Introducing Python as a Supported Language for Accelerator Controls at CERN

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Introduction

In 2019, Python was adopted as an officially supported language for interacting with CERN's accelerator controls. Highlighted here is some of the key infrastructure put in place to facilitate a user friendly, idiomatic and stable Python platform fit for operational high-level accelerator controls.

Acc-Py base distribution

- Lightweight, easy to install, used on local disk, containers and network drives
- Designed to be installed side-by-side with other versions of Acc-Py base
- Each invocation logged
- Not a pre-prepared fully-fledged distribution such as Anaconda or LCG

=> Designed to be extended by the user

Virtual environment

- A user can create an unlimited number of virtual environments
- No special privileges required
- Python interpreter and standard library linked from the base distribution

```
venv
├── bin
│   ├── python (symlink to base)
│   └── ...
├── lib
│   └── pythonX.Y
│       └── site-packages
│           └── <venv-packages>
├── include
├── share
└── pyvenv.cfg
```

pip install

- User can choose which packages to install
- Pre-configured to use the Acc-Py package index
- CERN-specific packages combined with those from the Python Package Index (PyPI)
- Tools built on top of pip (e.g. poetry) can be used

Python well-adapted for:

- Data processing and analysis
- Machine learning & deep learning
- System automation
- Rapid prototyping
- GUI development
- Mathematical modelling
- Hardware interfacing
- ...

Examples at CERN:

- Machine development (MD) studies
- Linac4 Source autopilot (WEPV018)
- Timing sequencer GUI (THPV015)
- Expert GUI applications
- Physics simulations
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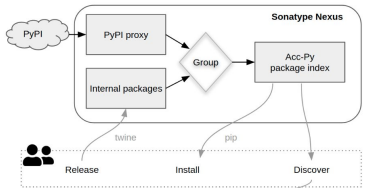
Python invocation logs

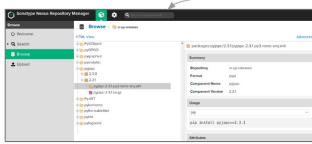
Each Acc-Py Python invocation is logged, along with data including the time, machine, username and a list of all packages installed in the environment.

This data has been invaluable in helping inform both technical and strategic decisions, and it provides a snapshot of usage of Python for accelerator controls.

In numbers, there are around 10,000 Python invocations per day and over 400 unique active users (September 2021).

Acc-Py package index





Motivation

- Access to PyPI from within technical network
- Ability to install internal and public packages using pip
- Filters to prevent unwanted or malicious packages being installed
- Archive of packages in case of PyPI outage or package removal

Development and deployment tools

Step 1: Create a project

```
$ acc-py init my-project
=> Writing setup.py
=> Writing README.md
=> Configuring my_project's directory structure
./my-project/
├── my_project/
│   ├── __init__.py
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```

- Create a new Python package following a simple structure
- Tests are a first-class component of the project
- Possibility to generate configuration for API Documentation (sphinx) and Continuous integration (GitLab-CI)

Step 2: Freeze dependencies

```
$ acc-py app lock ./my-project/
./my-project/deployment/app
├── config.json
├── requirements-jar.json
└── requirements.txt
```

- Resolve floating dependency versions
- Including Java dependencies
- Guarantees that the dependencies in production are the same as those tested in development

Step 3: Deploy to central location

```
$ acc-py app deploy ./my-project/
=> Building wheel for my-project
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/deployment/location/my-project
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- Consistent & repeatable deployment
- Based on a virtual environment
- Auditable history of application changes
- Common location for deployments

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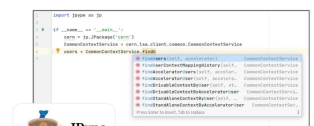


JPype

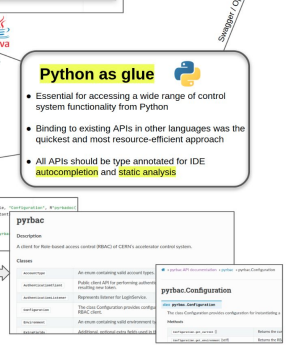
- Manages in-process JVM
- Zero-copy arrays between Python & Java
- Type annotations with `stubgenj`
- JARs automatically installed into the virtual environment

Python as glue

- Essential for accessing a wide range of control system functionality from Python
- Binding to existing APIs in other languages was the quickest and most resource-efficient approach
- All APIs should be type annotated for IDE autocompletion and static analysis

pybind11

- C++ based binding definition
- Easy to craft Pythonic bindings
- Creates shared-object module
- Released as pre-compiled `manylinux2014` Python wheels



openapi-generator
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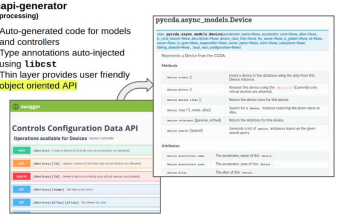
- Auto-generated code for models and controllers
- Type annotations auto-injected using `libcst`
- Thin layer provides user friendly object oriented API



Conclusion

There has been significant growth in the use of Python in the accelerator sector at CERN, with support for high-level accelerator controls having been introduced in 2019. To facilitate this, key infrastructure has been put in place, including development tools for a simple yet Pythonic experience, solutions for consistent application deployment and execution, and a suite of libraries for interacting with CERN's accelerator control system.

When considered together, the infrastructure presented here has resulted in a stable and effective platform from which Python users can efficiently build operational-quality libraries, applications and services for CERN's next accelerator run and beyond. Furthermore, such infrastructure is general in purpose, and would be a good fit for a diverse range of organisations wishing to adopt a robust and maintainable operational Python environment.

