to use
```
The Python-first approach to learn and model with AMPL!
AMPL Model Colaboratory (https://colab.ampl.com)

> Many examples: https://colab.ampl.com (live demo)
Hands-On Mathematical Optimization with AMPL in Python

Deploying optimization applications quickly and easily using AMPL with Python
AMPL on Streamlit

> https://ampl.com/streamlit (live demo)
Deploy anywhere with Docker

https://dev.ampl.com/ampl/docker/

AMPL can be easily used on Docker containers and deployed anywhere.

```
# Use any image as base image with python installed
FROM python:3.9-slim-bullseye

# Install amplpy and all necessary amplpy.modules:
RUN python -m pip install amplpy --no-cache-dir # Install amplpy
RUN python -m amplpy.modules install highs gurobi --no-cache-dir # Install modules
```
Example project showing how to deploy applications

> [https://amplpyfinance.ampl.com/](https://amplpyfinance.ampl.com/)

- How to use AMPL with Docker Containers:
  - A basic Docker Compose template for orchestrating a **Flask** application & a **Celery** queue with **Redis**.
  - [https://github.com/ampl/amplpyfinance/tree/master/deployment/docker](https://github.com/ampl/amplpyfinance/tree/master/deployment/docker)

- The same Docker images can be deployed to **Kubernetes Clusters**

- How to use AMPL in Continuous Integration Systems
  - This project uses **Azure Pipelines** and **GitHub Actions** for **CI/CD**
  - [https://dev.ampl.com/ampl/cicd/](https://dev.ampl.com/ampl/cicd/)
Continuous Integration Systems

- How to use AMPL in Continuous Integration Systems
  - This project uses Azure Pipelines and GitHub Actions for CI/CD
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```yaml
jobs:
  Test:
    runs-on: ubuntu-latest
    strategy:
      matrix:
        python-version: ["3.10"]
    steps:
      - uses: actions/checkout@v3
      - name: Set up Python ${{ matrix.python-version }}
        uses: actions/setup-python@v4
        with:
          python-version: ${{ matrix.python-version }}
      - name: Install dependencies
        run:
          set -ex
          python -m pip install -r requirements.txt
          python -m pip install amplpy
          python -m amplpy.modules install <solver1> <solver2>
          python -m amplpy.activate <license-uuid>
      - name: Install package
        run:
          python -m pip install .
      - name: Test package
        run:
          python -m <package-name>.tests
```
What about licenses for AMPL and Commercial Solvers?
Dynamic Licensing System
Free licenses to use on Google Colab (and locally!)

- **ampl.com/ce**
  - For personal use
  - Immediate access without approvals required!
  - No size-limits
  - Includes access to:
    - Open-source solvers
    - Commercial solver trials

- **ampl.com/courses**
  - For teaching
  - No size-limits
  - Full access to all solvers!
  - All students can use the license during the course.
Learn more

- https://ampl.com/mo-book
  - New AMPL+Python Book!
- https://ampl.com/streamlit
  - Streamlit App with many examples
- https://colab.ampl.com
  - Collection of AMPL models in Jupyter Notebooks
- https://amplpy.ampl.com
  - Python API Documentation
- https://mp.ampl.com/model-guide.html
  - Modeling Guide for MP-based AMPL Solvers
- https://ampl.com/courses
  - Free license for teaching