上海交通大学
SHANGHAI JIAO TONG UNIVERSITY

SJTU

Serverless Computing Labs

蔡子诺 博士生
计算机科学与工程系
上海交通大学

课程通知

- **联邦学习实验补交：**
  - DDL2024年12月17日23:59
- **联邦学习实验验收：**
  - 2024年12月18日14:00，地点电院3号楼229
  - 每个人15分钟，具体安排见课程群
- **无服务器计算实验**
  - DDL2024年12月31日23:59

无服务器计算实验

- 基于阿里云，在课上讲的MapReduce、高维矩阵运算、分布式机器学习训练、机器学习推理任务四个任务中进行实现。
- 作业提交：实验报告+源代码+必要的实验log数据+答辩ppt
- 作业DDL：2024年12月31日23:59
- Bonus: 在本地搭建Kubernetes集群和OpenWhisk或者KubeFaaS框架，基于该框架实现基本的无服务器计算任务。

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目录

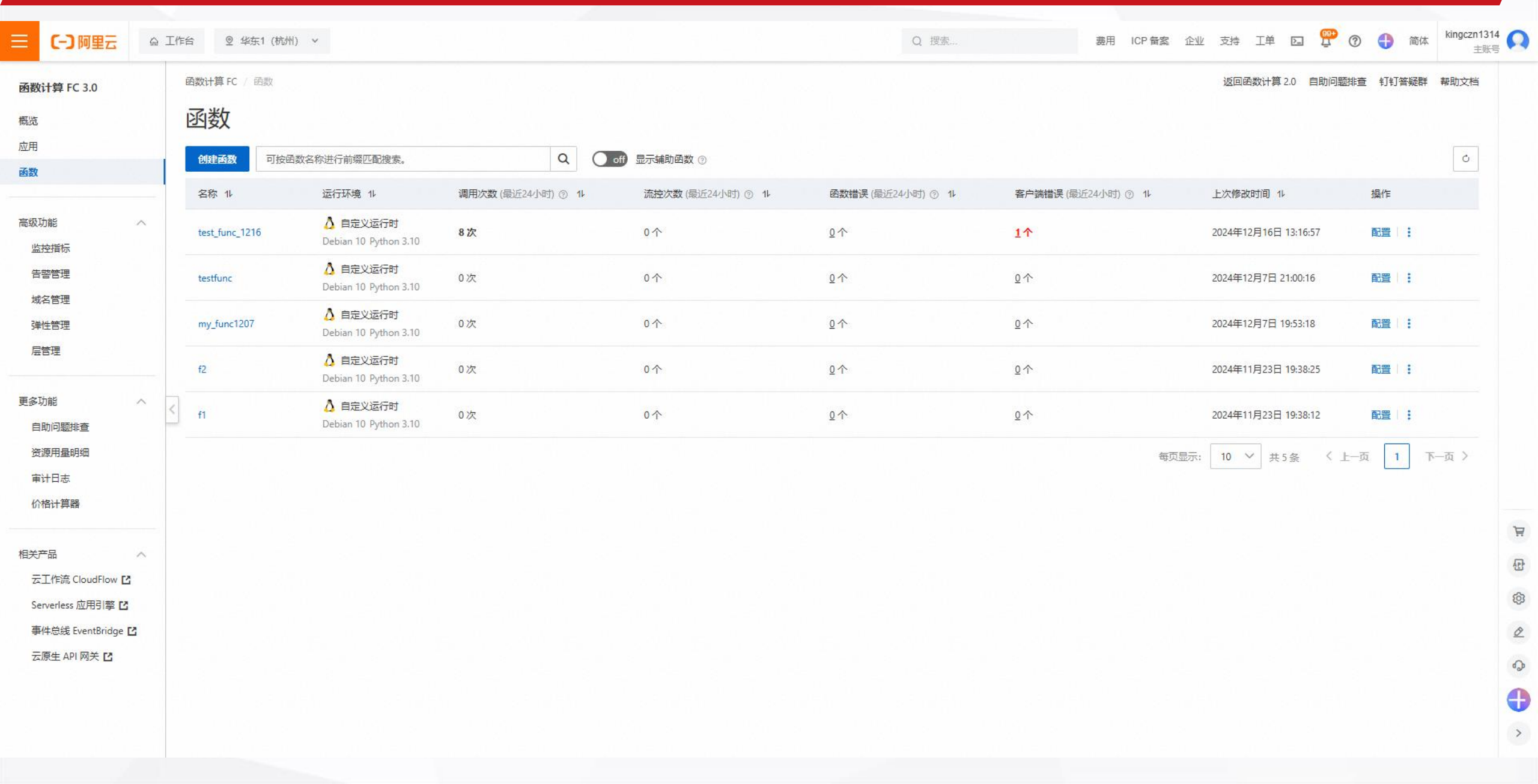
01

阿里云无服务器计算平台学习

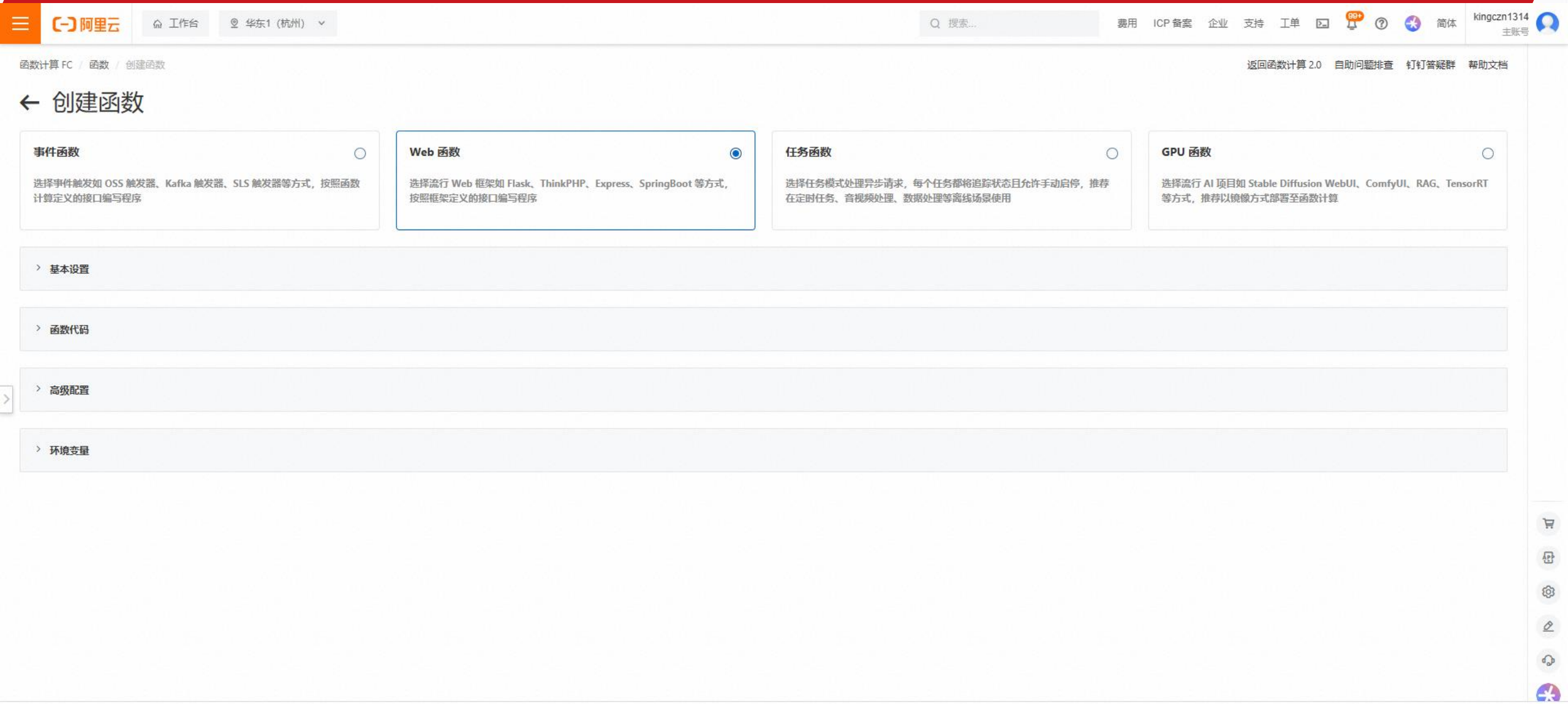
参考链接

- **函数计算 FC 3.0**
  - https://help.aliyun.com/zh/functioncompute/fc-3-0/
- **对象存储/开发参考/SDK参考**
  - https://help.aliyun.com/zh/oss/developer-reference/preface/

