

# Odahu Platform Tutorial

version 1.4.0-rc1

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# About Open Data Analytics Hub (ODAHU)

The ODAHU project is focused on creating system of services, extensions for third party systems and tools which help to accelerate building enterprise level systems with automated AI/ML models life cycle.

## Multi ML Frameworks

- Supporting major ML frameworks: Scikit-learn, Keras, Tensorflow, PyTorch, H2O (and more)
- Extends MLflow platform with enterprise level features

## Multi Infrastructure

- Kubernetes native system of services
- Deployment automation to Kubernetes cluster with Helm charts
- Supporting major Kubernetes platforms: AWS EKS, Azure AKS, GCP GKE, RedHat OpenShift

## Secure

- Single sign-on (SSO) based on OAuth2
- RESTful API secured with SSL
- Role based access control
- Users activity audit
- Credentials and keys manager based on HashiCorp Vault
- Internal traffic encryption with Istio

## Modular and Extensible

- Services for different ML phases: transform, train, package, deploy, evaluate
- Services are extensible and manageable via REST APIs, SDK and CLI
- Functionality can be extended with new services
- Connectors for data sources
- Connectors for package repositories
- Connectors for Docker container registries
- Plugins for data science IDEs
- Plugins for workflow engines (like Airflow and others)

## Scalable

- Systems based on ODAHU can be scaled from small to very large.
- Scalable ML model training phase
- Scalable ML model serving phase

## Manageable

- Pre-build monitoring dashboards
- Configurable alerting rules

## About Open Data Analytics Hub (ODAHU)

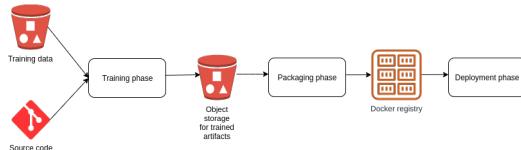
- Configurable logs collection
- Compatible with third party logs processing system

## Open

- It is free and open-source with the Apache2 License.
- Contribution to project is welcome!

# Concepts

## Phases



Odahu splits the ML/AI model lifecycle into three phases:

1. **Train**
2. **Package**
3. **Deploy**

Applications and tools can further automate each phase by implementing pluggable extensions as

1. **Trainer**
2. **Packager** or
3. **Deployer**

Trainers and Packagers can be registered as components of the Odahu Platform using:

1. **Trainer Extension**
2. **Packager Extension**

When registered, these components can use Odahu **Trainer Metrics** and **Trainer Tags**.

Users are encouraged to integrate third-party **Trainer Extensions** and **Packager Extensions**.

## Toolchains

Taken together a Trainer, Packager, and Deployer comprise a *Toolchain* that automates an end-to-end machine learning pipeline.

### Ready to use

Odahu provides a **Trainer Extension** and a **Packager Extension**

1. **MLflow Trainer**
2. **REST API Packager**

These power the default Toolchain.

## Model storage

Odahu Platform stores models in **Trained Model Binaries** for different languages.

Presently, Odahu Platform supports only:

### 1. General Python Prediction Interface

Users are encouraged to provide additional formats.

# Architecture

The following diagram shows the high level architecture of Odahu-flow project.



## Odahu-flow applications:

- Odahu-flow CLI is a command-line interface for interacting with Odahu-flow API service.
- The Odahu-flow Swagger UI provides swagger interface for Odahu-flow REST API.
- Odahu-flow Airflow plugin provides a set of custom operators that allow you to interact with a Odahu cluster using [Apache Airflow](#)
- The MLflow Tracking component is an API and UI for logging parameters, code versions, and metrics when running your machine learning code and for later visualizing the results.
- JupyterLab extension allows you to interact with an Odahu cluster from JupyterLab web-based IDEs.
- API service manages Odahu Platform entities: Connections, Trainings, Packaging, Deployments.
- Service catalog provides a Swagger UI for Model Deployments.
- TektonCD is an open source implementation to configure and run CI/CD style pipelines for your Kubernetes application.
- Knative Serving builds on Kubernetes and Istio to support deploying and serving of serverless applications and functions.
- Odahu-flow Model Training API provides features to manage remote training jobs.
- Odahu-flow packagers turn a **Trained Model Binary** artifact into a specific application.
- Odahu-flow Model Deployment API allows deploy ML models in a Kubernetes cluster.

# Distributions

## HELM charts

- Release and pre-release **Helm charts** are in github.

Helm chart name	Repository	Description
odahu-flow-fluentd	odahu/odahu-infra	Fluentd with gcp, s3 and abs plugins
odahu-flow-k8s-gke-saa	odahu/odahu-infra	GKE role assigner
odahu-flow-knative	odahu/odahu-infra	Custom knative chart
odahu-flow-monitoring	odahu/odahu-infra	Prometheus, grafana and alertmanager
odahu-flow-opa	odahu/odahu-infra	Open Policy Agent
odahu-flow-teknol	odahu/odahu-infra	Custom tekton chart
odahu-flow-core	odahu/odahu-flow	Core Odahu-flow services
odahu-flow-mlflow	odahu/odahu-trainer	Odahu-flow mlflow toolchain
odahu-flow-packagers	odahu/odahu-packager	Odahu-flow REST packager

## Docker Images

Release versions of images are on Docker Hub in the **odahu** team.

Image name	Repository	Description
odahu-flow-fluentd	odahu/odahu-infra	Fluentd with gcp, s3 and abs plugins
odahu-flow-api	odahu/odahu-flow	Odahu-flow API service
odahu-flow-model-cli	odahu/odahu-flow	Odahu-flow CLI
odahu-flow-model-trainer	odahu/odahu-flow	Trainer helper
odahu-flow-model-packager	odahu/odahu-flow	Packager helper
odahu-flow-service-catalog	odahu/odahu-flow	Swagger for model deployments

## Python packages

odahu-flow-operator	odahu/odahu-flow	Odahu-flow kubernetes orchestrator
odahu-flow-feedback-collector	odahu/odahu-flow	REST API for user feedback service
odahu-flow-feedback-rq-catcher	odahu/odahu-flow	Model deployment request-response catcher
odahu-flow-mlflow-toolchain	odahu/odahu-trainer	Odahu-flow mlflow toolchain
odahu-flow-mlflow-toolchain-gpu	odahu/odahu-trainer	Odahu-flow mlflow toolchain with NVIDIA GPU
odahu-flow-mlflow-tracking-server	odahu/odahu-trainer	MLflow tracking service
odahu-flow-packagers	odahu/odahu-packager	Odahu-flow packagers
base-notebook	odahu/odahu-flow-jupyterlab-plugin	Image with JupyterLab extension based on <a href="#">jupyter/base-notebook</a>
datascience-notebook	odahu/odahu-flow-jupyterlab-plugin	Image with JupyterLab extension based on <a href="#">jupyter/datascience-notebook</a>
tensorflow-notebook	odahu/odahu-flow-jupyterlab-plugin	Image with JupyterLab extension based on <a href="#">jupyter/tensorflow-notebook</a>

## Python packages

- Release versions of Python packages are on PyPi: [odahu](#).

Package name	Repository	Description
odahu-flow-cli	odahu/odahu-flow	Odahu-flow CLI
odahu-flow-sdk	odahu/odahu-flow	Odahu-flow SDK
odahu-flow-jupyterlab-plugin	odahu/odahu-flow-jupyterlab-plugin	Jupyterlab with the Odahu-flow plugin
odahu-flow-airflow-plugin	odahu/odahu-airflow-plugin	Odahu-flow Airflow plugin(operators, hooks and so on)

## NPM packages

- Release versions of Python packages are on npm in project odahu.

Package name	Repository	Description
--------------	------------	-------------

## Python packages

odahu-flow-jupyterlab-plugin	odahu/odahu-flow-jupyterlab-plugin	Jupyterlab with the Odahu-flow plugin
------------------------------	------------------------------------	---------------------------------------

# Security

Prime goals of ODAHU Security system is to provide [authentication](#), [authorization](#) and give users a flexible access control management solution.

The first section [Security overview](#) shows the general design of authentication and authorization is described. Look at this section to have a deep understanding of how ODAHU security works under the hood or to learn basic concepts.

The second section [Policies](#) describes default security policies for different ODAHU services and how to configure them

Implementation details of ODAHU Security system could be found here

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## Security overview

### Component roles

There are some common terms related to access control management systems. In this documentation, the next ones are commonly used.

#### Identity Provider (idP)

A component that provides information about an entity (user or service). In ODAHU the role of idP can do any [OpenID Connect](#) compatible provider.

#### Policy Enforcement Point (PEP)

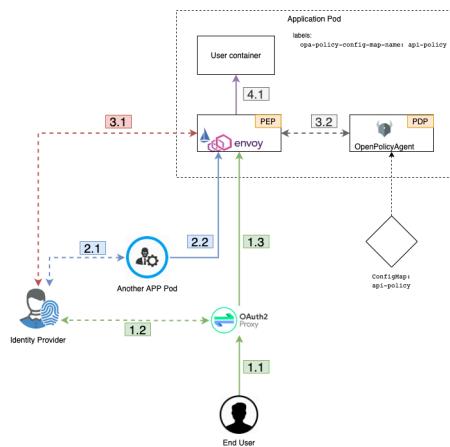
A component that enforces security policies against each request to API or other protected resources. In ODAHU the role of PEP plays [Envoy proxy](#).

#### Policy Decision Point (PDP)

A component that decides whether the request (action in the system) should be permitted or not. In ODAHU role of PDP plays [OpenPolicyAgent](#).

## API Request lifecycle

To have a better understanding of how all ODAHU security components work together let's review the API request lifecycle and describe what is happened for each HTTP request.



1. HTTP Request could be made from the outside of the cluster perimeter.
    1. In this case, the request is handled by **OAuth2Proxy** via Kubernetes ingress controller
    2. OAuth2Proxy looks up cookies that contain JWT Token issued by **idP**. If there are no such cookies it redirects the request to **idP**. After successful login OAuth2Proxy set issued token to cookies (and also to) and send the request to upstream. Before proxying requests to upstream OAuth2Proxy add **Authorization Request Header Field** from the cookie automatically by setting it from the cookie.
    3. OAuth2Proxy send request to upstream.
  2. HTTP Request from inside the cluster perimeter. Such requests usually made by background processes inside the cluster on behalf of service accounts.
    1. Service should previously authenticate in idP using **OpenID Connect** protocol. The most suitable way to authenticate services is **OAuth2 Client Credentials Grant**
    2. Service makes a request to API using issued JWT token as **Authorization Request Header Field**
  3. Envoy proxy as **PEP** that is configured as sidecar container by **Istio Pilot** for those ODAHU components that must be protected ensures that security policy allows making this request to ODAHU API
    1. Envoy verifies JWT token in **Authorization Request Header Field** using **JSON Web Token (JWT) Authentication filter**
    2. Envoy makes a query to **OpenPolicyAgent** sidecar as **PDP** using **External Authorization filter** passing parsed JWT token from the previous step. **OpenPolicyAgent** sidecars are injected for all pods that have *odahu-flow-authorization=enabled* label
  4. If a request is permitted by **OpenPolicyAgent**, it is sent to upstream (ODAHU API)
- UML sequence diagram of a successful API request described above is shown in the image:

## Policies

ODAHU is distributed with build-in policies that are written on [Rego policy language](#) and included into helm charts of appropriate services.

`Role-based access control`\_ is implemented by default for next services

- API
- Feedback aggregator
- *ODAHU deployed ML Models*

### ***ODAHU API and Feedback aggregator policies***

#### ***Overview***

API and Feedback aggregator are distributed with a pre-defined set of [OpenPolicyAgent](#) policies. These policies implement simple `Role-based access control`\_ (RBAC).

Next features are implemented using [Rego policy language](#):

1. Set of predefined roles with assigned permissions
2. Default mapper that match [JWT Claims](#) to attributes that ODAHU RBAC policy expects
3. ODAHU RBAC core policy

These features are implemented in the next files:

- roles.rego – all odahu roles are listed here
- permissions.rego – permissions for roles
- input\_mapper.rego – mapper to match [JWT Claims](#) to attributes ODAHU RBAC rely on. These attributes include:
  - user – info about user or service who makes the request (this property contains roles attribute with a list of roles)
  - action – HTTP verb of the request
  - resource – URL of the request
- core.rego – core implementation of [Role based access control](#).

All policies customization can be done on the stage of system configuration as described in installation guide

#### ***Customize***

In this section, different ways to customize pre-defined policies

## Policies

### Extend roles

To define new custom roles, you should add them as a variable in the *roles.rego* file  
*roles.rego*

```
1 package odahu.roles
2
3 admin := "admin"
4 data_scientist := "data_scientist"
5 viewer := "viewer"
6
7 # new role
8 connection_manager := "connection_manager"
```

Then you need to set permissions to that role in file *permissions.rego*

*permissions.rego*

```
1 package odahu.permissions
2
3 import data.odahu.roles
4
5 permissions := {
6     roles.data_scientist: [
7         [".*", "api/v1/model/deployment.*"],
8         [".*", "api/v1/model/packaging.*"],
9         [".*", "api/v1/model/training.*"],
10        ["GET", "api/v1/connection.*"],
11        ["GET", "api/v1/packaging/integration.*"],
12        ["GET", "api/v1/toolchain/integration.*"]
13    ],
14    roles.admin : [
15        [".*", ".*"]
16    ],
17    roles.viewer : [
18        ["GET", ".*"]
19    ],
20    roles.connection_manager : [
21        [".*", "api/v1/connection.*"]
22    ],
23 }
```

In this file, we:

- lines 20-22: add permissions to any request to `api/v1/connection.*` URL for a new role

### Customize default mapper

You can configure *mapper.rego* to extend input that is passed to *core.rego* file with RBAC implementation

*mapper.rego*

```
1 package odahu.mapper
2
3 import data.odahu.roles
4
5 roles_map = {
6     "odahu_admin": roles.admin,
7     "odahu_data_scientist": roles.data_scientist,
```

## Policies

```
8 "odahu_viewer": roles.viewer
9 }
10 jwt = input.attributes.metadata_context.filter_metadata["envoy.filters.http.jwt_authn"].fields.jwt_payload
11
12 keycloak_user_roles[role]{
13   role = jwt.Kind.StructValue.fields.realm_access.Kind.StructValue.fields.roles.Kind.ListValue.values[_].Kind.StringValue
14 }
15
16 user_roles[role]{
17   role = roles_map[keycloak_user_roles[_]]
18 }
19
20
21 parsed_input = {
22   "action": input.attributes.request.http.method,
23   "resource": input.attributes.request.http.path,
24   "user": {
25     "roles": user_roles
26   }
27 }
```

In this file, we:

- lines 5-9: map roles from jwt claims to policies roles from *roles.rego*
- lines 11-19: extract roles from claims and match them to policies roles
- lines 21-26: create input that is expected by file *core.rego* that contains resource, action and user's roles

### Create custom policies

If `Role-based access control` is not enough for your purposes you can customize policies to use more general `Attribute-based access control`. For this purpose, rewrite *core.rego* file or create your own rego policies from scratch

*core.rego*

```
1 package odahu.core
2
3 import data.odahu.mapper.parsed_input
4 import data.odahu.permissions.permissions
5
6 default allow = false
7
8 allow {
9   any_user_role := parsed_input.user.roles[_]
10  any_permission_of_user_role := permissions[any_user_role][_]
11  action := any_permission_of_user_role[0]
12  resource := any_permission_of_user_role[1]
13
14  re_match(action, parsed_input.action)
15  re_match(resource, parsed_input.resource)
16 }
17
18 allow {
19   parsed_input.action == "GET"
20   parsed_input.resource == "/"
21 }
22
23 allow {
24   parsed_input.action == "GET"
25   re_match("/swagger*", parsed_input.resource)
26 }
```

In this file, we:

## Policies

- lines 8-16: allow access if there are required permissions for action and resource for at least one user's roles
- lines 18-21: allow access to root for any user
- lines 23-26: allow access to swagger docs to any user

### ***ODAHU ML Models pods policies***

All deployed models contain default policies that permit requests to them for all users that have **Model Deployment Access Role Name**. This role can be set at the model deployment stage using .Spec.roleName key of the ModelDeployment manifest and also statically configured in policies during ODAHU deployment.

# Installation

To install ODAHU services, you need to provide a number of preliminary requirements for it.

In particular:

- Python 3.6 or higher; to install JupyterLab extension or Odahuflowctl which are interfaces for interacting with Odahu-flow cluster.
- Kubernetes cluster to perform base and accessory ODAHU services in it, as well as models training, packaging and deployment processes. To be able to use ODAHU services, minimum version of your Kubernetes cluster must be at least [1.16](#).
- object storage to store models training artifacts and get input data for models (S3, Google Cloud Storage, Azure Blob storage are supported)
- Docker registry (to store resulting Docker images from packagers)

## Kubernetes setup

### ***Deploy Kubernetes cluster in Google Compute Platform (GKE)***

#### **Prerequisites:**

- [GCP service account](#) to deploy Kubernetes cluster with and use its credentials for access to object storage and Google Cloud Registry
- Google Cloud Storage bucket (odahu-flow-test-store in examples below) to store models output data

Run deploy of a new Kubernetes cluster:

```
$ gcloud container clusters create <cluster-name> \
--cluster-version 1.13 \
--machine-type=n1-standard-2 \
--disk-size=100GB \
--disk-type=pd-ssd \
--num-nodes 4 \
--zone <cluster-region> \
--project <project-id>
```

#### **Note**

Make sure that the disk size on the cluster nodes is sufficient to store images for all services and packaged models. We recommend using a disk size of at least 100 GiB.

You can enable the GPU on your Kubernetes cluster, follow the [instructions](#) on how to use GPU hardware accelerators in your GKE clusters' nodes.

## Installation

Fetch your Kubernetes credentials for kubectl after cluster is successfully deployed:

```
$ gcloud container clusters get-credentials <cluster-name> \
--zone <cluster-region> \
--project <project-id>
```

## Deploy Kubernetes cluster in Amazon Web Services (EKS)

### Prerequisites

- Resources that are [described in AWS documentation](#)
- AWS S3 bucket (odahu-flow-test-store in examples below) to store models output data

After you've created VPC and a dedicated security group for it along with Amazon EKS service role to apply to your cluster, you can create a Kubernetes cluster with following command:

```
$ aws eks --region <cluster-region> create-cluster \
--name <cluster-name> --kubernetes-version 1.13 \
--role-arn arn:aws:iam::111122223333:role/eks-service-role-AWSServiceRoleForAmazonEKS-EXAMPLEBKZRQR \
--resources-vpc-config subnetIds=subnet-a9189fe2,subnet-50432629,securityGroupIds=sg-f5c54184
```

Use the AWS CLI update-kubeconfig command to create or update kubeconfig for your cluster:

```
$ aws eks --region <cluster-region> update-kubeconfig --name <cluster-name>
```

## Deploy Kubernetes cluster in Microsoft Azure (AKS)

### Prerequisites

- [Azure AD Service Principal](#) to interact with Azure APIs and create dynamic resources for an AKS cluster
- Azure Storage account with Blob container (odahu-flow-test-store in examples below) to store models output data

First, create a resource group in which all created resources will be placed:

```
$ az group create --location <cluster-region> \
--name <resource-group-name>
```

Run deploy of a new Kubernetes cluster:

```
$ az aks create --name <cluster-name> \
--resource-group <resource-group-name>
--node-vm-size Standard_DS2_v2 \
--node-osdisk-size 100GB \
--node-count 4 \
```

## Install base Kubernetes services

```
--service-principal <service-principal-appid> \
--client-secret <service-principal-password>
```

Fetch your Kubernetes credentials for kubectl after cluster is successfully deployed:

```
$ az aks get-credentials --name <cluster-name> \
--resource-group <resource-group-name>
```

## Install base Kubernetes services

### ***Install Helm (version 3.1.2)***

### ***Install Nginx Ingress***

Install nginx-ingress Helm chart:

```
$ helm install stable/nginx-ingress --name nginx-ingress --namespace kube-system
```

Get external LoadBalancer IP assigned to nginx-ingress service:

```
$ kubectl get -n kube-system svc nginx-ingress-controller \
-o=jsonpath='{.status.loadBalancer.ingress[*].ip}{"\n"}'
```

### ***Install Istio (with Helm and Tiller)***

#### **Note**

ODAHU services uses number of Istio custom resources actively, so Istio installation is mandatory.

Add Helm repository for Istio charts

```
$ helm repo add istio https://storage.googleapis.com/istio-release/releases/1.4.2/charts/
```

Create a namespace for the istio-system components

```
$ kubectl create namespace istio-system
```

Install the istio-init chart to bootstrap all the Istio's CustomResourceDefinitions

## Install base Kubernetes services

```
$ helm install istio/istio-init --name istio-init --namespace istio-system
```

Ensure that all `istio-init` jobs have been completed:

```
$ kubectl -n istio-system get job \
-o=jsonpath='{range.items[?(.status.succeeded==1)]}.metadata.name{"\n"}{end}'
```

Install Istio Helm chart with provided values.