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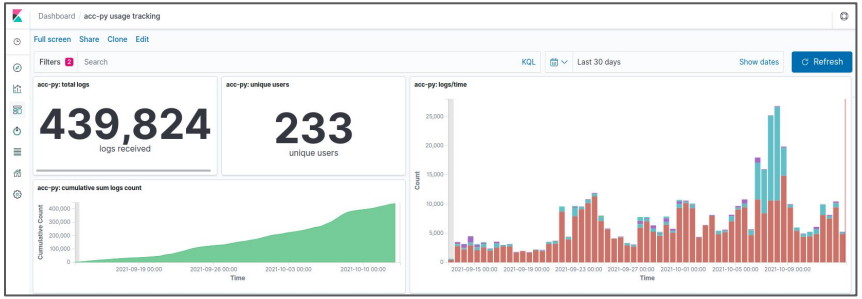

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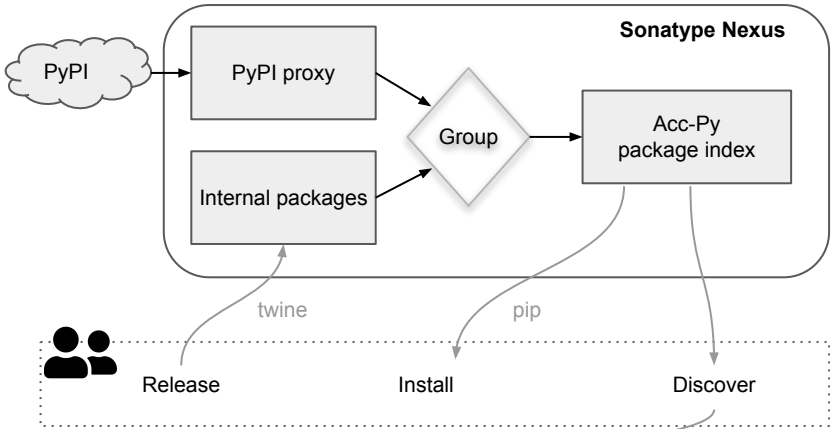

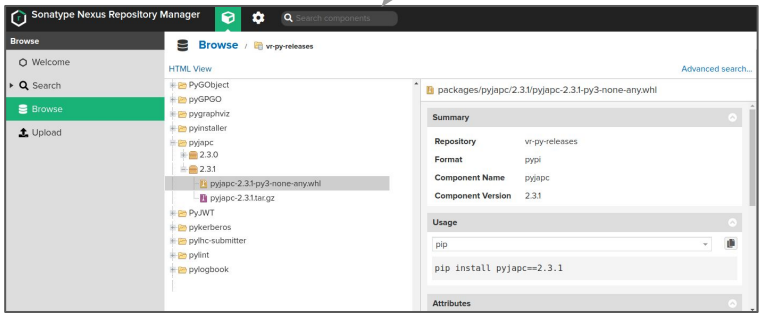

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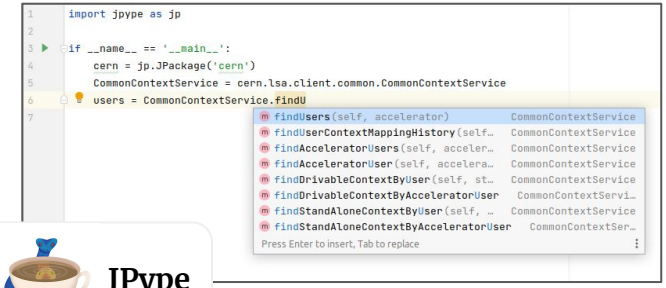

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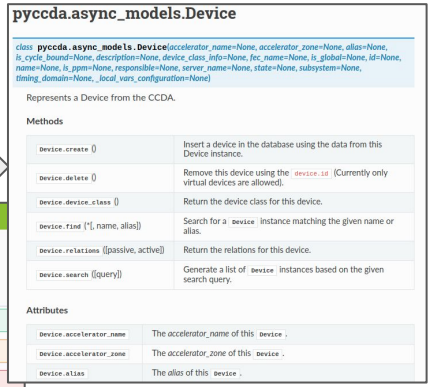
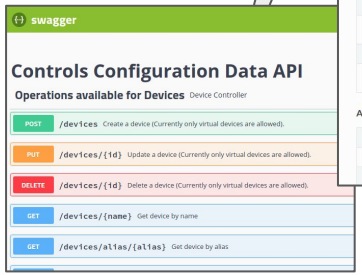
Swagger / OpenAPI





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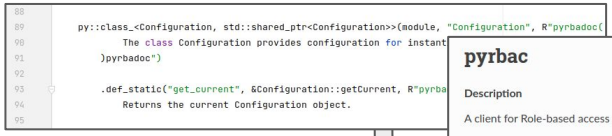

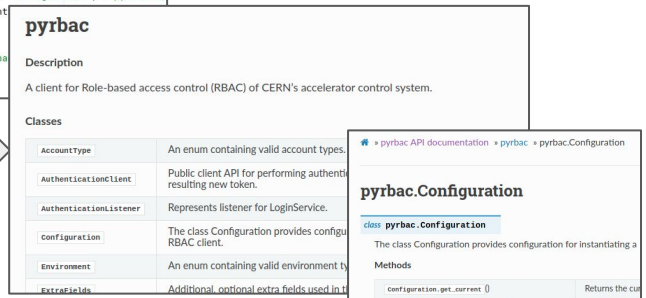

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