Example:

```
$ cat << EOF > istio_values.yaml
global:
  proxy:
    accessLogFile: "/dev/stdout"
    disablePolicyChecks: false
  sidecarInjectorWebhook:
    enabled: true
  pilot:
    enabled: true
  mixer:
    policy:
      enabled: true
    telemetry:
      enabled: true
  adapters:
    stdio:
      enabled: true
gateways:
  istio-ingressgateway:
    enabled: true
    type: ClusterIP
  meshExpansionPorts: []
  ports:
    - port: 80
      targetPort: 80
      name: http
    - port: 443
      name: https
    - port: 15000
      name: administration
  istio-egressgateway:
    enabled: true
prometheus:
  enabled: false
EOF

$ helm install istio/istio --name istio --namespace istio-system --values ./istio_values.yaml
```

## Add ODAHU Helm charts repository

```
$ helm repo add odahu https://raw.githubusercontent.com/odahu/odahu-helm/master
```

## Install Knative

Create namespace for Knative and label it for Istio injection:

## Install base Kubernetes services

```
$ kubectl create namespace knative-serving && \
  kubectl label namespace knative-serving istio-injection=enabled
```

Install Knative with [Helm chart](#) provided by ODAHU team:

```
$ helm install odahu/odahu-flow-knative --name knative --namespace knative-serving
```

## Install Tekton Pipelines

Create namespace for Tekton:

```
$ kubectl create namespace tekton-pipelines
```

Install Tekton Pipelines with [Helm chart](#) provided by ODAHU team:

```
$ helm install odahu/odahu-flow-tekton --name tekton --namespace tekton-pipelines
```

## Install Fluentd with set of cloud object storage plugins

In order to save models training logs to object storage of cloud provider you use, a container with fluentd is used, in which a set of [plugins](#) for popular cloud providers' object storages (AWS S3, Google Storage, Azure Blob) is added. Installation is done using a [fluentd Helm chart](#) provided by ODAHU team.

First, create an object storage bucket:

```
$ gsutil mb gs://odahu-flow-test-store/
```

Create namespace for Fluentd:

```
$ kubectl create namespace fluentd
```

Install Fluentd with specified values. Full list of values you can see in chart's [values.yaml](#).

Example:

```
$ cat << EOF > fluentd_values.yaml
output:
  target: gcs
  gcs:
    authorization: keyfile
    bucket: odahu-flow-test-store
    project: my-gcp-project-id-zzzzz
    private_key_id: 0bac0000000000000000000000000000
    private_key: -----BEGIN PRIVATE KEY-----\nprivate-key-here\n-----END PRIVATE KEY-----\n
    client_email: service-account@my-gcp-project-id-zzzzz.iam.gserviceaccount.com
    client_id: 00000000000000000000000000000000
    auth_uri: https://accounts.google.com/o/oauth2/auth
    token_uri: https://oauth2.googleapis.com/token
    auth_provider_x509_cert_url: https://www.googleapis.com/oauth2/v1/certs
    client_x509_cert_url: https://www.googleapis.com/robot/v1/metadata/x509/service-account%40my-gcp-project-id-zzzzz.iam.gserviceaccount.com
EOF
```

## Install base Kubernetes services

```
$ helm install odahu/odahu-flow-fluentd --name fluentd --namespace fluentd --values ./fluentd_values.yaml
```

## Install PostgreSQL (optional)

Create namespace for PostgreSQL:

```
$ kubectl create namespace postgresql
```

Install PostgreSQL Operator with Helm chart:

```
$ helm install postgres-operator/postgres-operator --name odahu-db --namespace postgresql
```

You must configure your PostgreSQL operator using next values

*Parameters to configure PostgreSQL Provider:*

```
$ cat << EOF > postgres.yaml
apiVersion: "acid.zalan.do/v1"
kind: postgresql
metadata:
  name: odahu
  namespace: postgres
spec:
  teamId: "postgres"
  volume:
    size: 10Gi
  numberInstances: 2
  users:
    mlflow: []
    jupyterhub: []
    odahu: []
  databases:
    mlflow: mlflow,
    jupyterhub: jupyterhub,
    odahu: odahu
  postgresql:
    version: "12"
---
apiVersion: v1
kind: Secret
metadata:
  name: jupyterhub.odahu-db.credentials.postgresql.acid.zalan.do
  namespace: postgres
type: Opaque
---
apiVersion: v1
kind: Secret
metadata:
  name: mlflow.odahu-db.credentials.postgresql.acid.zalan.do
  namespace: postgres
type: Opaque
---
apiVersion: v1
kind: Secret
metadata:
  name: odahu.odahu-db.credentials.postgresql.acid.zalan.do
  namespace: postgres
type: Opaque
EOF
```

Apply configuration to kubernetes: .. code:: bash

## Install ODAHU

```
kubectl apply -f postgres.yaml
```

### Install Open Policy Agent (optional)

To activate API authentication and authorization using Security install OpenPolicyAgent (OPA) helm chart with ODAHU built-in policies.

Create namespace for OPA

```
$ kubectl create namespace odahu-flow-opa
```

Install OpenPolicyAgent with [Helm chart](#) provided by ODAHU team:

```
$ helm install odahu/odahu-flow-opa --name odahu-flow-opa --namespace odahu-flow-opa
```

You must configure your OpenID provider (to allow envoy JWT token verifying) using next Helm values

*Parameters to configure OpenID provider*

```
# authn overrides configuration of envoy.filters.http.jwt_authn http filter
authn:
  # enabled activate envoy authn filter that verify jwt token and pass parsed data
  # to next filters (particularly to authz)
  oidcIssuer: ""
  oidcJwks: ""
  oidcHost: ""
  localJwks: ""
```

For information about *authn* section parameters see [docs for envoy authentication filter](#)

By default chart is delivered with **built-in policies** that implements Role based access system and set of pre-defined roles. To customize some of built-in policies files or define new ones use next Helm values

*Parameters to configure built-in policies*

```
opa:
  policies: {}
  # policies:
  #   file1: ".rego policy content encoded as base64"
  #   file2: ".rego policy content encoded as base64"
```

### Warning

Content of rego files defined in values.yaml should be base64 encoded

## Install ODAHU

## Install core ODAHU services

Create namespace for core ODAHU service:

```
$ kubectl create namespace odahu-flow &&\\
  kubectl label namespace odahu-flow project=odahu-flow
```

Create namespaces for ODAHU training, packaging and deployment.

```
$ for i in training packaging deployment; do \\
  kubectl create namespace odahu-flow-${i} &&\\
  kubectl label namespace odahu-flow-${i} project=odahu-flow; done
```

To provision pods in the deployment namespace according to node selectors and toleration from the config you need to label the namespace so the model deployment webhook use it as a target

```
$ kubectl label namespace odahu-flow-deployment odahu/node-selector-webhook=enabled
```

Deployment namespace should be also labeled for Istio injection.

```
$ kubectl label namespace odahu-flow-deployment istio-injection=enabled
```

Prepare YAML config with values for **odahu-flow-core** Helm chart.

Example:

```
$ cat << EOF > odahuflow_values.yaml
logLevel: debug
ingress:
  enabled: true
  globalDomain: odahu.example.com
edge:
  ingress:
    enabled: true
    domain: odahu.example.com
feedback:
  enabled: true
config:
  common:
    external_urls:
      - name: Documentation
        url: https://docs.odahu.org
    databaseConnectionString: postgresql://odahu:PASSWORD@odahu-db.postgresql/odahu
connection:
  enabled: true
  decrypt_token: somenotemptystring
  repository_type: kubernetes
deployment:
  edge:
    host: http://odahu.example.com
EOF
```

## Note

This example uses hostname odahu.example.com as entrypoint for cluster services. It should point to LoadBalancer IP got from Nginx Ingress section.

In order to setup ODAHU services along with ready-to-use **connections**, you may add according section to values YAML in advance.

To support training on GPU, you should provide the GPU node selectors and tolerations:

Example:

*Example of Connection GCS:*

```
config:  
  training:  
    gpu_tolerations:  
      key: dedicated  
      operator: Equal  
      value: training-gpu  
      effect: NO_SCHEDULE  
    gpu_node_selector:  
      mode: odahu-flow-training-gpu
```

Examples:

- Docker registry connection is used to pull/push Odahu packager resulting Docker images to a Docker registry

```
connections:  
- id: docker-hub  
  spec:  
    description: Docker registry for model packaging  
    username: "user"  
    password: "supersecure"  
    type: docker  
    uri: docker.io/odahu-models-repo  
    webUILink: https://hub.docker.com/r/odahu-models-repo
```

- Google Cloud Storage connection is used to store model trained artifacts and



If you install **Open Policy Agent** for ODAHU then you will need to configure service accounts which will be used by ODAHU core background services such as **<Trainer>** or **<Packager>**.

All service accounts below require *odahu-admin* ODAHU built-in role. (see more about built-in roles in **security docs**)

Next values with service account credentials are required :

*values.yaml*

```
1 config:  
2   operator:
```

## Install ODAHU

```
3  # OpenId Provider token url
4  oauth_oidc_token_endpoint: https://oauth2.googleapis.com/token
5  # Credentials from OAuth2 client with Client Credentials Grant
6  client_id: client-id
7  client_secret: client-secret
8
9 trainer:
10 # OpenId Provider token url
11 oauth_oidc_token_endpoint: https://oauth2.googleapis.com/token
12 # Credentials from OAuth2 client with Client Credentials Grant
13 client_id: client-id
14 client_secret: client-secret
15
16 packager:
17 # OpenId Provider token url
18 oauth_oidc_token_endpoint: https://oauth2.googleapis.com/token
19 # Credentials from OAuth2 client with Client Credentials Grant
20 client_id: client-id
21 client_secret: client-secret
22
23 # Service account used to upload odahu resources via odahuflowctl
24 resource_uploader_sa:
25   client_id: some-client-id
26   client_secret: client-secret
27
28 # OpenID provider url
29 oauth_oidc_issuer_url: ""
```

In this file, we:

- lines 2-7: configure service account for **Operator**
- lines 9-14: configure service account for **Trainer**
- lines 16-21: configure service account for **Packager**
- lines 24-29: configure service account Kubernetes Job that install some ODAHU Manifests using ODAHU API

Install odahu-flow core services:

```
$ helm install odahu/odahu-flow-core --name odahu-flow --namespace odahu-flow --values ./odahuflow_values.yaml
```

## Training service (MLFlow)

Prepare YAML config with values for **odahu-flow-mlflow** Helm chart.

```
$ cat << EOF > mlflow_values.yaml
logLevel: debug
ingress:
  globalDomain: example.com
  enabled: true
tracking_server:
  annotations:
    sidecar.istio.io/inject: "false"
toolchain_integration:
  enabled: true
EOF
```

If you install **Open Policy Agent** for ODAHU then you will need to configure service account for a Kubernetes Job that install some ODAHU Manifests using ODAHU API. This Service account should have role *odahu-admin*.

## Install ODAHU

Next values with service account credentials are required :

*values.yaml*

```
1 # Service account used to upload odahu resources via odahuflowctl
2 resource_uploader_sa:
3   client_id: some-client-id
4   client_secret: client-secret
5
6 # OpenID provider url
7 oauth_oidc_issuer_url: ""
```

Install Helm chart:

```
$ helm install odahu/odahu-flow-mlflow --name odahu-flow-mlflow --namespace odahu-flow \
--values ./mlflow_values.yaml
```

## Packaging service

If you install **Open Policy Agent** for ODAHU then you will need to configure service account for a Kubernetes Job that install some ODAHU Manifests using ODAHU API. This Service account should have role *odahu-admin*.

Next values with service account credentials are required :

*values.yaml*

```
1 # Service account used to upload odahu resources via odahuflowctl
2 resource_uploader_sa:
3   client_id: some-client-id
4   client_secret: client-secret
5
6 # OpenID provider url
7 oauth_oidc_issuer_url: ""
```

Install **odahu-flow-packagers** Helm chart:

```
$ helm install odahu/odahu-flow-packagers --name odahu-flow-packagers --namespace odahu-flow
```

## Install additional services (optional)

In order to provide additional functionality, ODAHU team also developed several Helm charts to install them into Kubernetes cluster. These are:

- **odahu-flow-monitoring** - Helm chart providing installation and setup of
  - **Prometheus operator** - to collect various metrics from models trainings
  - **Grafana** with set of custom dashboards - to visualize these metrics
- **odahu-flow-k8s-gke-saa** - Helm chart providing installation and setup of **k8s-gke-service-account-assigner** service.

## Delete ODAHU services

To delete and purge Helm chart run:

```
$ helm delete --purge odahu-flow
```

To clean up remaining CustomResourceDefinitions execute following command:

```
$ kubectl get crd | awk '/odahuflow/ {print $1}' | xargs -n1 kubectl delete crd
```

To purge everything installed in previous steps with single command, run

```
$ helm delete --purge odahu-flow-packagers odahu-flow-mlflow odahu-flow &&\\
kubectl delete namespace odahu-flow &&\\
for i in training packaging deployment; do \\
    kubectl delete namespace odahu-flow-${i} || true; done &&\\
kubectl get crd | awk '/odahuflow/ {print $1}' | xargs -n1 kubectl delete crd &&\\
kubectl -n istio-system delete job.batch/odahu-flow-feedback-rq-catcher-patcher &&\\
kubectl -n istio-system delete sa/odahu-flow-feedback-rq-catcher-patcher &&\\
kubectl -n istio-system delete cm/odahu-flow-feedback-rq-catcher-patch
```

## Conclusion

After successful deployment of a cluster, you may proceed to [Quickstart section](#) and learn how to perform base ML operations such as [train](#), [package](#) and [deploy](#) steps.

# Cluster Quickstart

In this tutorial you will learn how to Train, Package and Deploy a model from scratch on Odahu. Once deployed, the model serves RESTful requests, and makes a prediction when provided user input.

Odahu's API server performs Train, Package, and Deploy operations for you, using its REST API.

## Prerequisites

- Odahu cluster
- MLFlow and **REST API Packager** (installed by default)
- **Odahu-flow CLI** or **Plugin for JupyterLab** (installation instructions: CLI, Plugin)
- JWT token from API (**instructions**)
- Google Cloud Storage bucket on Google Compute Platform
- GitHub repository and an ssh key to connect to it

## Tutorial

In this tutorial, you will learn how to:

1. Create an MLFlow project
2. Setup Connections
3. Train a model
4. Package the model
5. Deploy the packaged model
6. Use the deployed model

This tutorial uses a dataset to predict the quality of the wine based on quantitative features like the wine's *fixed acidity*, *pH*, *residual sugar*, and so on.

Code for the tutorial is available on [GitHub](#).

### Create **MLFlow** project

Before	Odahu cluster that meets prerequisites
After	Model code that predicts wine quality

Create a new project folder:

```
$ mkdir wine && cd wine
```

## Cluster Quickstart

Create a training script:

```
$ touch train.py
```

Paste code into the file:

*train.py*

```
1 import os
2 import warnings
3 import sys
4 import argparse
5
6 import pandas as pd
7 import numpy as np
8 from sklearn.metrics import mean_squared_error, mean_absolute_error, r2_score
9 from sklearn.model_selection import train_test_split
10 from sklearn.linear_model import ElasticNet
11
12 import mlflow
13 import mlflow.sklearn
14
15 def eval_metrics(actual, pred):
16     rmse = np.sqrt(mean_squared_error(actual, pred))
17     mae = mean_absolute_error(actual, pred)
18     r2 = r2_score(actual, pred)
19     return rmse, mae, r2
20
21 if __name__ == "__main__":
22     warnings.filterwarnings("ignore")
23     np.random.seed(40)
24
25     parser = argparse.ArgumentParser()
26     parser.add_argument('--alpha')
27     parser.add_argument('--l1-ratio')
28     args = parser.parse_args()
29
30     # Read the wine-quality csv file (make sure you're running this from the root of MLflow!)
31     wine_path = os.path.join(os.path.dirname(os.path.abspath(__file__)), "wine-quality.csv")
32     data = pd.read_csv(wine_path)
33
34     # Split the data into training and test sets. (0.75, 0.25) split.
35     train, test = train_test_split(data)
36
37     # The predicted column is "quality" which is a scalar from [3, 9]
38     train_x = train.drop(["quality"], axis=1)
39     test_x = test.drop(["quality"], axis=1)
40     train_y = train[["quality"]]
41     test_y = test[["quality"]]
42
43     alpha = float(args.alpha)
44     l1_ratio = float(args.l1_ratio)
45
46     with mlflow.start_run():
47         lr = ElasticNet(alpha=alpha, l1_ratio=l1_ratio, random_state=42)
48         lr.fit(train_x, train_y)
49
50         predicted_qualities = lr.predict(test_x)
51
52         (rmse, mae, r2) = eval_metrics(test_y, predicted_qualities)
53
54         print("Elasticnet model (alpha=%f, l1_ratio=%f):" % (alpha, l1_ratio))
55         print(" RMSE: %s" % rmse)
56         print(" MAE: %s" % mae)
57         print(" R2: %s" % r2)
58
59         mlflow.log_param("alpha", alpha)
60         mlflow.log_param("l1_ratio", l1_ratio)
61         mlflow.log_metric("rmse", rmse)
62         mlflow.log_metric("r2", r2)
```

## Cluster Quickstart

```
63     mlflow.log_metric("mae", mae)
64     mlflow.set_tag("test", '13')
65
66     mlflow.sklearn.log_model(lr, "model")
67
68     # Persist samples (input and output)
69     train_x.head().to_pickle('head_input.pkl')
70     mlflow.log_artifact('head_input.pkl', 'model')
71     train_y.head().to_pickle('head_output.pkl')
72     mlflow.log_artifact('head_output.pkl', 'model')
```

In this file, we:

- Start MLflow context on line 46
- Train ElasticNet model on line 48
- Set metrics, parameters and tags on lines 59-64
- Save model with name `model` (`model` is serialized and sent to the MLflow engine) on line 66
- Save input and output samples (for persisting information about input and output column names) on lines 69-72

Create an `MLproject` file:

```
$ touch MLproject
```

Paste code into the file:

*MLproject*

```
name: wine-quality-example
conda_env: conda.yaml
entry_points:
  main:
    parameters:
      alpha: float
      l1_ratio: {type: float, default: 0.1}
    command: "python train.py --alpha {alpha} --l1-ratio {l1_ratio}"
```

### Note

Read more about `MLproject` structure on the [official MLFlow docs](#).

Create a `conda` environment file:

```
$ touch conda.yaml
```

Paste code to the created file:

*conda.yaml*

```
name: example
channels:
```

## Cluster Quickstart

```
- defaults
dependencies:
- python=3.6
- numpy=1.14.3
- pandas=0.22.0
- scikit-learn=0.19.1
- pip:
  - mlflow==1.0.0
```

### Note

All python packages that are used in training script must be listed in the conda.yaml file.

*Read more about conda environment on the [official conda docs](#).*

Make directory “data” and download the wine data set:

```
$ mkdir ./data
$ wget https://raw.githubusercontent.com/odahu/odahu-examples/develop/mlflow/sklearn/wine/data/wine-quality.csv -O ./data/wine-quality.csv
```

After this step the project folder should look like this:

```
.
├── MLproject
├── conda.yaml
├── data
│   └── wine-quality.csv
└── train.py
```

## Setup connections

Before	Odahu cluster that meets prerequisites
After	Odahu cluster with <b>Connections</b>

Odahu Platform uses the concept of **Connections** to manage authorizations to external services and data.

This tutorial requires three Connections:

- A GitHub repository, where the code is located
- A Google Cloud Storage folder, where input data is located (wine-quality.csv)
- A Docker registry, where the trained and packaged model will be stored for later use

You can find more detailed documentation about a connection configuration [here](#).

**Create a Connection to GitHub repository**

## Cluster Quickstart

Because [odahu-examples](#) repository already contains the required code we will just use this repository. But feel free to create and use a new repository if you want.

Odahu is REST-powered, and so we encode the REST “payloads” in this tutorial in YAML files. Create a directory where payloads files will be staged:

```
$ mkdir ./odahu-flow
```

Create payload:

```
$ touch ./odahu-flow/vcs_connection.odahu.yaml
```

Paste code into the created file:

*vcs\_connection.odahu.yaml*

```
kind: Connection
id: odahu-flow-tutorial
spec:
  type: git
  uri: git@github.com:odahu/odahu-examples.git
  reference: origin/master
  keySecret: <paste here your base64-encoded key github ssh key>
  description: Git repository with odahu-flow-examples
  webUILink: https://github.com/odahu/odahu-examples
```

### Note

Read more about [GitHub ssh keys](#)

Create a Connection using the **Odahu-flow CLI**:

```
$ odahuflowctl conn create -f ./odahu-flow/vcs_connection.odahu.yaml
```

Or create a Connection using **Plugin for JupyterLab**:

1. Open jupyterlab (available by <your.cluster.base.address>/jupyterhub);
2. Navigate to ‘File Browser’ (folder icon)
3. Select file ./odahu-flow/vcs\_connection.odahu.yaml and in context menu press submit button;

### Create Connection to wine-quality.csv object storage

Create payload:

```
$ touch ./odahu-flow/wine_connection.odahu.yaml
```

Paste this code into the file:

## Cluster Quickstart

*wine\_connection.odahu.yaml*

```
kind: Connection
id: wine-tutorial
spec:
  type: gcs
  uri: gs://<paste your bucket address here>/data-tutorial/wine-quality.csv
  region: <paste region here>
  keySecret: <paste base64-encoded key secret here> # should be enclosed in single quotes
  description: Wine dataset
```

Create a connection using the **Odahu-flow CLI** or **Plugin for JupyterLab**, as in the previous example.

If wine-quality.csv is not in the GCS bucket yet, use this command:

```
$ gsutil cp ./data/wine-quality.csv gs://<bucket-name>/data-tutorial/
```

## Create a Connection to a docker registry

Create payload:

```
$ touch ./odahu-flow/docker_connection.odahu.yaml
```

Paste this code into the file:

*docker\_connection.odahu.yaml*

```
kind: Connection # type of payload
id: docker-tutorial
spec:
  type: docker
  uri: <paste uri of your registry here> # uri to docker image registry
  username: <paste your username here>
  password: <paste your base64-encoded password here>
  description: Docker registry for model packaging
```

Create the connection using **Odahu-flow CLI** or **Plugin for JupyterLab**, as in the previous example.

Check that all Connections were created successfully:

```
- id: docker-tutorial
  description: Docker repository for model packaging
  type: docker
- id: odahu-flow-tutorial
  description: Git repository with odahu-flow-tutorial
  type: git
- id: models-output
  description: Storage for trained artifacts
  type: gcs
- id: wine-tutorial
  description: Wine dataset
  type: gcs
```

Congrats! You are now ready to train the model.

## Train the model

Before	Project code, hosted on GitHub
After	Trained <b>GPPI</b> model (a <b>Trained Model Binary</b> )

Create payload:

```
$ touch ./odahu-flow/training.odahu.yaml
```

Paste code into the file:

*./odahu-flow/training.odahu.yaml*

```

1 kind: ModelTraining
2 id: wine-tutorial
3 spec:
4   model:
5     name: wine
6     version: 1.0
7   toolchain: mlflow # MLFlow training toolchain integration
8   entrypoint: main
9   workDir: mlflow/sklearn/wine # MLproject location (in GitHub)
10  data:
11    - connName: wine-tutorial
12      # Where to save a local copy of wine-quality.csv from wine-tutorial GCP connection
13      localPath: mlflow/sklearn/wine/wine-quality.csv
14  hyperParameters:
15    alpha: "1.0"
16  resources:
17    limits:
18      cpu: 4
19      memory: 4Gi
20    requests:
21      cpu: 2
22      memory: 2Gi
23  vcsName: odahu-flow-tutorial

```

In this file, we:

- line 7: Set Odahu toolchain's name to mlflow
- line 8: Reference main method in entry\_points (which is defined for MLproject files)
- line 9: Point workDir to the MLFlow project directory. (This is the directory that has the MLproject in it.)
- line 10: A section defining input data
- line 11: connName id of the wine\_connection.odahu.yaml (created in the previous step)
- line 12: localPath relative (to Git repository root) path of the data file at the training (docker) container where data were put
- lines 13-14: Input hyperparameters, defined in MLProject file, and passed to main method
- line 22: vcsName id of the vcs\_connection.odahu.yaml (created in the previous step)

### Train using Odahu-flow CLI:

```
$ odahuflowctl training create -f ./odahu-flow/training.odahu.yaml
```

### Check Train logs:

```
$ odahuflowctl training logs --id wine-tutorial
```

The **Train** process will finish after some time.

To check the status run:

```
$ odahuflowctl training get --id wine-tutorial
```

When the Train process finishes, the command will output this YAML:

- state succeeded
- artifactName (filename of **Trained Model Binary**)

Or *Train* using the **Plugin for JupyterLab**:

1. Open jupyterlab
2. Open cloned repo, and then the folder with the project
3. Select file ./odahu-flow/training.odahu.yaml and in context menu press submit button

You can see model logs using Odahu cloud mode in the left side tab (cloud icon) in Jupyterlab

1. Open Odahu cloud mode tab
2. Look for TRAINING section
3. Press on the row with *ID=wine*
4. Press button LOGS to connect to **Train** logs

After some time, the **Train** process will finish. Train status is updated in column status of the TRAINING section in the Odahu cloud mode tab. If the model training finishes with success, you will see *status=succeeded*.

Then open **Train** again by pressing the appropriate row. Look at the *Results* section. You should see:

- artifactName (filename of **Trained Model Binary**)

artifactName is the filename of the trained model. This model is in **GPPI** format. We can download it from storage defined in the models-output Connection. (This connection is created during Odahu Platform installation, so we were not required to create this Connection as part of this tutorial.)

### Package the model

## Cluster Quickstart

Before	The trained model in <b>GPPI Trained Model Binary</b>
After	Docker image for the packaged model, including a model REST API

Create payload:

```
$ touch ./odahu-flow/packaging.odahu.yaml
```

Paste code into the file:

```
./odahu-flow/packaging.odahu.yaml
```

```
1 id: wine-tutorial
2 kind: ModelPackaging
3 spec:
4   artifactName: "<fill-in>" # Use artifact name from Train step
5   targets:
6     - connectionName: docker-tutorial # Docker registry where output image will be stored
7     - name: docker-push
8   integrationName: docker-rest # REST API Packager
```

In this file, we:

- line 4: Set to artifact name from the Train step
- line 6: Set to docker registry, where output will be staged
- line 7: Specify the docker command
- line 8: id of the **REST API Packager**

Create a **Package** using **Odahu-flow CLI**:

```
$ odahuflowctl packaging create -f ./odahu-flow/packaging.odahu.yaml
```

Check the **Package** logs:

```
$ odahuflowctl packaging logs --id wine-tutorial
```

After some time, the **Package** process will finish.

To check the status, run:

```
$ odahuflowctl packaging get --id wine-tutorial
```

You will see YAML with updated **Package** resource. Look at the status section. You can see:

- **image** # This is the filename of the Docker image in the registry with the trained model prediction, served via REST`.

Or run Package using the **Plugin for JupyterLab**:

1. Open jupyterlab

## Cluster Quickstart

2. Open the repository that has the source code, and navigate to the folder with the MLProject file
3. Select file `./odahu-flow/packaging.odahu.yaml` and in the context menu press the submit button

To view Package logs, use Odahu cloud mode in the side tab of your Jupyterlab

1. Open Odahu cloud mode tab
2. Look for PACKAGING section
3. Click on the row with `ID=wine`
4. Click the button for LOGS and view the Packaging logs

After some time, the **Package** process will finish. The status of training is updated in column status of the *PACKAGING* section in the Odahu cloud mode tab. You should see `status=succeeded`.

Then open PACKAGING again by pressing the appropriate row. Look at the *Results* section. You should see:

- image (this is the filename of docker image in the registry with the trained model as a REST service`);

## Deploy the model

Before	Model is packaged as image in the Docker registry
After	Model is served via REST API from the Odahu cluster

Create payload:

```
$ touch ./odahu-flow/deployment.odahu.yaml
```

Paste code into the file:

```
./odahu-flow/deployment.odahu.yaml
```

```
1 id: wine-tutorial
2 kind: ModelDeployment
3 spec:
4   image: "<fill-in>"
5   minReplicas: 1
6   imagePullConnectionID: docker-tutorial
```

In this file, we:

- line 4: Set the image that was created in the Package step
- line 6: Set the id of the **REST API Packager**

Create a **Deploy** using the **Odahu-flow CLI**:

## Cluster Quickstart

```
$ odahuflowctl deployment create -f ./odahu-flow/deployment.odahu.yaml
```

After some time, the **Deploy** process will finish.

To check its status, run:

```
$ odahuflowctl deployment get --id wine-tutorial
```

Or create a *Deploy* using the **Plugin for JupyterLab**:

1. Open jupyterlab
2. Open the cloned repo, and then the folder with the MLProject file
3. Select file `./odahu-flow/deployment.odahu.yaml`. In context menu press the submit button

You can see Deploy logs using the Odahu cloud mode side tab in your Jupyterlab

1. Open the Odahu cloud mode tab
2. Look for the DEPLOYMENT section
3. Click the row with *ID=wine*

After some time, the **Deploy** process will finish. The status of Deploy is updated in column status of the *DEPLOYMENT* section in the Odahu cloud mode tab. You should see *status=Ready*.

## Use the deployed model

Step input data	The deployed model
-----------------	--------------------

After the model is deployed, you can check its API in Swagger:

Open <your-odahu-platform-host>/service-catalog/swagger/index.html and look and the endpoints:

1. GET `/model/wine-tutorial/api/model/info` - OpenAPI model specification;
2. POST `/model/wine-tutorial/api/model/invoke` - Endpoint to do predictions;

But you can also do predictions using the **Odahu-flow CLI**.

Create a payload file:

```
$ touch ./odahu-flow/r.json
```

Add payload for `/model/wine-tutorial/api/model/invoke` according to the OpenAPI schema. In this payload we provide values for model input variables:

*./odahu-flow/r.json*

```
{  
  "columns": [
```

## Cluster Quickstart

```
"fixed acidity",
"volatile acidity",
"citric acid",
"residual sugar",
"chlorides",
"free sulfur dioxide",
"total sulfur dioxide",
"density",

```

Invoke the model to make a prediction:

```
$ odahuflowctl model invoke --mr wine-tutorial --json-file r.json
```

*./odahu-flow/r.json*

```
{"prediction": [6.0], "columns": ["quality"]}
```

Congrats! You have completed the tutorial.

# Local Quickstart

In this tutorial, we will walk through the training, packaging and serving of a machine learning model locally by leveraging ODAHUFlow's main components.

## Prerequisites

- Docker engine (at least version 17.0) with access from current user (`docker ps` should executes without errors)
- **Odahu-flow CLI**
- git
- wget

## Tutorial

We will consider the wine model from Cluster Quickstart. But now, we will train, package and deploy the model locally.

### Note

Code for the tutorial is available on [GitHub](#).

`odahuflowctl` has commands for local training and packaging.

```
$ odahuflowctl local --help
```

To train a model locally, you have to provide an ODAHU model training manifest and training toolchain. `odahuflowctl` tries to find them on your local filesystem. If it can not do it, then the CLI requests to ODAHU API.

*Local training arguments:*

--train-id, --id TEXT	Model training ID [required]
-f, --manifest-file PATH	Path to a ODAHU-flow manifest file
-d, --manifest-dir PATH	Path to a directory with ODAHU-flow manifests

The `mlflow/sklearn/wine/odahuflow` directory already contains training manifest file for wine model. If we don't have a running ODAHUFlow API server, we should create toolchain manifest manually.

Paste the toolchain manifest into the `mlflow/sklearn/wine/odahuflow/toolchain.yaml` file:

```
kind: ToolchainIntegration
id: mlflow
```

## Local Quickstart

```
spec:  
  defaultImage: "odahu/odahu-flow-mlflow-toolchain:1.1.0-rc11"  
  entrypoint: /opt/conda/bin/odahu-flow-mlflow-runner
```

We are ready to launch the local training. Copy, past and execute the following command.

```
$ odahuflowctl local train run -d mlflow/sklearn/wine/odahuflow --id wine
```

### Warning

MLFlow metrics does not propagate to the tracking server during training. This will be implemented in the near future.

*odahuflowctl* trains the model, verify that it satisfy the GPPI spec and save GPPI binary in the host filesystem. Execute the following command to take a look all trained models.

```
$ odahuflowctl local train list
```

Our next step is to package the trained model to a REST service. Like for local training, local packaging requires a model packaging and packaging integration manifests.

#### *Local packaging arguments:*

--pack-id, --id TEXT	Model packaging ID [required]
-f, --manifest-file PATH	Path to a ODAHU-flow manifest file
-d, --manifest-dir PATH	Path to a directory with ODAHU-flow manifest files
--artifact-path PATH	Path to a training artifact
-a, --artifact-name TEXT	Override artifact name from file

Paste the packaging integration manifest into the *mlflow/sklearn/wine/odahuflow/packager.yaml* file:

```
kind: PackagingIntegration  
id: docker-rest  
spec:  
  entrypoint: "/usr/local/bin/odahu-flow-pack-to-rest"  
  defaultImage: "odahu/odahu-flow-packagers:1.1.0-rc11"  
  privileged: true  
  schema:  
    targets:  
      - name: docker-push  
        connectionTypes: ["docker", "ecr"]  
        required: true  
      - name: docker-pull  
        connectionTypes: ["docker", "ecr"]  
        required: false  
  arguments:  
    properties:  
      - name: dockerfileAddCondaInstallation  
    parameters:  
      - name: description
```

## Local Quickstart

```
    value: Add conda installation code to training.Dockerfile
    - name: type
      value: boolean
      - name: default
        value: true
    - name: dockerfileBaseImage
      parameters:
        - name: description
          value: Base image for training.Dockerfile.
        - name: type
          value: string
        - name: default
          value: 'odahu/odahu-flow-docker-packager-base:1.1.0-rc11'
    - name: dockerfileCondaEnvLocation
      parameters:
        - name: description
          value: Conda env location in training.Dockerfile.
        - name: type
          value: string
        - name: default
          value: /opt/conda/envs/
    - name: host
      parameters:
        - name: description
          value: Host to bind.
        - name: type
          value: string
        - name: default
          value: 0.0.0.0
    - name: port
      parameters:
        - name: description
          value: Port to bind.
        - name: type
          value: integer
        - name: default
          value: 5000
    - name: timeout
      parameters:
        - name: description
          value: Serving timeout in seconds.
        - name: type
          value: integer
        - name: default
          value: 60
    - name: workers
      parameters:
        - name: description
          value: Count of serving workers.
        - name: type
          value: integer
        - name: default
          value: 1
    - name: threads
      parameters:
        - name: description
          value: Count of serving threads.
        - name: type
          value: integer
        - name: default
          value: 4
    - name: imageName
      parameters:
        - name: description
          value: |
            This option provides a way to specify the Docker image name. You can hardcode the full name or specify a template. Available template values:
            - Name (Model Name)
            - Version (Model Version)
            - RandomUUID
            The default value is '{{ Name }}/{{ Version }}:{{ RandomUUID }}'.
            Image name examples:
            - myservice:123
            - {{ Name }}:{{ Version }}
        - name: type
          value: string
        - name: default
          value: "{{ Name }}-{{ Version }}:{{ RandomUUID }}"

```

Choose the name of trained artifact and execute the following command:

```
$ odahuflowctl --verbose local pack run -d mlflow/sklearn/wine/odahuflow --id wine -a wine-1.0-wine-1.0-01-Mar-2020-18-33-35
```

The last lines of output must contains a name of model REST service.

At the last step, we run our REST service and make a predict.

```
$ docker run -it --rm -p 5000:5000 wine-1.0:cbe184d0-4b08-45c4-8efb-17e28a3b537e
```

```
$ odahuflowctl model invoke --url http://0:5000 --json-file mlflow/sklearn/wine/odahuflow/request.json
```

## Invoke ODAHU models for prediction

You want to call the model that was deployed on ODAHU programmatically

You can call ODAHU models using *REST API* or using *Python SDK*

### Python SDK

#### 1. Install python SDK

```
pip install odahu-flow-sdk
```

#### 2. Configure SDK

By default SDK config is located in `~/.odahuflow/config`

But you can override it location using `ODAHUFLOW_CONFIG` environment variable

Configure next values in the config

```
[general]
api_url = https://replace.your.models.host
api_issuing_url = https://replace.your.oauth2.token.url
```

#### 3. In python use ModelClient to invoke models

```
from odahuflow.sdk.clients.model import ModelClient, calculate_url
from odahuflow.sdk.clients.api import RemoteAPIClient
from odahuflow.sdk import config

# Change model deployment name to model name which you want to invoke
MODEL_DEPLOYMENT_NAME = "<model-deployment-name>"

# Get api token using client credentials flow via Remote client
remote_api = RemoteAPIClient(client_id='<your-client-id>', client_secret='<your-secret>')
remote_api.info()

# Build model client and invoke models
client = ModelClient(
    calculate_url(config.API_URL, model_deployment=MODEL_DEPLOYMENT_NAME),
    remote_api.authenticator.token
)

# Get swagger specification of model service
print(client.info())

# Invoke model
print(client.invoke(columns=['col1', 'col2'], data=[
    ['row1_at1', 'row1_at2'],
    ['row2_at1', 'row2_at2'],
]))
```

### REST

If you use another language you can use pure REST to invoke models

## Invoke ODAHU models for prediction

You should get token by yourself using OpenID provider and [OAuth2 Client Credentials Grant](#)

Then call ODAHU next way

To get the swagger definition of model service

```
curl -X GET "https://replace.your.models.host/model/${MODEL_DEPLOYMENT_NAME}/api/model/info" \
-H "accept: application/json" \
-H "Authorization: Bearer <token>"
```

To invoke the model

```
curl -X POST "https://replace.your.models.host/model/${MODEL_DEPLOYMENT_NAME}/api/model/invoke" \
-H "accept: application/json" \
-H "Authorization: Bearer <token>" \
-d @body.json
```

# API

**API service** manages Odahu Platform entities.

- **Connections**
- **Trainings**
- **Packaging**
- **Deployments**

**API service** can provide the following data, when queried:

- Model Train and Deploy logs
- Model **Trainer Metrics**
- Model **Trainer Tags**

## API-provided URLs

All information about URLs that **API service** provides can be viewed using the auto-generated, interactive Swagger page. It is located at <api-address>/swagger/index.html. You can read all of the up-to-date documentation and invoke all methods (allowed for your account) right from this web page.

## Authentication and authorization

**API service** distributed in odahu-flow-core helm chart with enabled authorization and pre-defined OPA policies. If **Security Subsystem** is installed, then all requests to API service will be enforced using pre-defined OPA policies.

## Implementation details

**API service** is a REST server, written in GoLang. For easy integration, it provides a Swagger endpoint with up-to-date protocol information.

Technologies used	GoLang
Distribution representation	Docker Image
Source code location	<a href="#">packages/operator</a>
Can be used w/o Odahu Platform?	Yes
Does it connect to other services?	Yes (Kubernetes API)
Can it be deployed locally?	If a local Kubernetes cluster is present
Does it provide any interface?	Yes (HTTP REST API)

# Feedback aggregator

**Feedback aggregator** is a service that provides a **Model Feedback API** and gathers input and output **prediction requests**

## API-provided URLs

**Model Feedback API** provide just single endpoint that allow you send feedback on a **prediction request**:

*POST /api/v1/feedback*

Information about this URL can be viewed using the auto-generated, interactive Swagger page. It is located at <api-address>/swagger/index.html. You can read all of the up-to-date documentation and invoke this endpoint (allowed for your account) right from this web page.

## Authentication and authorization

**Feedback aggregator** distributed in odahu-flow-core helm chart with enabled authorization and pre-defined OPA policies. If **Security Subsystem** is installed, then all requests to **Model Feedback API** service will be enforced using pre-defined OPA policies.

## Implementation details

**Feedback aggregator** contains two major subcomponents

- REST Server provides **Model Feedback API** and sends them to configured fluentd server
- Envoy Proxy tap filter catches all requests and responses of deployed models and sends this info to configured fluentd server

Technologies used	GoLang, Envoy Proxy
Distribution representation	Docker Image
Source code location	<a href="#">packages/operator</a>
Can be used w/o Odahu Platform?	No
Does it connect to other services?	Yes (Fluentd, Envoy Proxy)
Can it be deployed locally?	If a local Kubernetes cluster is present
Does it provide any interface?	Yes (HTTP REST API)

# Operator

**Operator** monitors Odahu-provided Kubernetes (K8s) [Custom Resources](#). This gives Operator the ability to manage Odahu entities using K8s infrastructure (Secrets, Pods, Services, etc). The K8s entities that belong to Odahu are referred to as [Odahu-flow's CRDs](#).

Operator is a mandatory component in Odahu clusters.

## Implementation details

**Operator** is a Kubernetes Operator, written using Kubernetes Go packages.

Technologies used	GoLang
Distribution representation	Docker Image
Source code location	<a href="#">packages/operator</a>
Can be used w/o Odahu Platform?	Yes
Does it connect to another services?	Yes (Kubernetes API)
Can be deployed locally?	If local Kubernetes cluster is present
Does it provide any interface?	No

# MLFlow Trainer

Odahu provides a **Trainer Extension** for the popular **MLflow** framework.

This allows model **Training** in Python, and provides support for MLflow APIs. Trained models are packaged using the **General Python Prediction Interface**.

## Limitations

- Odahu supports Python (v. 3) libraries (e.g. Keras, Sklearn, TensorFlow, etc.)
- MLeap is not supported
- Required packages (system and python) must be declared in a conda environment file
- Train must save only one model, using one MLproject entry point method. Otherwise an exception will occur
- Input and output columns should be mapped to the specially-named head\_input.pkl and head\_output.pkl files to make it into the Packaged artifact
- Training code should avoid direct usage of MLflow client libraries

## Implementation Details

Support	official
Language	Python 3.6+

Source code is available on [GitHub](#).

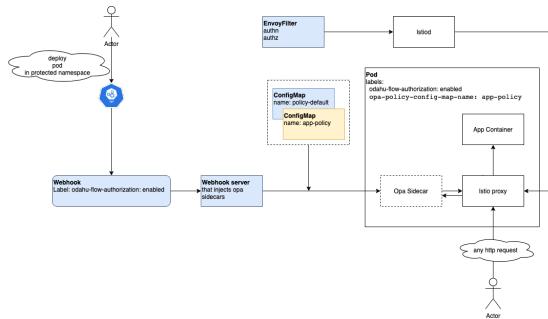
Low-level integration details are provided [here](#).

# Security subsystem

Security subsystem is distributed as a helm chart and relies on [OpenPolicyAgent](#) to make decisions about authorization and [Istio](#) to enforce authorization for requests to the protected services.

You can read about ODAHU security concepts in an appropriate docs section

## Implementation details



Helm chart deploys

- Webhook server that injects [OpenPolicyAgent](#) sidecars into pods that labeled by `odahu-flow-authorization=enabled`
- EnvoyFilter that configures Istio-proxy sidecars located in pods labeled by `odahu-flow-authorization=enabled` to force authentication and authorization for all incoming http requests
- ConfigMap with common policy that included into all [OpenPolicyAgent](#) sidecars and implements masking of a sensitive data
- ConfigMap with default policy that included into [OpenPolicyAgent](#) sidecars when pod does not specify ConfigMap with its polices

When the webhook server deploys [OpenPolicyAgent](#) sidecar, it attaches policies from ConfigMap. ConfigMap can be found by the value of the pod label `opa-policy-config-map-name`. If this label is missed, then the default policy will be used. Default policy – reject all requests.

Different ODAHU components such as API and Feedback aggregator are distributed with a pre-defined set of [OpenPolicyAgent](#) policies. They create ConfigMap with their policies during the deployment process.

If you change ConfigMap with policies then the appropriate pod must be restarted to refresh its policies.

Technologies used	OpenPolicyAgent, Istio
Distribution representation	Helm chart
Source code location	<a href="#">packages/operator</a>
Can be used w/o Odahu Platform?	No
Does it connect to other services?	Yes (Kubernetes, OpenPolicyAgent, Istio)
Can it be deployed locally?	If a local Kubernetes cluster is present

## Security subsystem

Does it provide any interface?	No
--------------------------------	----

## Metrics

Odahu is pluggable and can integrate with a variety of metrics monitoring tools, allowing monitoring for:

- Model training metrics
- Model performance metrics
- System metrics (e.g. operator counters)

Odahu's installation Helm chart bootstraps a [Prometheus](#) operator to persist metrics and [Grafana](#) dashboard to display them.

Alternative integrations can be similarly constructed that swap in other monitoring solutions.

# Airflow

Odahu-flow provides a set of custom operators that allow you to interact with a Odahu cluster using [Apache Airflow](#)

## Connections

The Airflow plugin should be authorized by Odahu. Authorization is implemented using regular [Airflow Connections](#)

All custom Odahu-flow operators accept `api_connection_id` as a parameter that refers to *Odahu-flow Connection*

### ***Odahu-flow Connection***

The Odahu connection provides access to a Odahu cluster for Odahu custom operators.

#### ***Configuring the Connection***

Host (required)

The host to connect to. Usually available at: `odahu.<cluster-base-url>`

Type (required)

`HTTP`

Schema (optional)

`https`

Login (required)

Specify the user name to connect.

Password (required)

Specify the password to connect.

Extra (optional)

Specify the extra parameters (as json dictionary) that can be used in Odahu connection. Because Odahu uses OpenID authorization, additional OpenID/OAuth 2.0 parameters may be supplied here.

The following parameters are supported and must be defined:

- **`auth_url`**: url of [authorization server](#)
- **`client_id`**: The client identifier issued to the client during the registration process. [See more](#)
- **`client_secret`**: The client secret. The client MAY omit the parameter if the client secret is an empty string. [See more](#)
- **`scope`**: Access Token Scope

Example “extras” field:

```
{  
    "auth_url": "https://keycloak.<my-app-domain>",  
    "client_id": "my-app",  
    "client_secret": "*****",  
    "scope": "openid profile email offline_access groups",  
}
```

## Custom operators

This chapter describes the custom operators provided by Odahu.

### **Train, Pack, Deploy operators**

`class TrainingOperator (training=None, api_connection_id=None, *args, **kwargs)`

The operator that runs **Train** phase

Use *args* and *kwargs* to override other operator parameters

Parameters

- :
  - **training** (*odahuflow.sdk.models.ModelTraining*) - describes the **Train** phase
  - **api\_connection\_id** (*str*) - conn\_id of Odahu-flow Connection

`class TrainingSensor (training_id=None, api_connection_id=None, *args, **kwargs)`

The operator that waits for **Train** phase is finished

Use *args* and *kwargs* to override other operator parameters

Parameters

- :
  - **training\_id** (*str*) - *Train* id waits for
  - **api\_connection\_id** (*str*) - conn\_id of Odahu-flow Connection

`class PackagingOperator (packaging=None, api_connection_id=None, trained_task_id: str = "", *args, **kwargs)`

The operator that runs **Package** phase

Use *args* and *kwargs* to override other operator parameters

Parameters

- :
  - **packaging** (*odahuflow.sdk.models.ModelPackaging*) - describes the **Package** phase
  - **api\_connection\_id** (*str*) - conn\_id of Odahu-flow Connection
  - **trained\_task\_id** (*str*) - finished task id of TrainingSensor

`class PackagingSensor (training_id=None, api_connection_id=None, *args, **kwargs)`

The operator that waits for **Package** phase is finished

Use *args* and *kwargs* to override other operator parameters

## Custom operators

- Parameters :
  - **packaging\_id** (str) - Package id waits for
  - **api\_connection\_id** (str) - conn\_id of Odahu-flow Connection

**class DeploymentOperator** (deployment=None, api\_connection\_id=None, \*args, \*\*kwargs)

The operator that runs **Deploy** phase

Use args and kwargs to override other operator parameters

- Parameters :
  - **packaging** (*odahuflow.sdk.models.ModelDeployment*) - describes the **Deploy** phase
  - **api\_connection\_id** (str) - conn\_id of Odahu-flow Connection
  - **packaging\_task\_id** (str) - finished task id of PackagingSensor

**class DeploymentSensor** (training\_id=None, api\_connection\_id=None, \*args, \*\*kwargs)

The operator that waits for **Deploy** phase is finished

Use args and kwargs to override other operator parameters

- Parameters :
  - **deployment\_id** (str) - Deploy id waits for
  - **api\_connection\_id** (str) - conn\_id of Odahu-flow Connection

## Model usage operators

These operators are used to interact with deployed models.

**class ModelInfoRequestOperator** (self, model\_deployment\_name: str, api\_connection\_id: str, model\_connection\_id: str, md\_role\_name: str = "", \*args, \*\*kwargs)

The operator what extract metadata of deployed model.

Use args and kwargs to override other operator parameters

- Parameters :
  - **model\_deployment\_name** (str) - Model deployment name
  - **api\_connection\_id** (str) - conn\_id of Odahu-flow Connection
  - **model\_connection\_id** (str) - id of Odahu **Connection** for deployed model access
  - **md\_role\_name** (str) - Role name

**class ModelPredictRequestOperator** (self, model\_deployment\_name: str, api\_connection\_id: str, model\_connection\_id: str, request\_body: typing.Any, md\_role\_name: str = "", \*args, \*\*kwargs)

The operator request prediction using deployed model.

Use args and kwargs to override other operator parameters

## How to describe operators

Parameters :

- **model\_deployment\_name** (str) - <paste>
- **api\_connection\_id** (str) - conn\_id of Odahu-flow Connection
- **model\_connection\_id** (str) - id of Odahu **Connection** for deployed model access
- **request\_body** (dict) - JSON Body with model parameters
- **md\_role\_name** (str) - Role name

## Helper operators

These operators are helpers to simplify using Odahu-flow.

```
class GcpConnectionToOdahuConnectionOperator(self, api_connection_id: str,
google_cloud_storage_conn_id: str, conn_template: typing.Any, *args, **kwargs)
    Create Odahu-flow Connection using GCP Airflow Connection
    Use args and kwargs to override other operator parameters
```

Parameters :

- **api\_connection\_id** (str) - conn\_id of Odahu-flow Connection
- **google\_cloud\_storage\_conn\_id** (str) - conn\_id to Gcp Connection
- **conn\_template**  
(*odahuflow.sdk.models.connection.Connection*) - Odahu-flow Connection template

## How to describe operators

When you initialize Odahu custom operators such as TrainingOperator, PackagingOperator, or DeploymentOperator you should pass odahu resource payload as a parameter.

Actually, this is a payload that describes a resource that will be created at Odahu-flow cluster. You should describe such payloads using *odahuflow.sdk* models

### *Creating training payload*

```
training = ModelTraining(
    id=training_id,
    spec=ModelTrainingSpec(
        model=ModelIdentity(
            name="wine",
            version="1.0"
        ),
        toolchain="mlflow",
        entrypoint="main",
        work_dir="mlflow/sklearn/wine",
        hyper_parameters={
            "alpha": "1.0"
        },
        data=[
            DataBindingDir(
                path="path/to/dataset"
            )
        ]
    )
)
```

## How to describe operators

```
        conn_name='wine',
        local_path='mlflow/sklearn/wine/wine-quality.csv'
    ),
],
resources=ResourceRequirements(
    requests=ResourceList(
        cpu="2024m",
        memory="2024Mi"
    ),
    limits=ResourceList(
        cpu="2024m",
        memory="2024Mi"
    )
),
vcs_name="odahu-flow-examples"
),
)
```

But if you did some RnD work with Odahu-flow previously, it's likely that you already have yaml/json files that describe the same payloads. You can reuse them to create odahuflow.sdk models automatically

*Using plain yaml/json text*

```
from odahuflow.airflow.resources import resource

packaging_id, packaging = resource("""
id: airflow-wine
kind: ModelPackaging
spec:
    artifactName: <fill-in>
    targets:
        - connectionName: docker-ci
          name: docker-push
          integrationName: docker-rest
"""
)"""
```

Or refer to yaml/json files that must be located at Airflow DAGs folder or Airflow Home folder (these folders are configured at airflow.cfg file)

*Creating training payload*

```
from odahuflow.airflow.resources import resource
training_id, training = resource('training.odahuflow.yaml')
```

In this file, we refer to file *training.odahuflow.yaml* that is located at airflow dag's folder

For example, if you use [Google Cloud Composer](#) then you can locate your yaml's inside DAGs bucket and refer to them by relative path:

```
gsutil cp ~/.training.odahuflow.yaml gs://<your-composer-dags-bucket>/
```

## DAG example

The example of the DAG that uses custom Odahu-flow operators is shown below. Four DAGs are described.

## How to describe operators

*dag.py*

```
1 from datetime import datetime
2 from airflow import DAG
3 from airflow.contrib.operators.gcs_to_gcs import GoogleCloudStorageToGoogleCloudStorageOperator
4 from airflow.models import Variable
5 from airflow.operators.bash_operator import BashOperator
6 from odahuflow.sdk.models import ModelTraining, ModelTrainingSpec, ModelIdentity, ResourceRequirements, ResourceList, \
7     ModelPackaging, ModelPackagingSpec, Target, ModelDeployment, ModelDeploymentSpec, Connection, ConnectionSpec, \
8     DataBindingDir
9
10 from odahuflow.airflow.connection import GcpConnectionToOdahuConnectionOperator
11 from odahuflow.airflow.deployment import DeploymentOperator, DeploymentSensor
12 from odahuflow.airflow.model import ModelPredictRequestOperator, ModelInfoRequestOperator
13 from odahuflow.airflow.packaging import PackagingOperator, PackagingSensor
14 from odahuflow.airflow.training import TrainingOperator, TrainingSensor
15
16 default_args = {
17     'owner': 'airflow',
18     'depends_on_past': False,
19     'start_date': datetime(2019, 9, 3),
20     'email_on_failure': False,
21     'email_on_retry': False,
22     'end_date': datetime(2099, 12, 31)
23 }
24
25 api_connection_id = "odahuflow_api"
26 model_connection_id = "odahuflow_model"
27
28 gcp_project = Variable.get("GCP_PROJECT")
29 wine_bucket = Variable.get("WINE_BUCKET")
30
31 wine_conn_id = "wine"
32 wine = Connection(
33     id=wine_conn_id,
34     spec=ConnectionSpec(
35         type="gcs",
36         uri=f'gs://[{wine_bucket}]/data/wine-quality.csv',
37         region=gcp_project,
38     )
39 )
40
41 training_id = "airflow-wine"
42 training = ModelTraining(
43     id=training_id,
44     spec=ModelTrainingSpec(
45         model=ModelIdentity(
46             name="wine",
47             version="1.0"
48         ),
49         toolchain="mlflow",
50         entrypoint="main",
51         work_dir="mlflow/sklearn/wine",
52         hyper_parameters={
53             "alpha": "1.0"
54         },
55         data=[
56             DataBindingDir(
57                 conn_name='wine',
58                 local_path='mlflow/sklearn/wine/wine-quality.csv'
59             ),
60         ],
61         resources=ResourceRequirements(
62             requests=ResourceList(
63                 cpu="2024m",
64                 memory="2024Mi"
65             ),
66             limits=ResourceList(
67                 cpu="2024m",
68                 memory="2024Mi"
69             )
70         ),
71         vcs_name="odahu-flow-examples"
72     ),
73 )
74
75 packaging_id = "airflow-wine"
76 packaging = ModelPackaging(
77     id=packaging_id,
78     spec=ModelPackagingSpec(
79         targets=[Target(name="docker-push", connection_name="docker-ci")],
80         integration_name="docker-rest"
```

```
72     ),
73 )
74
75 packaging_id = "airflow-wine"
76 packaging = ModelPackaging(
77     id=packaging_id,
78     spec=ModelPackagingSpec(
79         targets=[Target(name="docker-push", connection_name="docker-ci")],
80         integration_name="docker-rest"
```

## How to describe operators

```
81     ),
82 )
83
84 deployment_id = "airflow-wine"
85 deployment = ModelDeployment(
86     id=deployment_id,
87     spec=ModelDeploymentSpec(
88         min_replicas=1,
89     ),
90 )
91
92 model_example_request = {
93     "columns": ["alcohol", "chlorides", "citric acid", "density", "fixed acidity", "free sulfur dioxide", "pH",
94                 "residual sugar", "sulphates", "total sulfur dioxide", "volatile acidity"],
95     "data": [[12.8, 0.029, 0.48, 0.98, 6.2, 29, 3.33, 1.2, 0.39, 75, 0.66],
96              [12.8, 0.029, 0.48, 0.98, 6.2, 29, 3.33, 1.2, 0.39, 75, 0.66]]
97 }
98
99 dag = DAG(
100     'wine_model',
101     default_args=default_args,
102     schedule_interval=None
103 )
104
105 with dag:
106     data_extraction = GoogleCloudStorageToGoogleCloudStorageOperator(
107         task_id='data_extraction',
108         google_cloud_storage_conn_id='wine_input',
109         source_bucket=wine_bucket,
110         destination_bucket=wine_bucket,
111         source_object='input/*.csv',
112         destination_object='data/',
113         project_id=gcp_project,
114         default_args=default_args
115     )
116     data_transformation = BashOperator(
117         task_id='data_transformation',
118         bash_command='echo "imagine that we transform a data"',
119         default_args=default_args
120     )
121     odahuflow_conn = GcpConnectionToOdahuConnectionOperator(
122         task_id='odahuflow_connection_creation',
123         google_cloud_storage_conn_id='wine_input',
124         api_connection_id=api_connection_id,
125         conn_template=wine,
126         default_args=default_args
127     )
128
129     train = TrainingOperator(
130         task_id="training",
131         api_connection_id=api_connection_id,
132         training=training,
133         default_args=default_args
134     )
135
136     wait_for_train = TrainingSensor(
137         task_id='wait_for_training',
138         training_id=training_id,
139         api_connection_id=api_connection_id,
140         default_args=default_args
141     )
142
143     pack = PackagingOperator(
144         task_id="packaging",
145         api_connection_id=api_connection_id,
146         packaging=packaging,
147         trained_task_id="wait_for_training",
148         default_args=default_args
149     )
150
151     wait_for_pack = PackagingSensor(
152         task_id='wait_for_packaging',
153         packaging_id=packaging_id,
```

```
154         api_connection_id=api_connection_id,
155         default_args=default_args
156     )
157
158     dep = DeploymentOperator(
159         task_id="deployment",
160         api_connection_id=api_connection_id,
161         deployment=deployment,
162         packaging_task_id="wait_for_packaging",
```

## How to describe operators

```
163     default_args=default_args
164 )
165
166 wait_for_dep = DeploymentSensor(
167     task_id='wait_for_deployment',
168     deployment_id=deployment_id,
169     api_connection_id=api_connection_id,
170     default_args=default_args
171 )
172
173 model_predict_request = ModelPredictRequestOperator(
174     task_id="model_predict_request",
175     model_deployment_name=deployment_id,
176     api_connection_id=api_connection_id,
177     model_connection_id=model_connection_id,
178     request_body=model_example_request,
179     default_args=default_args
180 )
181
182 model_info_request = ModelInfoRequestOperator(
183     task_id='model_info_request',
184     model_deployment_name=deployment_id,
185     api_connection_id=api_connection_id,
186     model_connection_id=model_connection_id,
187     default_args=default_args
188 )
189
190 data_extraction >> data_transformation >> odahuflow_conn >> train
191 train >> wait_for_train >> pack >> wait_for_pack >> dep >> wait_for_dep
192 wait_for_dep >> model_info_request
193 wait_for_dep >> model_predict_request
```

In this file, we create four dags:

- DAG on line 190 extract and transform data, create Odahu-flow connection and run **Train**
- DAG on line 191 sequentially run phases **Train, Package, Deploy**
- DAG on line 192 wait for model deploy and then extract schema of model predict API
- DAG on line 193 wait for model deploy and then invoke model prediction API

# JupyterLab extension

Odahu-flow provides the JupyterLab extension that allows you to interact with an Odahu cluster from JupyterLab web-based IDEs.

## Installation

### Prerequisites:

- Python 3.6 or higher
- Jupyterlab GUI
- Preferable to use Google Chrome or Mozilla Firefox browsers

To install the extension, perform the following steps:

```
pip install odahu-flow-jupyterlab-plugin
jupyter serverextension enable --sys-prefix --py odahuflow.jupyterlab
jupyter labextension install odahu-flow-jupyterlab-plugin
```

Another option is [prebuilt Jupyterlab Docker Image](#) with the extension.

## Configuration

The extension can be configured through the environment variables.

Environment name	Default	Value example	Description
DEFAULT_API_ENDPOINT		<a href="https://odahu.company.com/">https://odahu.company.com/</a>	Default URL to the Odahu-flow API server
API_AUTH_ENABLED	true	true	Change the value to false if authorization is disabled on the Odahu-flow API server
ODAHUFLOWCTL_OAUTH_AUTH_URL		<a href="https://keycloak.company.org/auth/realms/master/protocol/openid-connect/auth">https://keycloak.company.org/auth/realms/master/protocol/openid-connect/auth</a>	Keycloak authorization endpoint
JUPYTER_REDIRECT_URL		<a href="http://localhost:8888">http://localhost:8888</a>	JupyterLab external URL

## Login

ODAHUF LOWCTL_ OAUTH_ CLIENT_I D			Oauth client ID
ODAHUF LOWCTL_ OAUTH_ CLIENT_S ECRET			Oauth2 client secret

To enable SSO, you should provide the following options:

- *ODAHUFLOWCTL\_OAUTH\_AUTH\_URL*
- *JUPYTER\_REDIRECT\_URL*
- *ODAHUFLOWCTL\_OAUTH\_CLIENT\_SECRET*
- *ODAHUFLOWCTL\_OAUTH\_CLIENT\_ID*

## Login

To authorize on an Odahu-flow API service in the Jupyterlab extension, you should perform the following steps:

- Copy and paste the Odahu-flow API service URL.
- Open an API server URL in a browser to get the token. Copy and paste this token in the login form.

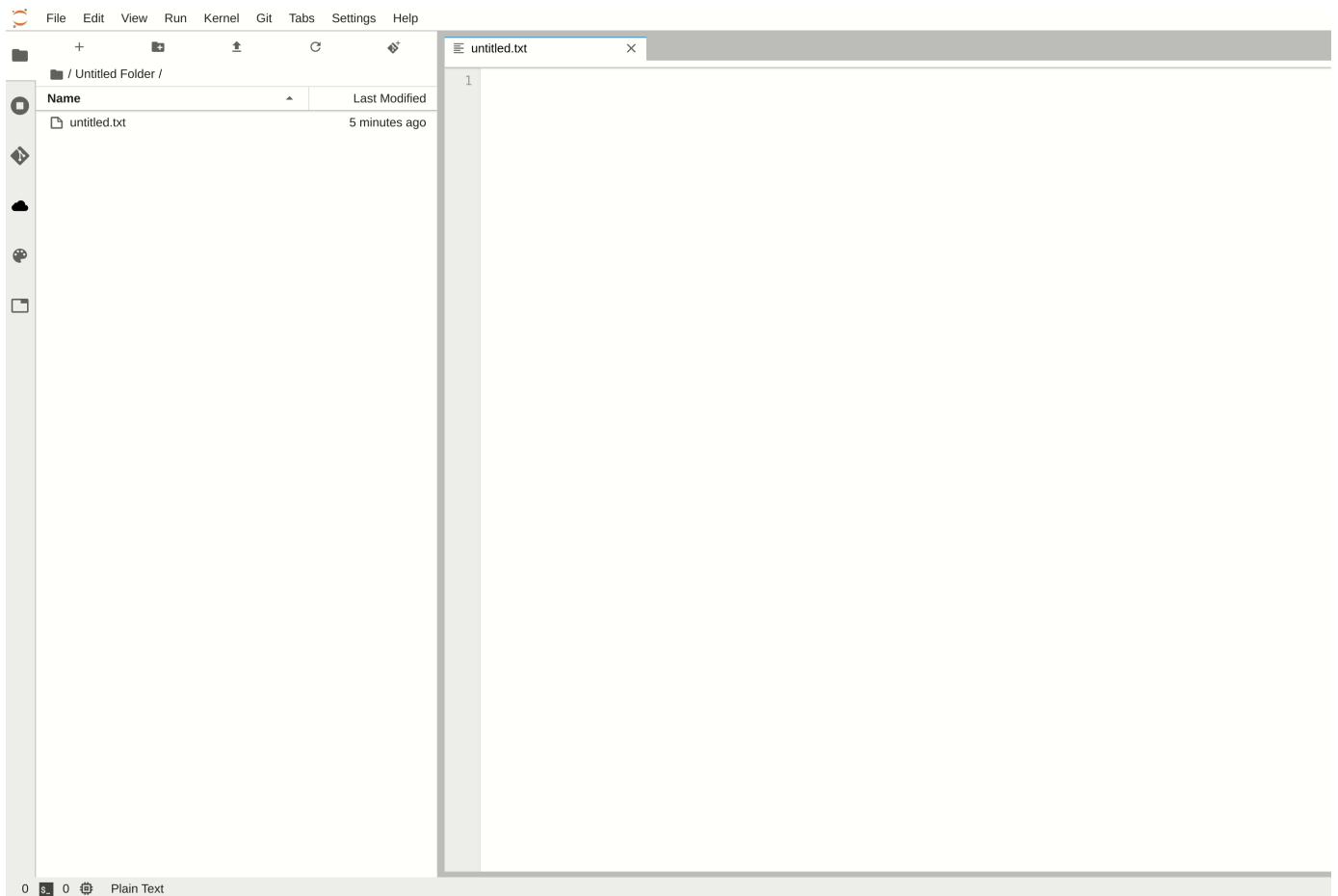
## Usage

Below we consider all views of the JupyterLab extension.

## Templates

The extension provides predefined list of API file templates. You can create a file from a template.

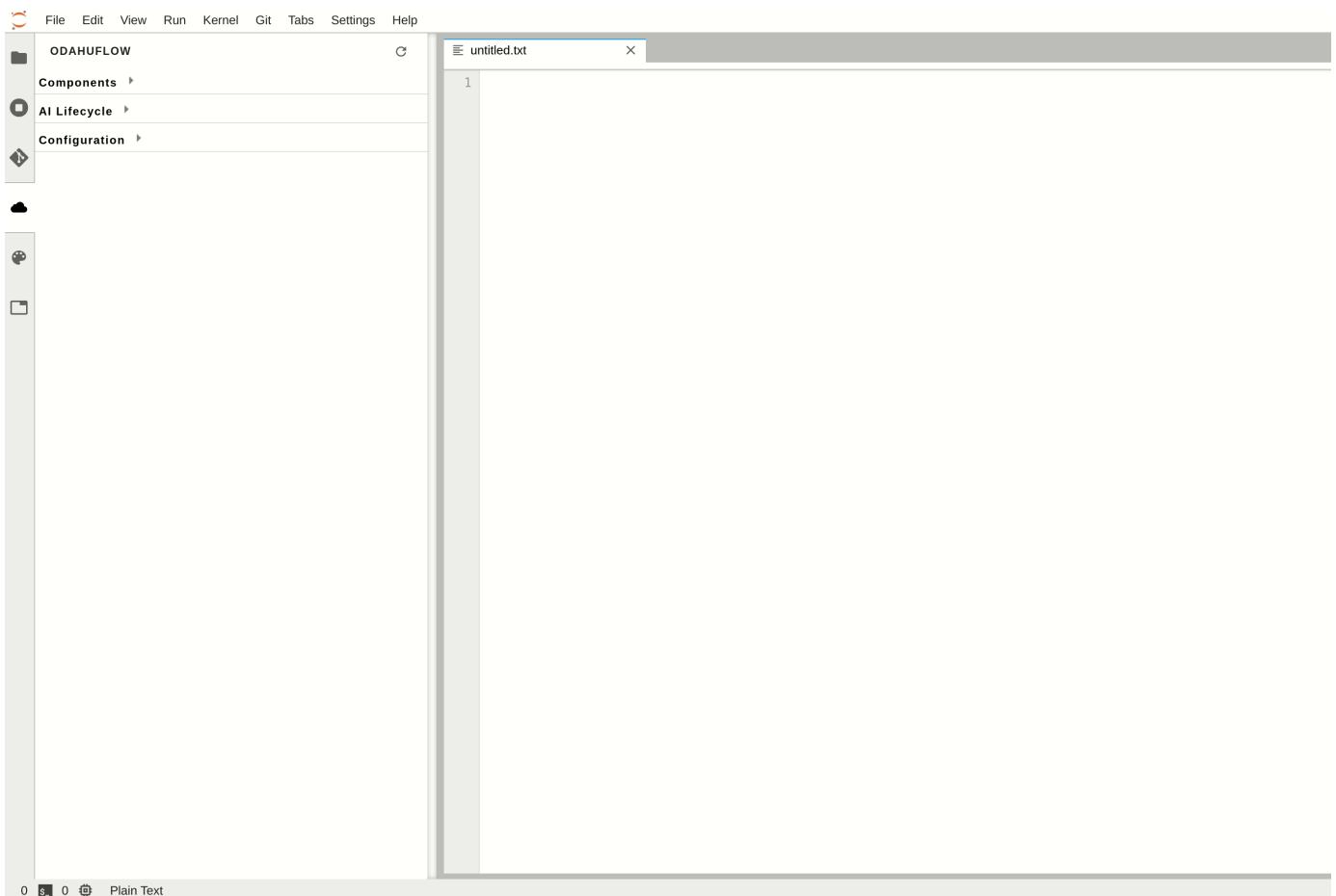
## Login



### Main view

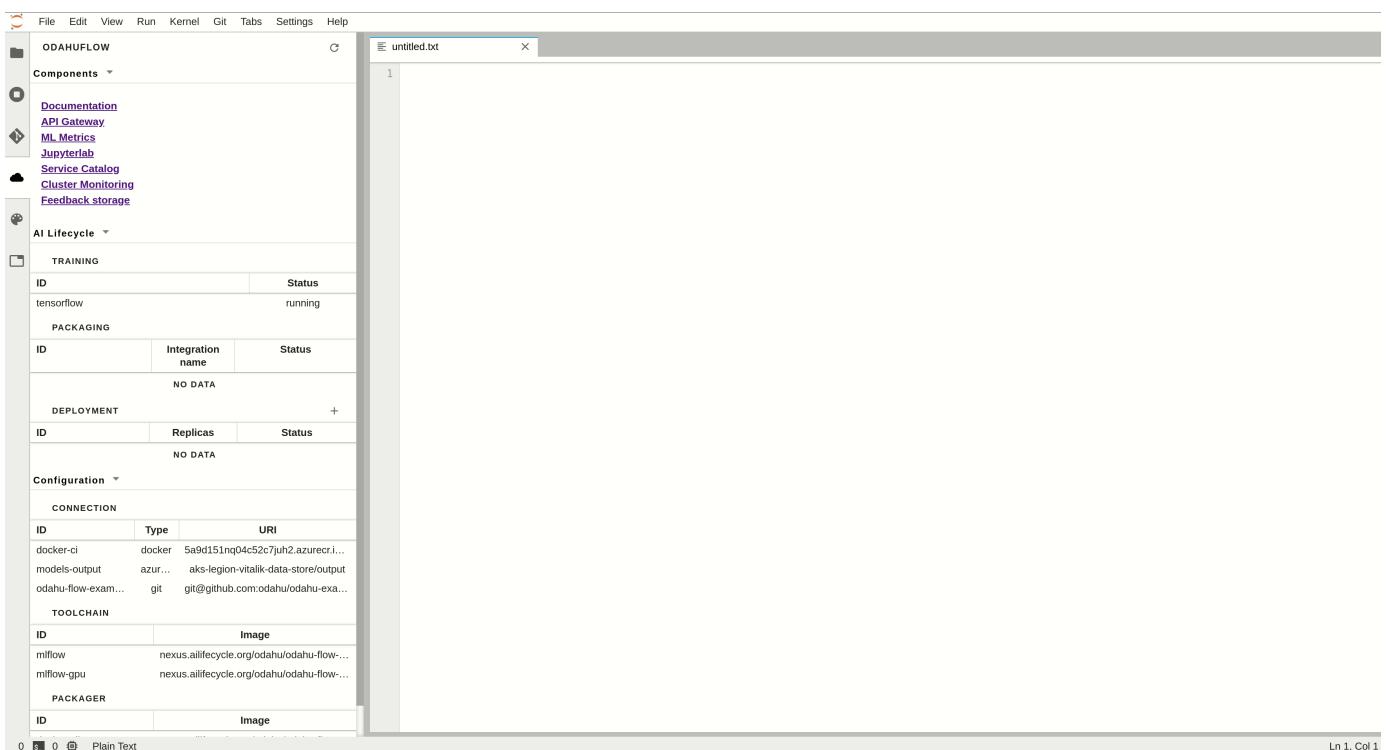
The main view contains all Odahu-flow entities. You can view or delete them.

## Login



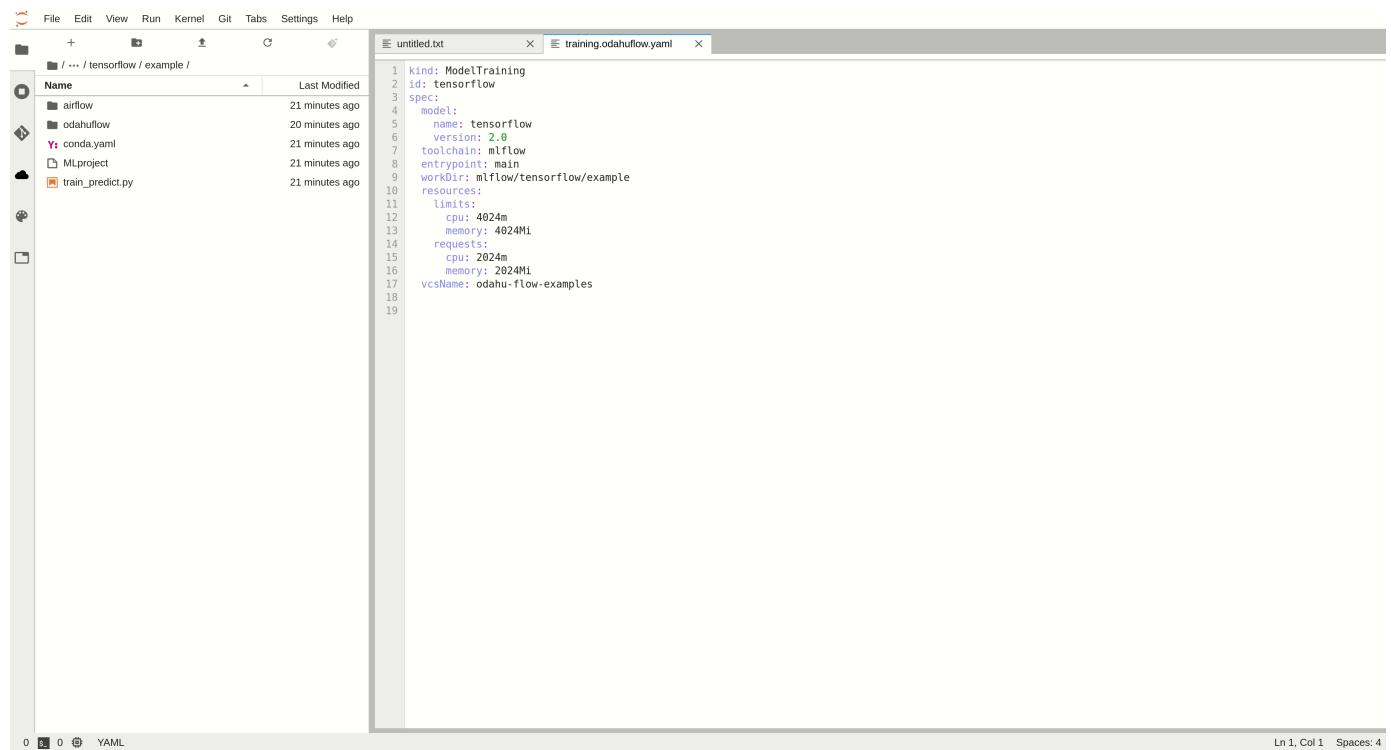
## Log viewer

For troubleshooting, you can get access to the training, packaging or deployment logs. If the job is running then logs will be updated in runtime.



## Submit resources

You can create any Odahu-flow entities from the extension. The button **Submit** only appears in the context menu when file ends with .yaml or json.



The screenshot shows the Odahu Flow extension interface. On the left is a file explorer sidebar with a tree view of files in the directory `/ ... / tensorflow / example /`. The files listed are `airflow`, `odahuflow`, `conda.yaml` (highlighted in yellow), `MLproject`, and `train_predict.py`. The main area contains two code editors. The left editor has the tab `untitled.txt` and displays the following YAML configuration:

```
1 kind: ModelTraining
2 id: tensorflow
3 spec:
4   model:
5     name: tensorflow
6     version: 2.0
7     toolchain: mlflow
8     entrypoint: main
9     workDir: mlflow/tensorflow/example
10    resources:
11      limits:
12        cpu: 4024m
13        memory: 4024Mi
14      requests:
15        cpu: 2024m
16        memory: 2024Mi
17    vcsName: odahu-flow-examples
18
19
```

The right editor has the tab `training.odahuflow.yaml` and is currently empty. At the bottom of the interface, there are status indicators: 0 files, 0 errors, and 1 warning, followed by the text "YAML". On the far right, there is a status bar with the text "Ln 1, Col 1 Spaces: 4".

# Odahuflowctl

Odahuflowctl (odahuflowctl) is a command-line interface for interacting with Odahu-flow API service.

## Prerequisites:

- Python 3.6 or higher

## Installation

Odahu-flow CLI is available in PyPi repository. You should execute the following command to install odahuflowctl:

```
pip install odahu-flow-cli  
odahuflowctl --version
```

## Help

To read odahuflowctl help, you should use the following command:

```
odahuflowctl --help
```

for a specific command, for example, get list of model deployments:

```
odahuflowctl deployment get --help
```

## Login

There are two authentication types for Odahu CLI.

### ***Specifying of a token explicitly***

You should open an API server URL in a browser to get the login command. The command already contains your token. Copy and paste provided command into your shell.

Example of command:

```
odahuflowctl login --url <api-url> --token <your-token>
```

## Completion

### ***Sign in interactively***

This method will use a web browser to sign in.

Run the login command:

```
odahuflowctl login --url <api-url>
```

Odahu CLI will open an IAM server in your default browser. Sign in with your account credentials.

## Completion

odahuflowctl cli supports completion for following shells: bash, zsh, fish, PowerShell.

To activate it, evaluate the output of  
odahuflowctl completion <YOUR\_SHELL>. <YOURSHELL> is the optional, it can be automatically identified.

Bash example:

```
source <(odahuflowctl completion bash)
```

PowerShell example:

```
odahuflowctl completion > $HOME\.odahuflow\odahu_completion.ps1;
. $HOME\.odahuflow\odahu_completion.ps1;
Remove-Item $HOME\.odahuflow\odahu_completion.ps1
```

To activate completion automatically in any new shell, you can save the completion code to a file and add it to your shell profile.

Bash example:

```
odahuflowctl completion bash > ${HOME}/.odahuflow/odahuflowctl_completion.sh
(echo ""; echo "source ${HOME}/.odahuflow/odahuflowctl_completion.sh"; echo "") >> ${HOME}/.bashrc
```

PowerShell example:

```
write ``# odahuflowctl completion" (odahuflowctl completion) >> $PROFILE.CurrentUserAllHosts
```

# Model Format

The **Odahu Model Artifact Format** (OMAF) describes a format to package, store, and transport ML models.

Models can be built in different languages and use different platform libraries. For example: {Python, Scala, R, ...} using {scikit-learn, tensorflow, keras, ...}.

An OMAF **Artifact** is stored as a file-system folder packed into a ZIP file using the Deflate ZIP compression algorithm.

The Artifact contains:

- `odahuflow.model.yaml` a YAML file in the root folder. This file contains meta-information about the type of binary model and other model related information (e.g. language, import endpoints, dependencies).
- Additional folders and files, depending upon meta-information declared in `odahuflow.model.yaml`.

## odahuflow.model.yaml

File structure:

- `binaries` - Language and dependencies that should be used to load model binaries
- `binaries.type` - Required Odahu Model Environments. See section [Odahu Model Environments](#).
- `binaries.dependencies` - Dependency management system, compatible with the selected Odahu Model Environment
- `binaries.<additional>` - Model Environment and dependency management system values, for example 'a path to the requirements file'
- `model` - Location of the model artifact Model artifact format depends on [Odahu Model Environment](#).
- `model.name` - name of the model, [a-Z0-9-]+
- `model.version` - version of model. Format is <Apache Version>-<Additional suffix>, where Additional suffix is a [a-Z0-9-.]+ string.
- `model.workDir` - working directory to start model from.
- `model.entrypoint` - name of model artifact (e.g. Python module or Java JAR file).
- `odahuflowVersion` - OMAF version
- `toolchain` - toolchain used for training and preparing the Artifact
- `toolchain.name` - name of the toolchain
- `toolchain.version` - version of used toolchain.
- `toolchain.<additional>` - additional fields, related to used toolchain (e.g. used submodule of toolchain).

## Odahu Model Environments

### Examples:

Example with GPPI using conda for dependency management, mlflow toolchain.

```
binaries:
  type: python
  dependencies: conda
  conda_path: mlflow/model/mlflow_env.yml
model:
  name: wine-quality
  version: 1.0.0-12333122
  workDir: mlflow/model
  entrypoint: entrypoint
  odahuflowVersion: '1.0'
toolchain:
  name: mlflow
  version: 1.0.0
```

## Odahu Model Environments

Odahu supports these model environments:

- General Python Prediction Interface (GPPI). Can import a trained model as a python module and use a predefined function for prediction. Value for binaries.type should be python.
- General Java Prediction Interface (GJPI). Can import a trained model as a Java Library and use a predefined interfaces for prediction. Value for binaries.type should be java.

### ***Odahu's General Python Prediction Interface (GPPI)***

#### ***General Information***

#### ***Description***

This interface is an importable Python module with a declared interface (functions with arguments and return types). Toolchains that save models in this format must provide an entrypoint with this interface or they may provide a wrapper around their interface for this interface.

#### ***Required Environment variables***

- MODEL\_LOCATION – path to model's file, relative to working directory.

## ***Interface declaration***

Interface functions:

# Connections

Odahu needs to know how to connect to a bucket, git repository, and so on. This kind of information is handled by Connection API.

## General connection structure

All types of connections have the same general structure. But different connections require a different set of fields. You can find the examples of specific type of connection in the id of the Connection types section. Below you can find the description of all fields:

### Connection API

```

kind: Connection
# Unique value among all connections
# Id must:
# * contain at most 63 characters
# * contain only lowercase alphanumeric characters or '-'
# * start with an alphanumeric character
# * end with an alphanumeric character
id: "id-12345"
spec:
# Optionally description of a connection
description: "Some description"
# Optionally link to the web resource. For example, git repo or a gcp bucket
webUILink: https://test.org/123
# URI. It is a required value.
uri: s3://some-bucket/path/file
# Type of a connection. Available values: s3, gcs, azureblob, git, docker, ecr.
type: s3
# Username
username: admin
# Password, must be base64-encoded
password: admin
# Service account role
role: some-role
# AWS region or GCP project
region: some region
# VCS reference
reference: develop
# Key ID, must be base64-encoded
keyID: "1234567890"
# SSH or service account secret, must be base64-encoded
keySecret: b2RhaHUK
# SSH public key, must be base64-encoded
publicKey: b2RhaHUK

```

## Connection management

Connections can be managed using the following ways.

### Swagger UI

Swagger UI is available at <http://api-service/swagger/index.html> URL.

## Connection types

### Odahu-flow CLI

Odahuflowctl supports the connection API. You must be login if you want to get access to the API.

- Getting all connections in json format:

```
odahuflowctl conn get --format json
```

- Getting the reference of the connection:

```
odahuflowctl conn get --id odahu-flow-examples -o 'jsonpath=[*].spec.reference'
```

- Creating of a connection from *conn.yaml* file:

```
odahuflowctl conn create -f conn.yaml
```

- All connection commands and documentation:

```
odahuflowctl conn --help
```

### JupyterLab

Odahu-flow provides the JupyterLab extension for interacting with Connection API.

## Connection types

For now, Odahu-flow supports the following connections types:

- S3
- Google Cloud Storage
- Azure Blob storage
- GIT
- Docker
- Amazon Elastic Container Registry

### S3

An S3 connection allows interactions with s3 API. This type of connection is used as storage of:

- model trained artifacts.

## Connection types

- input data for ML models.

### Note

You can use any S3 compatible API, for example minio or Ceph.

Before usage, make sure that:

- You have created an AWS S3 bucket. [Examples of Creating a Bucket](#).
- You have created an IAM user that has access to the AWS S3 bucket. [Creating an IAM User in Your AWS Account](#).
- You have created the IAM keys for the user. [Managing Access Keys for IAM Users](#).

### Note

At that moment, Odahu-flow only supports authorization through [IAM User](#). We will support AWS service role and authorization using temporary credentials in the near future.

The following fields of connection API are required:

- spec.type - It must be equal **s3**.
- spec.keyID - **base64-encoded** access key ID (for example, AKIAIOSFODNN7EXAMPLE).
- spec.keySecret - **base64-encoded** secret access key (for example, wJalrXUtnFEMI/K7MDENG/bPxRfCYEXAMPLEKEY).
- spec.uri - S3 compatible URI, for example s3://<bucket-name>/dir1/dir2/
- spec.region - [AWS Region](#), where a bucket was created.

*Example of Connection S3:*

```
id: "training-data"
spec:
  type: s3
  uri: s3://raw-data/model/input
  # keyID before base64-encoding: AKIAIOSFODNN7EXAMPLE
  keyID: "QUTJQULPU0ZPRE50N0VYQU1QTEU="
  # keySecret before base64 encoding: wJalrXUtnFEMI/K7MDENG/bPxRfCYEXAMPLEKEY
  keySecret: "d0phbHJYVXRuRkVNSS9LN01ERU5HL2JQeFJmaUNZRVhBTVBMRUtFWQ=="
  description: "Training data for a model"
  region: eu-central-1
```

## Google Cloud Storage

Google Cloud Storage allows storing and accessing data on Google Cloud Platform infrastructure. This type of connection is used as storage of:

## Connection types

- model trained artifacts.
- input data for ML models.

Before usage, make sure that:

- You have created an GCS bucket. [Creating storage buckets](#).
- You have created an service account. [Creating and managing service accounts](#).
- You have assigned roles/storage.objectAdmin role on the service account for the GCS bucket. [Using Cloud IAM permissions](#).
- You have created the IAM keys for the service account. [Creating and managing service account keys](#).

### Note

Workload Identity is the recommended way to access Google Cloud services from within GKE due to its improved security properties and manageability. We will support the Workload Identity in the near future.

The following fields of connection API are required:

- spec.type - It must be equal **gcs**.
- spec.keySecret - **base64-encoded** service account key in json format.
- spec.uri - GCS compatible URI, for example gcs://<bucket-name>/dir1/dir2/
- spec.region - [GCP Region](#), where a bucket was created.

#### Example of Connection GCS

*Original service account JSON key, that is used in the example above, before base64-encoding:*

```
{  
  "type": "service_account",  
  "project_id": "project_id",  
  "private_key_id": "private_key_id",  
  "private_key": "-----BEGIN PRIVATE KEY-----\nprivate_key\n-----END PRIVATE KEY-----\n",  
  "client_email": "test@project_id.iam.gserviceaccount.com",  
  "client_id": "123455678",  
  "auth_uri": "https://accounts.google.com/o/oauth2/auth",  
  "token_uri": "https://oauth2.googleapis.com/token",  
  "auth_provider_x509_cert_url": "https://www.googleapis.com/oauth2/v1/certs",  
  "client_x509_cert_url": "https://www.googleapis.com/robot/v1/metadata/x509/test@project_id.iam.gserviceaccount.com"  
}
```

## Azure Blob storage

Odahu-flow uses the Blob storage in Azure to store:

## Connection types

- model trained artifacts.
- input data for ML models.

Before usage, make sure that:

- You have created a storage account . [Create a storage account](#).
- You have created a storage container in the storage account . [Create a container](#).
- You have created a SAS token. [Create an account SAS](#).

The following fields of connection API are required:

- spec.type - It must be equal **azureblob**.
- spec.keySecret - Odahu-flow uses the [shared access signatures](#) to authorize in Azure. The key has the following format: “<primary\_blob\_endpoint>/<sas\_token>” and must be **base64-encoded**.
- spec.uri - Azure storage compatible URI, for example <bucket-name>/dir1/dir2/

### Example of Connection Blob Storage:

```
id: "training-data"
spec:
  type: azureblob
  url: raw.githubusercontent.com/odahu/odahu-examples/v15/b331LnOpnFvd9ubmVlczY2X00oX81PwNc2zqT2uMz29t03wc0v2z30wv2z3w14t01M0zec3M9YyYac3209hac3Q9fjAx05b0cCbW0yHtUz0Tf4J7NBH2aJnLPT7LwTfLtb0g9tB0M011M0tHy0z20T2w2zcj113hWuP233n0pc0b04jguH541LjyaTE204LjJuuz2AnC8yPhnbd0z2n0p2z16J7H0t2BwY0Z2ay0Hc8bGeVn81u013rV2z2zH0NaHfU1hY1NE1=description: "Training data for a model"
```

## GIT

Odahu-flow uses the GIT type connection to download a ML source code from a git repository.

The following fields of connection API are required:

- spec.type - It must be equal **git**.
- spec.keySecret - a base64 encoded SSH private key.
- spec.uri - GIT SSH URL, for example <git@github.com:odahu/odahu-examples.git>

spec.reference must be provided either in a connection OR in a model training object (General training structure).

Example of command to encode ssh key:

```
cat ~/.ssh/id_rsa | base64 -w0
```

## Note

Odahu-flow only supports authorization through SSH.

## Connection types

### **Warning**

We recommend using the read-only deploy keys: [Github docs](#) or [Gitlab docs](#).

*Example of GIT Connection:*

```
id: "ml-repository"
spec:
  type: git
  uri: git@github.com:odahu/odahu-examples.git
  keySecret: ClnVUEVSIFNFQ1JFVAoK
  reference: master
  description: "Git repository with the Odahu-Flow examples"
  webUILink: https://github.com/odahu/odahu-examples
```

### **Docker**

This type of connection is used for pulling and pushing of the Odahu packager result Docker images to a Docker registry. We have been testing the following Docker repositories:

- Docker Hub
- Nexus
- Google Container Registry
- Azure Container Registry

### **Warning**

Every docker registry has its authorization specificity. But you must be able to authorize by a username and password. Read the documentation.

Before usage, make sure that:

- You have a username and password.

The following fields of connection API are required:

- spec.type - It must be equal **docker**.
- spec.username - docker registry username.
- spec.password - **base64-encoded** docker registry password.
- spec.uri - docker registry host.

### **Warning**

Connection URI must not contain a URI schema.

## Connection types

### Example of GCR Docker connection

Original service account JSON key, that is used in the example above, before base64-encoding:

```
{  
    "type": "service_account",  
    "project_id": "project_id",  
    "private_key_id": "private_key_id",  
    "private_key": "-----BEGIN PRIVATE KEY-----\\nprivate_key\\n-----END PRIVATE KEY-----\\n",  
    "client_email": "test@project_id.iam.gserviceaccount.com",  
    "client_id": "123455678",  
    "auth_uri": "https://accounts.google.com/o/oauth2/auth",  
    "token_uri": "https://oauth2.googleapis.com/token",  
    "auth_provider_x509_cert_url": "https://www.googleapis.com/oauth2/v1/certs",  
    "client_x509_cert_url": "https://www.googleapis.com/robot/v1/metadata/x509/test@project_id.iam.gserviceaccount.com"  
}
```

### Example of Docker Hub

```
id: "docker-registry"  
spec:  
  type: docker  
  uri: docker.io/odahu/  
  username: username  
  # password before encoding: mypassword  
  password: bXlwYXNzd29yZA==
```

## Amazon Elastic Container Registry

Amazon Elastic Container Registry is a managed AWS Docker registry. This type of connection is used for pulling and pushing of the Odahu packager result Docker images.

### Note

The Amazon Docker registry does not support a long-lived credential and requires explicitly to create a repository for every image. These are the reasons why we create a dedicated type of connection for the ECR.

Before usage, make sure that:

- You have created an ECR repository. [Creating an ECR Repository](#).
- You have created an IAM user that has access to the ECR repository. [Creating an IAM User in Your AWS Account](#).
- You have created the IAM keys for the user. [Managing Access Keys for IAM Users](#).

The following fields of connection API are required:

- `spec.type` - It must be equal **ecr**.
- `spec.keyID` - **base64-encoded** access key ID (for example, AKIAIOSFODNN7EXAMPLE).

## Connection types

- spec.keySecret - **base64-encoded** secret access key (for example, wJalrXUtnFEMI/K7MDENG/bPxRfiCYEXAMPLEKEY).
- spec.uri - The url must have the following format, aws\_account\_id.dkr.ecr.`region`.amazonaws.com/some-prefix.
- spec.region - **AWS Region**, where a docker registry was created.

*Example of Connection ECR:*

```
id: "docker-registry"
spec:
  type: ecr
  uri: 5555555555.dkr.ecr.eu-central-1.amazonaws.com/odahuflow
  # keyID before base64-encoding: "AKIAIOSFODNN7EXAMPLE"
  keyID: QUtJQUlPU0ZPRE50N0VYQU1QTEU=
  # keySecret before base64-encoding: "wJalrXUtnFEMI/K7MDENG/bPxRfiCYEXAMPLEKEY"
  keySecret: d0phbHJYVXRuRkVNSS9LN01ERU5HL2JQeFJmaUNZRVhBTVBMRUtFWQ==
  description: "Packager registry"
  region: eu-central-1
```

# Model Trainings

The Odahu-flow Model Training API provides features to manage remote training jobs. The primary goal of API is to create a **Trained Model Binary** for a **Packager**. The API is pluggable and can be extended for different ML frameworks.

You can find the list of out-of-the-box trainers below:

- MLFlow

## General training structure

### *Training API*

```

kind: ModelTraining
# Some unique value among all trainings. if not, the training with the same name will be overwritten.
# Id must:
# * contain at most 63 characters
# * contain only lowercase alphanumeric characters or '-'
# * start with an alphanumeric character
# * end with an alphanumeric character
id: wine-12345
spec:
model:
  # Human-readable model name
  name: wine
  # Human-readable model version
  version: 3.0
  # Optionally, you can specify template for output artifact
  # The default value is {{ .Name }}-{{ .Version }}-{{ .RandomUUID }}.zip
  # where:
  # Name - spec.model.name
  # Version - spec.model.version
  # RandomUUID - a random UUID v4, for example be17d12d-df43-4588-99e7-56a0db3cad77
  artifactNameTemplate: {{ .Name }}-{{ .Version }}-{{ .RandomUUID }}.zip
# The toolchain parameter is a point of extension for different ML frameworks.
# For now, we only support the Mlflow toolchain
toolchain: mlflow
# Mlflow MLProject file contains the list of entrypoints. You must choose one of those.
entrypoint: main
# Working directory inside a training (docker) container, which GIT repository copied in.
workdir: workdir
# The training data for a ML script. You can find full description there: https://docs.odahu.org/ref_trainings.html#training-data
data:
  # You can specify a connection name
  - connName: wine
  # Path to a file or a dir where data will copy from a bucket; relative to your Git repository root directory.
  localPath: mlflow/wine-quality/
  # Path to the dir or file in a bucket
  # Optional. If it is missing then the path from connection will be used.
  remotePath: training-data/
# You can specify the map of hyperparameters
hyperParameters:
  key: value
  var2: test
# Compute resources for the training job.
resources:
  limits:
    cpu: 1
    memory: 1Gi
  requests:
    cpu: 1
    memory: 1Gi
# Custom environment variables that should be set before entrypoint invocation.
envs:

```

```

  # The name of variable
  - name: TEST_ENV_KEY
  # The value of variable
  value: TEST_ENV_VALUE
# A Docker image where the training will be launched.
# By default, the image from a toolchain is used.
# image: python:3.8
# A connection which describes credentials to a GIT repository

```

## Training data

```
vcsName: <git-connection>
# Git reference (branch or tag)
# This must be specified here OR in Git connection itself
reference: master
# Node selector that exactly matches a node pool from ODAHU config
# This is optional; when omitted, ODAHU uses any of available training node pools
# Read more about node selector: https://kubernetes.io/docs/concepts/scheduling-eviction/assign-pod-node/
nodeSelector:
  label: value
status:
# One of the following states: scheduling, running, succeeded, failed, unknown
state: running
# List of training results
artifacts:
  # Mlflow run ID
  - runId: 12345678
    # Trained artifact name
    artifactName: wine-10.zip
    # VCS commit ID
    commitID: d3d6e8ed776ed37fd2efd7a1b8d5fabdd7e3eea5
```

## Training data

Odahu-flow allows downloading data from various sources to the local file system of a training job. Data source supports the following types of Odahu-flow connections:

- S3
- Google Cloud Storage
- Azure Blob storage

Let's consider the following example of downloading training data from Google Cloud Storage.

Prerequisites:

- The training data set is located in the *wine-training-data* bucket by *wine/11-11-2011/* directory.
- The ML script expects that the data will be located in the training (docker) container by *data/* directory relative to the root git directory.

First of all, we should create an Odahu-flow GCS connection.



Finally, we provide a data section of Model Training.

*Example of Connection GCS:*

```
spec:
data:
  - connName: wine-training-data-conn
    localPath: data/
    remotePath: wine/11-11-2011/
```

## GPU

Odahu-flow supports model training on GPU nodes.

## Model Dependencies Cache

You can find more about GPU deployment configuration in the installation guide.

In order to provision a training container in the GPU node pool, you must specify the GPU resource in the model training manifest.

### *Training on GPU*

```
kind: ModelTraining
id: gpu-model
spec:
  resources:
    limits:
      cpu: 1
      memory: 1Gi
      gpu: 1
    requests:
      cpu: 1
      memory: 1Gi
```

NVIDIA libraries will be mounted by ODAHU to the training container. But if you want to use a CUDA library, you should install it manually.

For example, you can add the following dependencies to a conda file: cudatoolkit-dev and cudatoolkit.

## Model Dependencies Cache

ODAHU Flow downloads your dependencies on every model training launch. You can experience the following troubles with this approach:

- downloading and installation of some dependencies can take a long time
- network errors during downloading dependencies

To overcome these and other problems, ODAHU Flow provides a way to specify a prebuilt training Docker image with your dependencies.

### **Note**

If you have different versions of a library in your model conda file and cache container, then the model dependency has a priority. It will be downloaded during model training.

First of all, you have to describe the Dockerfile:

- Inherit from a release version of odahu-flow-mlflow-toolchain
- Optionally, add install dependencies
- Add a model conda file
- Update the odahu\_model conda environment.

*Example of Dockerfile:*

## Trainings management

```
FROM odahu/odahu-flow-mllflow-toolchain:1.1.0-rc11

# Optionally
# apt-get install -y wget

ADD conda.yaml .
RUN conda env update -n ${ODAHU_CONDA_ENV_NAME} -f conda.yaml
```

Build the docker image:

```
docker build -t training-model-cache:1.0.0 .
```

Push the docker image to a registry:

```
docker push training-model-cache:1.0.0
```

Specify the image in a model training:

*Training example*

```
kind: ModelTraining
id: model-12345
spec:
  image: training-model-cache:1.0.0
  ...
```

## Trainings management

Trainings can be managed using the following ways.

### Swagger UI

ModelTraining and ToolchainIntegration are available on the Swagger UI at <http://api-service/swagger/index.html> URL.

### Odahu-flow CLI

Odahuflowctl supports the Training API. You must be logged in if you want to get access to the API.

Getting all trainings in json format:

```
odahuflowctl train get --format json
```

Getting the model name of the trainings:

```
odahuflowctl train get --id tensorflow-cli -o 'jsonpath=[*].spec.model.name'
```

## MLFlow

- Creating a training from *train.yaml* file:

```
odahuflowctl train create -f train.yaml
```

- Reruning a training from *train.yaml* file:

```
odahuflowctl train edit -f train.yaml
```

- All training commands and documentation:

```
odahuflowctl train --help
```

We also have local training:

```
odahuflowctl local train --help
```

and can run trainings locally:

```
odahuflowctl local train run --id [Model training ID] -d [Path to Odahu manifest files]
```

more information you can find at [Local Quickstart](#)

## JupyterLab

Odahu-flow provides the JupyterLab extension for interacting with Training API.

## MLFlow

MLflow is library-agnostic. You can use it with any machine learning library, and in any programming language, since all functions are accessible through a REST API and CLI.

## Installation

The most straightforward way to install the MLFlow trainer on an Odahu Cluster is to deploy the *odahu-flow-mlflow* helm chart. The helm chart registers the trainer in the API Odahu and deploys an [MLflow Tracking Server](#). By default, the deployed MLflow Tracking Server is available at <https://cluster-url/mlflow> address.

```
# Add the odahu-flow helm repository
helm repo add odahu-flow 'https://raw.githubusercontent.com/odahu/odahu-helm/master/'
helm repo update
# Fill in the values for the chart or leave the default values
```

## MLFlow

```
helm inspect values odahu-flow/odahu-flow-mlflow --version 1.0.0 > values.yaml
vim values.yaml
# Deploy the helm chart
helm install odahu-flow/odahu-flow-mlflow --name odahu-flow-mlflow --namespace odahu-flow --debug -f values.yaml --atomic --wait --timeout 120
```

### Warning

Odahu-flow must be deployed before the mlflow trainer.

## MLProject file

Let's look at how the MLProject file is related to Model Training API.

```
name: My Project

entry_points:
  main:
    parameters:
      data_file: path
      regularization: {type: float, default: 0.1}
    command: "python train.py -r {regularization} {data_file}"
  test:
    parameters:
      data_file: path
    command: "python validate.py {data_file}"
```

Model Training API can contain only one entry point. You have to add all hyperparameters, which do not have a default value, to a Model Training. Next, you can find the Model Trainings for the MLProject file.

```
spec:
  entrypoint: main
  hyperParameters:
    data_file: test/123.txt
    regularization: 0.2
```

```
spec:
  entrypoint: main
  hyperParameters:
    data_file: test/456.txt
```

```
spec:
  entrypoint: test
  hyperParameters:
    data_file: test/123.txt
```

## MLFlow protocol

Odahu-flow requires that a model is logged through mlflow API.

*Example of sklearn model logging:*

```
mlflow.sklearn.log_model(lr, "model")
```

Optionally, you can provide input and output samples for Odahu-flow. It allows determining input and output types for Odahu-flow packagers. These names must be *head\_input.pkl* and *head\_output.pkl*, respectively.

*Example of input and output samples logging:*

```
train_x.head().to_pickle('head_input.pkl')
mlflow.log_artifact('head_input.pkl', 'model')
train_y.head().to_pickle('head_output.pkl')
mlflow.log_artifact('head_output.pkl', 'model')
```

# Model Packagers

Odahu-flow packagers turn a **Trained Model Binary** artifact into a specific application. You can find the list of out-of-the-box packagers below:

- Docker REST
- Docker CLI

## Installation

A packager installation is the creation of a new `PackagingIntegration` entity in the **API service**. The most straightforward way is to deploy the *odahu-flow-packagers* helm chart.

```
# Add the odahu-flow helm repository
helm repo add odahu-flow 'https://raw.githubusercontent.com/odahu/odahu-helm/master/'
helm repo update
# Fill in the values for the chart or leave the default values
helm inspect values odahu-flow/odahu-flow-packagers --version 1.0.0-rc35 > values.yaml
vim values.yaml
# Deploy the helm chart
helm install odahu-flow/odahu-flow-packagers --name odahu-flow-packagers --namespace odahu-flow --debug -f values.yaml --atomic --wait --timeout 120
```

### Warning

Odahu-flow must be deployed before the packagers installation.

## General packager structure

All packagers have the same structure. But different packagers provide a different set of arguments and targets. You can find the description of all fields below:

### Packager API

```
kind: ModelPackaging
# Unique value among all packagers
# Id must:
# * contain at most 63 characters
# * contain only lowercase alphanumeric characters or '-'
# * start with an alphanumeric character
# * end with an alphanumeric character
id: "id-12345"
spec:
# Type of a packager. Available values: docker-rest, docker-cli.
integrationName: docker-rest
# Training output artifact name
artifactName: wine-model-123456789.zip
# Compute resources
resources:
limits:
  cpu: 1
  memory: 1Gi
requests:
  cpu: 1
  memory: 1Gi
```

## Packagers management

```
# List of arguments. Depends on a Model Packaging integration.  
# You can find specific values in the sections below.  
# This parameter is used for customizing a packaging process.  
arguments: {}  
# List of targets. Depends on a Model Packaging integration.  
# You can find specific values in the sections below.  
# A packager can interact with a Docker registry, PyPi repository, and so on.  
# You should provide a list of connections for a packager to get access to them.  
targets: []  
# You can set connection which points to some bucket where the Trained Model Binary is stored  
# then packager will extract your binary from this connection  
outputConnection: custom-connection  
# Node selector that exactly matches a node pool from ODAHU config  
# This is optional; when omitted, ODAHU uses any of available packaging node pools  
# Read more about node selector: https://kubernetes.io/docs/concepts/scheduling-eviction/assign-pod-node/  
nodeSelector:  
  label: value  
# Every packager saves its results into status field.  
# Example of fields: docker image or python packager name.  
status:  
  results:  
    - name: some_param  
      value: some_value
```

### Note

You can find an artifactName in the *status.artifactName* field of a model training entity.

## Packagers management

Packagers can be managed using the following ways.

### Swagger UI

ModelPackaging and PackagingIntegration are available on the Swagger UI at <http://api-service/swagger/index.html> URL.

### Odahu-flow CLI

Odahuflowctl supports the Packagers API. You must be logged in if you want to get access to the API.

Getting all packaging in json format:

```
odahuflowctl pack get --format json
```

Getting the arguments of the packagers:

```
odahuflowctl pack get --id tensorflow-cli -o 'jsonpath=[*].spec.arguments'
```

## Model Docker Dependencies Cache

- Creating of a packager from `pack.yaml` file:

```
odahuflowctl pack create -f pack.yaml
```

- All commands and documentation for packager at Odahu cluster:

```
odahuflowctl pack --help
```

We also have local packager:

```
odahuflowctl local pack --help
```

and can run packaging locally:

```
odahuflowctl local pack run --id [Model packaging ID] -d [Path to an Odahu manifest file]
```

more information you can find at [Local Quickstart](#)

## JupyterLab

Odahu-flow provides the JupyterLab extension for interacting with Packagers API.

## Model Docker Dependencies Cache

ODAHU Flow downloads your dependencies on every docker model packaging launch. You can experience the following troubles with this approach:

- downloading and installation of some dependencies can take a long time
- network errors during downloading dependencies

To overcome these and other problems, ODAHU Flow provides a way to specify a prebuilt packaging Docker image with your dependencies.

### Note

If you have different versions of a library in your model conda file and cache container, then the model dependency has a priority. It will be downloaded during model packaging.

First of all, you have to describe the Dockerfile:

## Docker REST

- Inherit from a release version of odahu-flow-docker-packager-base
- Optionally, add install dependencies
- Add a model conda file
- Update the odahu\_model conda environment.

*Example of Dockerfile:*

```
FROM odahu/odahu-flow-docker-packager-base:1.1.0-rc11

# Optionally
# RUN pip install gunicorn[gevent]

ADD conda.yaml .
RUN conda env update -n ${ODAHU_CONDA_ENV_NAME} -f conda.yaml
```

Build the docker image:

```
docker build -t packaging-model-cache:1.0.0 .
```

Push the docker image to a registry:

```
docker push packaging-model-cache:1.0.0
```

Specify the image in a model packaging:

*Packaging example*

```
kind: ModelPackaging
id: model-12345
spec:
  arguments:
    dockerfileBaseImage: packaging-model-cache:1.0.0
  ...
```

## Docker REST

The Docker REST packager wraps an ML model into the REST service inside a Docker image. The resulting service can be used for point prediction through HTTP.

The packager provides the following list of targets:

Target Name	Connection Types	Required	Description
docker-push	docker, ecr	True	The packager will use the connection for pushing a Docker image result
docker-pull	docker, ecr	False	The packager will use the connection for pulling a custom base Docker image

The packager provides the following list of arguments:

Argument Name	Type	Default	Required	Description
imageName	string	{}{ Name } }-{}{ Version } }:{}{ RandomUUID }	False	This option provides a way to specify the Docker image name. You can hardcode the full name or specify a template. Available template values: Name (Model Name), Version (Model Version), RandomUUID. Examples: myservice:123, {}{ Name } }:{}{ Version }
port	integer	5000	False	Port to bind
timeout	integer	60	False	Serving timeout in seconds.
workers	integer	1	False	Count of serving workers
threads	integer	4	False	Count of serving threads
host	string	0.0.0.0	False	Host to bind
dockerfileBaseImage	string	python:3.6	False	Base image for Dockerfile

The packager provides the following list of result fields:

Name	Type	Description
image	string	The full name of a built Docker image

Let's build a couple of examples of Docker REST packager. The packager requires docker or ecr connection types. The following example assumes that you have created a connection with `test-docker-registry` id and `gcr.io/project/odahuflow` URI.

#### *Minimal Example of Docker REST packager*

```
id: "docker-rest-packager-example"
spec:
  integrationName: docker-rest
  artifactName: wine-model-123456789.zip
  targets:
    - connectionName: test-docker-registry
      name: docker-push
```

Then a result of the packager will be something like this:  
`"gcr.io/project/odahuflow/wine-0-1:ec1bf1cd-216d-4f0a-a62f-bf084c79c58c"`.

Now, let's try to change the docker image name and number of workers.

#### *Docker REST packager with custom arguments*

## Docker REST

```
id: "docker-rest-packager-example"
spec:
  integrationName: docker-rest
  artifactName: wine-model-123456789.zip
  targets:
    - connectionName: test-docker-registry
      name: docker-push
  arguments:
    imageName: "wine-test:prefix-{{ RandomUUID }}"
    workers: 4
```

```
odahuflowctl pack get --id "docker-rest-packager-example" -o 'jsonpath=$[0].status.results[0].value'
```

Then a result of the packager will be something like this:

"gcr.io/project/odahuflow/wine-test:prefix-ec1bf1cd-216d-4f0a-a62f-bf084c79c58c".

You can run the image locally using the following command:

```
docker run -it --rm --net host gcr.io/project/odahuflow/wine-test:prefix-ec1bf1cd-216d-4f0a-a62f-bf084c79c58c
```

The model server provides two urls:

- GET /api/model/info - provides a swagger documentation for a model
- POST /api/model/invoke - executes a prediction

```
curl http://localhost:5000/api/model/info
curl -X POST -d '{"columns": ["features","features","features"], "data": [[1, 2, 3], [4, 5, 6]]}' -H "Content-Type: application/json" http://localhost:5000/api/model/invoke
```

### Docker REST predict API

```
{
  "columns": [
    "features",
    "features",
    "features"
  ],
  "data": [
    [
      1,
      2,
      3,
    ],
    [
      4,
      5,
      6,
    ]
  ]
}
```

### Docker REST prediction result

```
{
  "prediction": [
    0.09405578672885895
  ],
  [
    0.01238546592343845
  ]
}
```

```

    ],
  "columns": [
    "predictions"
  ]
}

```

## Docker CLI

The Docker CLI packager wraps an ML model into the CLI inside a Docker image. The resulting service can be used for batch prediction.

The packager provides the following list of targets:

Target Name	Connection Types	Required	Description
docker-push	docker, ecr	True	The packager will use the connection for pushing a Docker image result
docker-pull	docker, ecr	False	The packager will use the connection for pulling a custom base Docker image

The packager provides the following list of arguments:

Argument Name	Type	Default	Required	Description
imageName	string	<code>{{Name}}-{{Version}}:{{RandomUUID}}</code>	False	This option provides a way to specify the Docker image name. You can hardcode the full name or specify a template. Available template values: Name (Model Name), Version (Model Version), RandomUUID. Examples: myservice:123, {{Name}}:{{Version}}
dockerfileBaseImage	string	python:3.6	False	Base image for Dockerfile

The packager provides the following list of result fields:

Name	Type	Description
image	string	The full name of a built Docker image

Let's build a couple of examples of Docker CLI packager. The packager requires docker or ecr connection types. The following example assumes that you have created a connection with `test-docker-registry` id and `gcr.io/project/odahuflow` URI.

*Minimal Example of Docker CLI packager*

```
id: "docker-cli-packager-example"
```

## Docker CLI

```
spec:  
  integrationName: docker-cli  
  artifactName: wine-model-123456789.zip  
  targets:  
    - connectionName: test-docker-registry  
      name: docker-push
```

Then a result of the packager will be something like this:  
“gcr.io/project/odahuflow/wine-0-1:ec1bf1cd-216d-4f0a-a62f-bf084c79c58c”.

Now, let's try to change the docker image name and the base image.

### *Docker CLI packager with custom arguments*

```
id: "docker-cli-packager-example"  
spec:  
  integrationName: docker-cli  
  artifactName: wine-model-123456789.zip  
  targets:  
    - connectionName: test-docker-registry  
      name: docker-push  
  arguments:  
    imageName: "wine-test:prefix-{{ RandomUUID }}"  
    dockerfileBaseImage: "python:3.7"
```

```
odahuflowctl pack get --id "docker-cli-packager-example" -o 'jsonpath=$[0].status.results[0].value'
```

Then a result of the packager will be something like this:  
“gcr.io/project/odahuflow/wine-test:prefix-ec1bf1cd-216d-4f0a-a62f-bf084c79c58c”.

You can run the image locally using the following command:

```
docker run -it --rm --net host gcr.io/project/odahuflow/wine-test:prefix-ec1bf1cd-216d-4f0a-a62f-bf084c79c58c --help
```

The model CLI provides two commands:

- *predict* - Make predictions using GPPI model
- *info* - Show model input/output data schema

### *Docker CLI info command*

```
docker run -it --rm --net host gcr.io/project/odahuflow/wine-test:prefix-ec1bf1cd-216d-4f0a-a62f-bf084c79c58c info
```

### *Docker CLI info command output*

```
Input schema:  
{  
  "columns": {  
    "example": [  
      "features",  
      "features",  
      "features",  
    ],  
    "items": {  
      "type": "string"  
    },  
    "type": "array"
```

## Docker CLI

```
},
  "data": {
    "items": {
      "items": {
        "type": "number"
      },
      "type": "array"
    },
    "type": "array",
    "example": [
      [
        0,
        0,
        0,
        0
      ]
    ]
  }
}
Output schema:
{
  "prediction": {
    "example": [
      [
        0
      ],
      "items": {
        "type": "number"
      },
      "type": "array"
    },
    "columns": {
      "example": [
        "predictions"
      ],
      "items": {
        "type": "string"
      },
      "type": "array"
    }
  }
}
```

Let's make a batch prediction.

### Create a predict file

```
mkdir volume
cat > volume/predicts.json <<EOL
{
  "columns": [
    "features",
    "features",
    "features",
    "features"
  ],
  "data": [
    [
      [
        1,
        2,
        3
      ],
      [
        4,
        5,
        6
      ]
    ]
  ]
}EOL
docker run -it --rm --net -v volume:/volume host gcr.io/project/odahuflow/wine-test:prefix-eclbf1cd-216d-4f0a-a62f-bf084c79c58c predict /volume/predicts.json /volume
```

### Result of prediction

```
cat volumes/result.json
{
  "prediction": [
    [
      0.09405578672885895
    ]
  ]
}
```

## Docker CLI

```
  ],
  [
    0.01238546592343845
  ]
},
"columns": [
  "predictions"
]
}
```

# Model Deployments

Odahu-flow Model Deployment API allows deploy of ML models in a Kubernetes cluster. Additionally, it provides the following set of features:

- Feedback loop
- Scale to zero
- Dynamic Model swagger
- Monitoring of Model Deployment

### **Important**

Model could be deployed only if docker image was packaged through Docker REST packager.

## General deployment structure

### *Deployment API*

```
kind: ModelDeployment
# Some unique value among all deployments
# Id must:
# * contain at most 63 characters
# * contain only lowercase alphanumeric characters or '-'
# * start with an alphabetic character
# * end with an alphanumeric character
id: wine-12345
spec:
  # Model image is required value. Change it
  image: gcr.io/project/test-e2e-wine-1.0:b591c752-43d4-43e0-8392-9a5715b67573
  # If the Docker image is pulled from a private Docker repository then
  # you have to create a Odahu-flow connecton and specify its id here.
  # imagePullConnID: test

  # Compute resources for the deployment job.
  resources:
    limits:
      cpu: 1
      memory: 1Gi
    requests:
      cpu: 1
      memory: 1Gi

  # Minimum number of replicas
  minReplicas: 0
  # Maximum number of replicas
  maxReplicas: 1
```

## Model Deployment management

Model Deployments can be managed using the following ways.

### Swagger UI

ModelDeployments are available in the Swagger UI at <http://api-service/swagger/index.html> URL.

### Odahu-flow CLI

Odahuflowctl supports the Model Deployment API. You must be logged in if you want to access the API.

Getting all model deployments in json format:

```
odahuflowctl deployment get --format json
```

Getting the model name of the model deployments:

```
odahuflowctl deployment get --id tensorflow-cli -o 'jsonpath=[*].spec.model.name'
```

- Creating of a deployment from *deploy.yaml* file:

```
odahuflowctl deployment create -f deploy.yaml
```

- All model deployments commands and documentation:

```
odahuflowctl deployment --help
```

- All model deployments commands and documentation:

```
odahuflowctl deployment --help
```

- Getting a model deployment information:

```
odahuflowctl model info --md wine
```

- Making a prediction:

```
odahuflowctl model invoke --md wine --file request.json
```

### JupyterLab

Odahu-flow provides the JupyterLab extension for interacting with Model Deployments API.

## Service Catalog

Service catalog provides a Swagger UI for Model Deployments.

### Note

The model must provide input and output samples to appear in the Service Catalog

Service catalog Swagger UI:

The screenshot shows the Swagger UI interface for the Service Catalog. At the top, there's a navigation bar with a logo, the path `./data.json`, and a green "Explore" button. Below the header, the title "Service Catalog 1.0" is displayed, along with links for `/data.json`, "Catalog of model services", "Terms of service", and "Apache 2.0". A dropdown menu for "Schemes" is open, showing "HTTPS" as the selected option. The main content area is titled "model-123" and contains two API endpoints: a blue "GET /model/model-123/api/model/info Info" button and a green "POST /model/model-123/api/model/invoke Prediction" button.

Example of a prediction request:

This screenshot shows the "Execute prediction" dialog for the POST endpoint. It includes fields for "Parameters" (with a "Cancel" button) and "PredictionParameters" (with a "required" note). The "PredictionParameters" field contains a JSON object representing wine data. At the bottom, there are "Cancel" and "Execute" buttons, and a dropdown for "Parameter content type" set to "application/json".

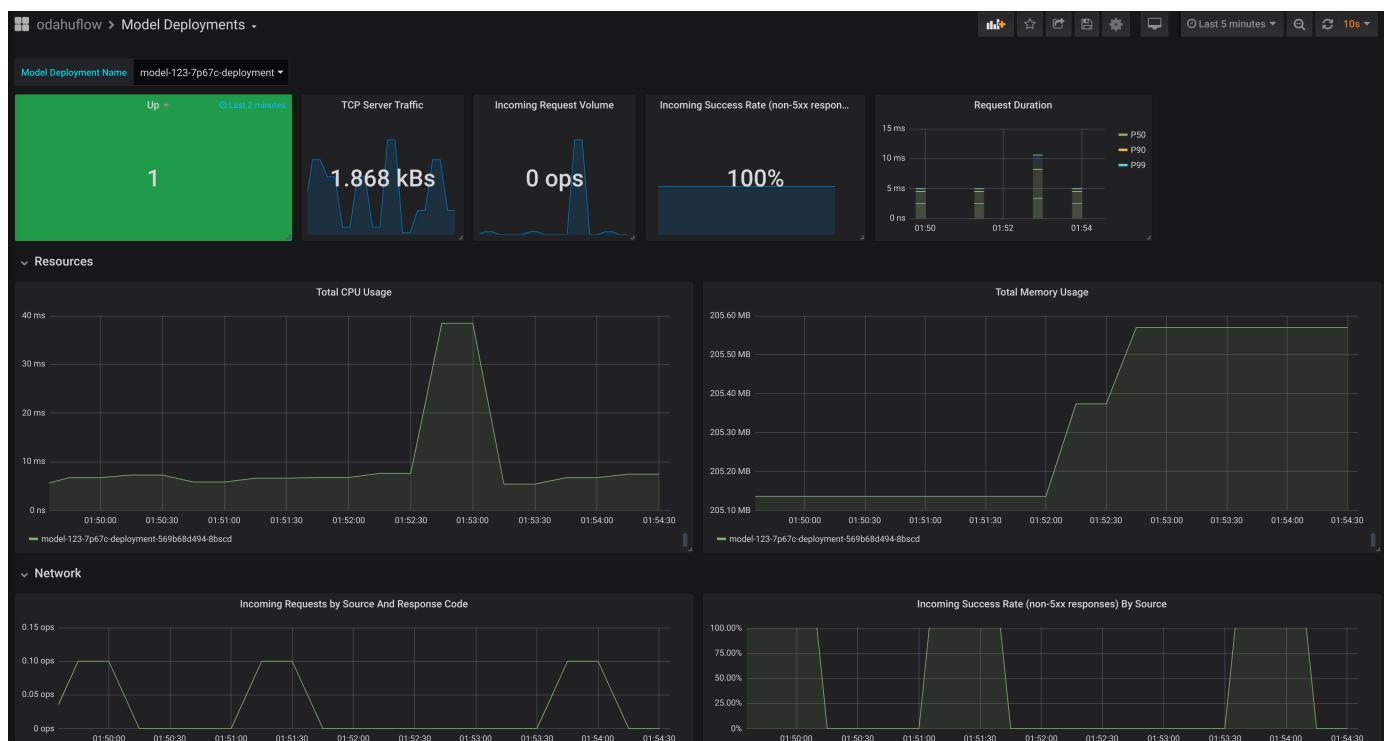
## Grafana Dashboard

## Feedback

Out of the box, Odahu-flow provides the Grafana Model Deployment dashboard. It contains the charts with following system metrics:

- availability
- replicas
- CPU
- memory
- number of failed HTTP requests
- latency
- ...

Example of the dashboard:



## Feedback

**Model Feedback** provides a view of performance over all stages of model lifecycle. The mechanism is simple:

1. Ask Deploy for prediction (with or without Request-Id provided)
2. Send prediction feedback to Odahu-flow (with Request-Id returned from previous step)
3. Odahu-flow stores the prediction and feedback to a configurable location

### Important

This flow requires feedback to be enabled in `values.yaml` during Helm chart installation

## Protocol

1. If prediction is requested without Request-ID: Request-ID header with random ID is added to the request. Otherwise, Request-ID is not generated.
2. Request and response are stored on configured external storage (eg. S3, GCS)
3. User sends Model Feedback as an argument to the feedback endpoint. (Feedback can be arbitrary JSON.)
4. All Feedback is persisted on external storage and can be used by models during subsequent Trains.

## Working example

### Making a prediction request:

```
curl -X POST -vv "https://cluster-url/model/" "model-deployment-id" "/api/model/invoke" \
-H "Authorization: Bearer " \
-H "Accept: application/json" \
-H "Content-Type: application/json" \
-d "{ \"columns\": [ \"fixed acidity\", \"volatile acidity\", \"citric acid\", \"density\", \"residual sugar\", \"chlorides\", \"total sulfur dioxide\", \"density\", \"pH\", \"sulphates\", \"alcohol\" ], \"data\": [ [ 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 ] ] }"
```

The response contains a generated Request-ID header.

```
HTTP/2 200
server: nginx/1.13.12
date: Tue, 17 Dec 2019 10:58:49 GMT
content-type: application/json
content-length: 45
model-name: test-e2e-wine
model-version: 1.0
request-id: 6faf1f636-fb80-9979-b8c6-d78f5e90f0c1
x-envoy-upstream-service-time: 43
strict-transport-security: max-age=15724800; includeSubDomains

{"prediction": [6.0], "columns": ["quality"]}
```

Requests and responses are persisted in a bucket. (File name `~/request_response/income/1.1/year=2019/month=07/day=24/2019072414_4.json`)

The first file contains meta-information about request and response:

```
{
  "request_id": "6faf1f636-fb80-9979-b8c6-d78f5e90f0c1",
  "model_name": "test-e2e-wine",
  "model_version": "1.0",
  "date": "Tue, 17 Dec 2019 10:58:49 GMT",
  "x_envoy_upstream_service_time": 43,
  "strict_transport_security": "max-age=15724800; includeSubDomains",
  "content_type": "application/json",
  "content_length": 45,
  "request": {
    "method": "POST",
    "url": "https://cluster-url/api/model/invoke"
  },
  "response": {
    "status": 200,
    "headers": [
      "Content-Type: application/json",
      "Content-Length: 45",
      "Date: Tue, 17 Dec 2019 10:58:49 GMT",
      "Server: nginx/1.13.12",
      "X-Envoy-Upstream-Service-Time: 43",
      "Strict-Transport-Security: max-age=15724800; includeSubDomains"
    ],
    "body": "[{"prediction": 6.0, "columns": ["quality"]}]"
  }
}
```

The second file contains the response body with the same Request-ID (File name `~/response_body/income/1.1/year=2019/month=07/day=24/2019072414_1.json`)

```
{
  "request_id": "6faf1f636-fb80-9979-b8c6-d78f5e90f0c1",
```

## Feedback

```
"model_version": "1.0",
"model_name": "test-e2e-wine",
"response_content": "{\"prediction\": [6.0], \"columns\": [\"quality\"]}",
"time": "2019-12-17 08:46:40 +0000"
}
```

### Working Example - Send Feedback as Payload

Send Model Feedback request:

```
curl -X POST -vv "${BASE_URL}/feedback/model/" \
-H "Authorization: Bearer ${JWT}" \
-H "x-model-name: income" \
-H "x-model-version: 1.1" \
-H "Request-ID: previous-prediction-id" \
-H "Content-Type: application/json" \
-d '{"truthful": 1}'
```

Note that the -d argument can pass arbitrary JSON.

A successful feedback request will have the following properties:

- HTTP response: 200
- Response field error is false.
- Response field registered is true.
- Response field message is what was sent to storage.

*Example response*

```
{
  "message": {
    "RequestID": "previous-prediction-id",
    "ModelVersion": "1.0",
    "modelName": "test-e2e-wine",
    "Payload": {
      "json": {
        "truthful": 1
      }
    }
  }
}
```

File name ~=

/feedback/test-e2e-wine/1.0/year=2019/month=11/day=23/2019072311\_2.json  
will have a format like this, with feedback stored in the payload field:

```
{
  "request_id": "previous-prediction-id",
  "model_version": "1.0",
  "model_name": "test-e2e-wine",
  "payload": {
    "json": {
      "truthful": 1.0
    }
  },
  "time": "2019-12-17 20:08:05 +0000"
}
```

## Feedback

# Glossary

## VCS

Version control system. A service that stores model source code for development and deployment procedures (e.g. a GitHub Repository).

## Trained Model Binary

An archive containing a trained ML/AI model (inference code, model weights, etc). Odahu defines a format for these binaries. See <ref\_model\_format.html>

## Trainer

Application that uses model source code, **Data Bindings, Connections** and **Training Hyperparameters** to produce a **Trained Model Binary**.

## Data Binding

Reference to remote data (e.g. files from S3) should be placed for a **Train** process.

## Connection

Credentials for an external system. For example: Docker Registry, cloud storage location, etc.

## Training Hyperparameters

Parameter for Training process. For example, count of epochs in evolution algorithms.

## Train

A containerized process that converts model source code, **Data Bindings**, **Connections** and **Training Hyperparameters** to **Trained Model Binary** using a **Trainer** defined in a **Trainer Extension**

## Trainer Extension

A pluggable **Train** implementation.

## Packager

Containerized application that uses a **Trained Model Binary** and **Connections** and converts them into a target Archive. Typically this is a Docker image with REST API.

## Package

Containerized process which turns a **Trained Model Binary** into a Docker image with REST API using a **Packager Extension**.

## Packager Extension

A pluggable **Package** implementation.

## Deployer

Containerized application that uses the results of a **Package** process and **Connections** to deploy a packaged model on a Kubernetes cluster.

## Deploy

Containerized process that deploys results of a **Package** operation to Kubernetes cluster with a REST web service.

## Trainer Metrics

## Glossary

Metrics set by *Trainer* code during *Train* (e.g. accuracy of model). These metrics can be used for querying and comparing *Train* events.

### Trainer Tags

Key/value pairs that are set by *Trainer* code (e.g. type of algorithm). Can be used for querying and comparing *Train* runs.

### General Python Prediction Interface

Format of storing models, written in a Python language

### MLflow Trainer

Integration of MLflow library for training models, written in a Python. Details - [MLFlow Trainer](#)

### REST API Packager

Integration for packing trained models into Docker Image with served via REST API

### API service

API for managing Odahu Platform resources for cloud deployed Platform

### Operator

A Kubernetes Operator that manages Kubernetes resources (Pods, Services and etc.) for Odahu [Train](#), [Package](#), and [Deploy](#) instances.

### Prediction

A deployed model output, given input parameters.

### Model prediction API

API provided by deployed models to allow users to request predictions through a web service.

### Prediction Feedback

Feedback versus the previous [prediction](#), e.g. prediction correctness.

### Model Feedback API

An API for gathering [Prediction Feedback](#)

### Feedback aggregator

A service that provides a [Model Feedback API](#) and gathers input and output [prediction requests](#)

### Odahu-flow SDK

An extensible Python client library for [API service](#), written in Python language. Can be installed from PyPi.

### Odahu-flow CLI

Command Line Interface for [API service](#), written in Python. Can be installed from PyPi. It uses the [Odahu-flow SDK](#).

### Plugin for JupyterLab

A odahu-specific plugin that provides Odahu Platform management controls in JupyterLab.

### Plugin for Jenkins

A library for managing Odahu Platform resources from Jenkins Pipelines.

### Plugin for Airflow

## Glossary

A library that provides Hooks and Operators for managing Odahu Platform resources from Airflow.

### Model Deployment Access Role Name

Name of scope or role for accessing model deployments.

### JWT Token

A JSON Web Token that allows users to query deployed models and to provide feedback. This token contains an encoded **role name**.

### A/B testing

Process of splitting predictions between multiple **Model Deployments** in order to compare prediction metrics and **Model Feedback** for models, which can vary by **source code**, **dataset** and/or **training hyperparameters**

### Odahu distribution

A collection of Docker Images, Python packages, or NPM packages, which are publicly available for installation as a composable Odahu Platform.

### Odahu Helm Chart

A YAML definition for Helm that defines a Odahu Platform deployed on a Kubernetes cluster.

### Odahu-flow's CRDs

Objects that **API service** creates for actions that require computing resources to be stored. For example: **connections**, **Trains**, etc.

These objects are Kubernetes Custom Resources and are managed by **operator**.

### Identity Provider (idP)

A component that provides information about an entity (user or service).

### Policy Enforcement Point (PEP)

A component that enforces security policies against each request to API or other protected resources.

### Policy Decision Point (PDP)

A component that decides whether the request (action in the system) should be permitted or not.

# Changelog

## Odahu 1.4.0

### **Features:**

### **Updates:**

- CLI:
  - We added --disable-target option for odahuflowctl local pack run command's targets which will be passed to packager process. You can use multiple options at odahuflowctl local pack run ... --disable-target=docker-pull --disab
  - odahuflowctl local pack run command's options --disable-package-targets/-no-disable-package-targets are deprecated.
  - odahuflowctl local pack run behavior that implicitly disables all targets by default is deprecated.

### **Bug Fixes:**

## Odahu 1.3.0, 07 October 2020

### **Features:**

- Core:
  - Persistence Agent added to synchronize k8s CRDS into main storage ([#268](#)).
  - All secrets passed to ODAHU API now should be base64 encoded. Decrypted secrets retrieved from ODAHU API via /connection/:id/decrypted are now also base64 encoded. ([#181](#), [#308](#)).
  - Positive and negative (for 404 & 409 status codes) API tests via odahuflow SDK added ([#247](#)).

## Updates:

- Core:

- Robot tests will now output pods state after each API call to simplify debugging.

## Bug Fixes:

- Core:

- Refactoring: some abstractions & components were renamed and moved to separate packages to facilitate future development.
  - For connection create/update operations ODAHU API will mask secrets in response body.
  - Rclone output will not reveal secrets on unit test setup stage anymore.
  - *Output-dir* option path is now absolute ([#208](#)).
  - Respect *artifactNameTemplate* for local training result directory name ([#193](#)).
  - Allow to pass Azure BLOB URI without schema on connection creation ([#345](#))
  - Validate model deployment ID to ensure it starts with alphabetic character ([#294](#))

- UI:

- State of resources now updates correctly after changing in UI ([#11](#)).
  - User aren't able to submit training when resource request is bigger than limit ('[#355](#)).
  - Mask secrets on review page during conenction creation process ([#42](#))
  - UI now responds correct in case of concurrent deletion of entities ([#44](#)).
  - Additional validation added to prevent creation of resources with unsupported names ([#342](#), [#34](#)).
  - Sorting added for training & packaging views ([#13](#), [#48](#)).
  - *reference* field become optional for VCS connection ([#50](#)).
  - Git connection hint fixed ([#7](#)).

- CLI:

- Configuration secrets is now masked in config output ([#307](#)).
  - Local model output path will now display correctly ([#371](#)).
  - Local training output will now print only local training results ([#370](#)).
  - Help message fixed for *odahuflowctl gppi* command ([#375](#)).

- SDK:

- All API connection errors now should be correctly handled and retried.

## Odahu 1.2.0, 26 June 2020

### Features:

- Core:

- PostgreSQL became main database backend as part of increasing project maturity ([#175](#)). You can find additional documentation in instructions.

- ODAHU CLI:

- Option `-ignore-if-exist` added for entities creation ([#199](#)).
- Descriptions updated for commands & options ([#160](#), [#197](#), [#209](#)).

- ODAHU UI:

- ODAHU UI turned into open-source software and now available on [github](#) under Apache License Version 2.0. ODAHU UI is an WEB-interface for ODAHU based on React and TypeScript. It provides ODAHU workflows overview and controls, log browsing and entity management.

### Updates:

- Knative updated to version 0.15.0. That makes it possible to deploy model services to different node pools ([#123](#)).
- Go dependencies was globally updated to migrate from GOPATH to go modules ([#32](#)).

### Bug Fixes:

- Core:

- Training now will fail if wrong data path or unexisted storage bucket name is provided ([#229](#)).
- Training log streaming is now working on log view when using native log viewer ([#234](#)).
- ODAHU pods now redeploying during helm chart upgrade ([#111](#)).
- ODAHU docker connection now can be created with blank username & password to install from docker public repo ([#184](#)).

- ODAHU CLI:
  - Return training artifacts list sorted by name (#165).
  - Don't output logs for bulk command (#200).
  - Fix *local pack cleanup-containers* command (#204).
  - Return correct message if entity not found (#210).
  - Return correct message if no options provided (#211).
- ODAHU UI:
  - Fix description of replicas of Model Deployment.
  - Trim spaces for input values.
  - Fix incorrect selection of VCS connection.
  - Close 'ODAHU components' menu after opening link in it.

## Odahu 1.1.0, 16 March 2020

### New Features:

- Jupyterhub:

Supported the JupyterHub in our deployment scripts. JupyterHub allows spawning multiple instances of the JupyterLab server. By default, we provide the prebuilt ODAHU JupyterLab plugin in the following Docker images: [base-notebook](#), [datascience-notebook](#), and [tensorflow-notebook](#). To build a custom image, you can use [our Docker image template](#) or follow the instructions.
- GPU:

Added the ability to deploy a model training on GPU nodes. You can find an example of training [here](#). This is one of the official MLFlow examples that classifies flower species from photos.
- Security:

We integrated our WEB API services with [Open Policy Agent](#) that flexibly allows managing ODAHU RBAC. Using [Istio](#), we forbid non-authorized access to our services. You can find the ODAHU security documentation [here](#).
- Vault:

ODAHU-Flow has the Connection API that allows managing credentials from Git repositories, cloud storage, docker registries, and so on. The default backend for Connection API is Kubernetes. We integrated the [Vault](#) as a storage backend for the backend for Connection API to manage your credentials securely.
- Helm 3:

We migrated our Helm charts to the Helm 3 version. The main goals were to simplify a deployment process to an Openshift and to get rid of the tiller.

- ODAHU UI:

ODAHU UI provides a user interface for the ODAHU components in a browser. It allows you to manage and view ODAHU Connections, Trainings, Deployments, and so on.

- Local training and packaging:

You can train and package an ML model with the *odahuflowctl* utility using the same ODAHU manifests, as you use for the cluster training and packaging. The whole process is described here.

- Cache for training and packaging:

ODAHU Flow downloads your dependencies on every model training and packaging launch. To avoid this, you can provide a prebuilt Docker image with dependencies. Read more for model training and packagings.

- Performance improvement training and packaging:

We fixed multiple performance issues to speed up the training and packaging processes. For our model examples, the duration of training and packaging was reduced by 30%.

- Documentation improvement:

We conducted a hard work to improve the documentation. For example, the following new sections were added: Security, Installation, Training, Packager, and Model Deployment.

- Odahu-infra:

We created the new [odahu-infra](#) Git repository, where we placed the following infra custom helm charts: Fluentd, Knative, monitoring, Open Policy Agent, Tekton.

- Preemptible nodes:

Preemptible nodes are priced lower than standard virtual machines of the same types. But they provide no availability guarantees. We added new deployment options to allow training and packaging pods to be deployed on preemptible nodes.

- Third-parties updates:

- Istio
- Grafana
- Prometheus
- MLFlow
- Terraform
- Buildah
- Kubernetes

## ***Misc/Internal***

- Google Cloud Registry:

We have experienced multiple problems while using Nexus as a main dev Docker registry. This migration also brings us additional advantages, such as in-depth vulnerability scanning.

- Terragrunt:

We switched to using Terragrunt for our deployment scripts. That allows reducing the complexity of our terraform modules and deployment scripts.

# Development

## Pre requirements

To participate in developing of Odahu project you have to meet these requirements:

- Linux/macOS operating systems (due to tools used for development)
- Python:
  - Python v3.6
  - Pipenv
- Golang:
  - Golang v1.14
  - Dep
  - golangci-lint
  - Kubebuilder
  - swag
  - gotestsum
- JupyterLab plugin:
  - Typescript
  - Yarn
- Infra:
  - HELM v3.2.4
  - Kubectl v1.16.10
  - Docker v17+
  - Swagger codegen 2.4.7

## Useful links

- Python:
  - Mlflow
  - Robot Framework Guide
  - Odahu Airflow Plugins Development
- Golang:
  - Kubebuilder
- JupyterLab plugin:
  - Typescript handbook

## Development

- [React documentation](#)
- [JupyterLab plugin Extension Developer Guide](#)
- Infra:
  - [Helm](#)

# Repositories

## A repository directory structure

- containers - docker files
- helms - core helm chart
- packages - source code of packages and applications.
- scripts - utility scripts for CI/CD process.

### odahu/odahu-flow

Core services of Odahu-flow project.

- odahu-flow-cli python package
- odahu-flow-sdk python package
- E2E Odahu tests
- Training, packaging and deployment operator
- API server
- Feedback services

### odahu/odahu-trainer

Collection of training extensions:

- mlflow

### odahu/odahu-packager

Collection of model packagers:

- docker-rest
- docker-cli

### odahu/odahu-flow-jupyterlab-plugin

The jupyterlab-plugin that provides UI for Odahu-flow API service.

odahu/odahu-airflow-plugin

## odahu/odahu-airflow-plugin

An apache airflow plugin for the Odahu Platform.

## odahu/odahu-docs

The repository contains Odahu documentation, which is available [here](#).

## odahu/odahu-examples

Examples of ML models.

## odahu/odahu-infra

Docker images and deployments script for third-party services.

# Development hints

## Set up a development environment

Odahu product contains 5 main development parts:

- Python packages
  - Executes the `make install-all` command to download all dependencies and install Odahu python packages.
  - Verifies that the command finished successfully, for example: `odahuflowctl --version`
  - Main entrypoints:
    - Odahu-flow SDK - `packages/sdk`
    - Odahu-flow CLI - `packages/cli`
- Odahu-flow JupyterLab plugin
  - Workdir is `odahu/jupyterlab-plugin`
  - Executes the `yarn install` command to download all JavaScript dependencies.
  - Executes the `npm run build && jupyter labextension install` command to build the JupyterLab plugin.
  - Starts the JupyterLab server using `jupyter lab` command.
- Golang services:
  - Executes the `dep ensure` command in the `packages/operator` directory to download all dependencies.
  - Executes the `make build-all` command in the `packages/operator` to build all Golang services.
  - Main entrypoints:
    - API Gateway service - `packages/operator/cmd/edi/main.go`
    - Kubernetes operator - `packages/operator/cmd/operator/main.go`
    - AI Trainer - `packages/operator/cmd/trainer/main.go`
    - AI Packager - `packages/operator/cmd/packager/main.go`
    - Service catalog - `packages/operator/cmd/service_catalog/main.go`
- Odahu-flow Mlflow integration
  - Executes the `pip install -e .` command in the `odahu-flow-mlflow` repository.
- Odahu-flow Airflow plugin
  - Executes the `pip install -e .` command in the `odahu-flow-airflow-plugins` repository.

## Update dependencies

- Python. Update dependencies in a Pipfile. Execute `make update-python-deps` command.
- Golang. Update dependencies in a `go.mod`. Execute `go build ./...` command in packages/operator directory.
- Typescript. Odahu-flow uses the `yarn` to manipulate the typescript dependencies.

## Make changes in API entities

All API entities are located in `packages/operator/pkg/api` directory.

To generate swagger documentation execute `make generate-all` in `packages/operator` directory. Important for Mac users: Makefile uses GNU sed tool, but MacOS uses BSD sed by default. They are not fully compatible. So you need install and use GNU sed on your Mac for using Makefile.

After previous action you can update python and typescript clients using the following command: `make generate-clients`.

## Actions before a pull request

Make sure you have done the following actions before a pull request:

- for python packages:
  - `make unittest` - Run the python unit tests.
  - `make lint` - Run the python linters.
- for golang services in the `packages/operator` directory:
  - `make test` - Run the golang unit tests.
  - `make lint` - Run the golang linters.
  - `make build-all` - Compile all golang Odahu-flow services
- for typescript code in the `packages/jupyterlab-plugin` directory:
  - `yarn lint` - Run the typescript linter.
  - `jlpm run build` - Compile the jupyterlab plugin.

## Local Helm deploy

During development, you often have to change the helm chart, to test the changes you can use the following command quickly: `make helm-install`.

## Update dependencies

Optionally, you can create the variables helm file and specify it using the HELM\_ADDITIONAL\_PARAMS Makefile option. You always can download real variables file from a Terraform state.

# Integration Testing

This page provides information about testing of ODAHU. ODAHU uses [Robot Framework](#) for an integration, system and end-to-end testings.

All tests are located in the following directories of the [ODAHU project](#):

- packages/robot/ - a python package with additional Robot libraries. For example: kubernetes, auth\_client, feedback, and so on.
- packages/tests/stuff/ - artifacts for integration testing. For example: pre-trained ML artifacts, test toolchain integrations, and so on.
- packages/tests/e2e/ - directory with the RobotFramework tests.

## Preparing for testing

It's expected that you are using Unix-like operating system and have installed Python 3.6.9+ and pip.

[Clone](#) ODAHU project from git repository and proceed to main dir – odahu-flow.

[Create](#) Python virtual environment e.g. in the folder  
./odahu-flow/virtual\_environment/ and activate one.

[Install](#) Robot Framework

Update and/or install **pip** and **setuptools**:

```
$ pip install -U pip setuptools
```

Proceed to the odahu-flow main directory where the Makefile is located and run **make** command:

```
/odahu-flow$ make install-all
```

Check that odahuflowctl works:

```
/odahu-flow$ odahuflowctl
```

Also, you should have installed [jq](#) and [rclone](#) packages.

## Running tests

We set up robot tests for gke-odahu-flow-test cluster in the example below.

**NB.** Do not forget change **your cluster url** and **odahu-flow version**.

## Integration Testing

By default put `cluster_profile.json` file in `odahu-flow/.secrets/` folder (by default) or you can specify another default name of file or directory in '`Makefile`' in parameters: `SECRET_DIR` and `CLUSTER_PROFILE`.

You can optionally override the following parameters in `.env` file (which by default are taken from `Makefile`).

- `CLUSTER_NAME`
- `ROBOT_OPTIONS`
- `ROBOT_FILES`
- `HIERA_KEYS_DIR`
- `SECRET_DIR`
- `CLOUD_PROVIDER`
- `DOCKER_REGISTRY`
- `EXPORT_HIERA_DOCKER_IMAGE`
- `ODAHUFLOW_PROFILES_DIR`
- `ODAHUFLOW_VERSION`, etc.

For that, you should create `.env` file in the main dir of the project (`odahu-flow`).

In our example, we will override the parameters of `Makefile` in `.env` file:

```
# Cluster name
CLUSTER_NAME=gke-odahu-flow-test
# Optionally, you can provide RobotFramework settings below.
# Additional robot parameters. For example, you can specify tags or variables.
ROBOT_OPTIONS=-e disable
# Robot files
ROBOT_FILES=**/*.robot
# Cloud which will be used
CLOUD_PROVIDER=gcp
# Docker registry
DOCKER_REGISTRY=gcr.io/or2-msq-<myprojectid>-tliyulu/odahu
# Version of odahu-flow
ODAHUFLOW_VERSION=1.1.0-rc8
```

Afterwards, you should prepare an Odahu cluster for Robot Framework tests by using the command:

```
/odahu-flow$ make setup-e2e-robot
```

**NB.** You should execute the previous command only once for a new cluster.

Finally, start the robot tests:

```
/odahu-flow$ make e2e-robot
```

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