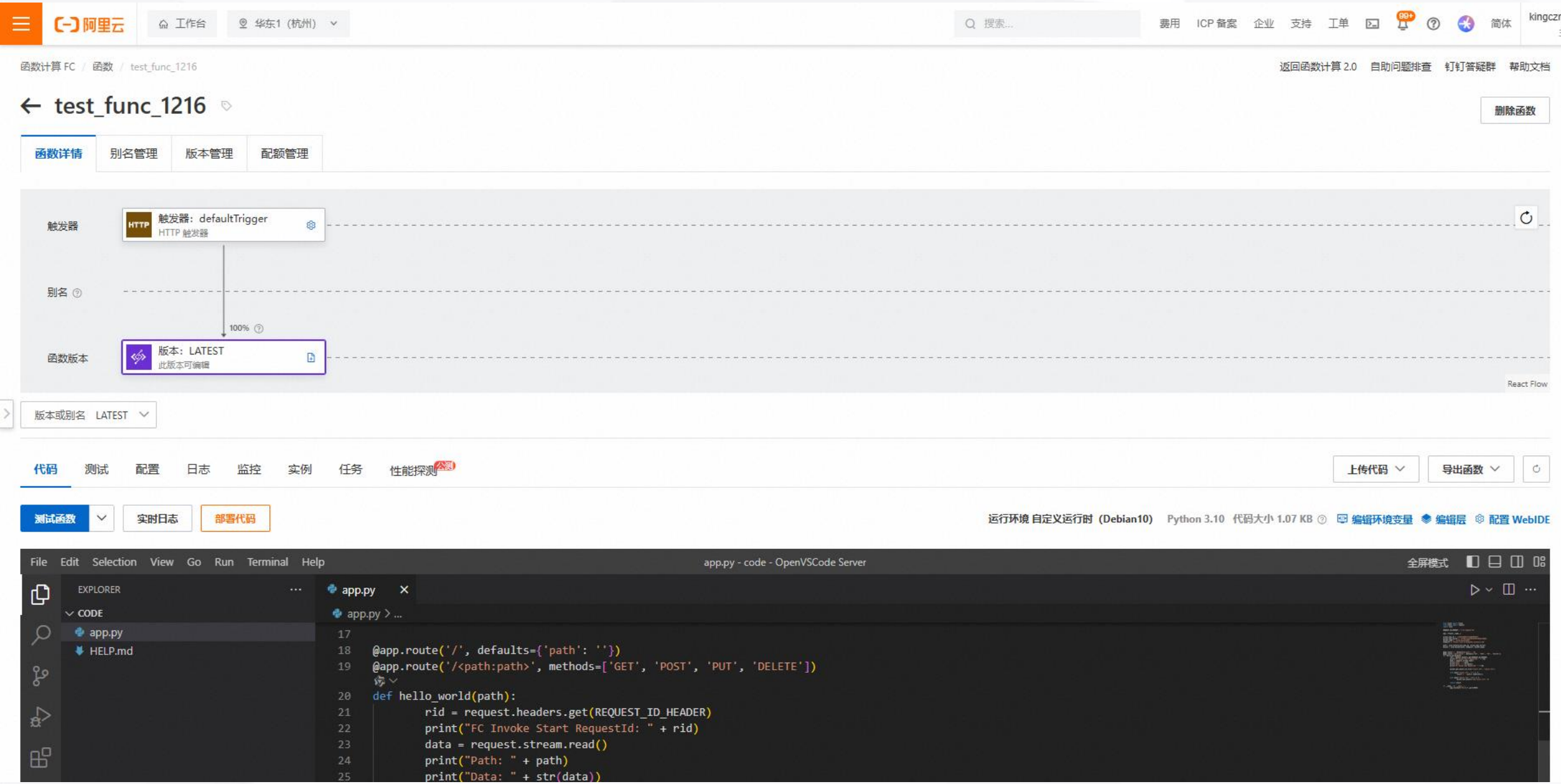
函数创建（1）


阿里云
工作台
华东1（杭州）
搜索...
费用
ICP 备案
企业
支持
工单
简体
kingczn1314
主账号
函数计算 FC 3.0
概览
应用
函数
高级功能
监控指标
告警管理
域名管理
弹性管理
层管理
更多功能
自助问题排查
资源用量明细
审计日志
价格计算器
相关产品
云工作流 CloudFlow
Serverless 应用引擎
事件总线 EventBridge
云原生 API 网关
函数计算 FC / 函数
返回函数计算 2.0
自助问题排查
钉钉答疑群
帮助文档
函数
创建函数
可按函数名称进行前缀匹配搜索。
off
显示辅助函数
名称
运行环境
调用次数 (最近24小时)
流控次数 (最近24小时)
函数错误 (最近24小时)
客户端错误 (最近24小时)
上次修改时间
操作
test_func_1216
自定义运行时
Debian 10 Python 3.10
8 次
0 个
0 个
1 个
2024年12月16日 13:16:57
配置
testfunc
自定义运行时
Debian 10 Python 3.10
0 次
0 个
0 个
0 个
2024年12月7日 21:00:16
配置
my_func1207
自定义运行时
Debian 10 Python 3.10
0 次
0 个
0 个
0 个
2024年12月7日 19:53:18
配置
f2
自定义运行时
Debian 10 Python 3.10
0 次
0 个
0 个
0 个
2024年11月23日 19:38:25
配置
f1
自定义运行时
Debian 10 Python 3.10
0 次
0 个
0 个
0 个
2024年11月23日 19:38:12
配置
每页显示:
10
共 5 条
上一页
1
下一页

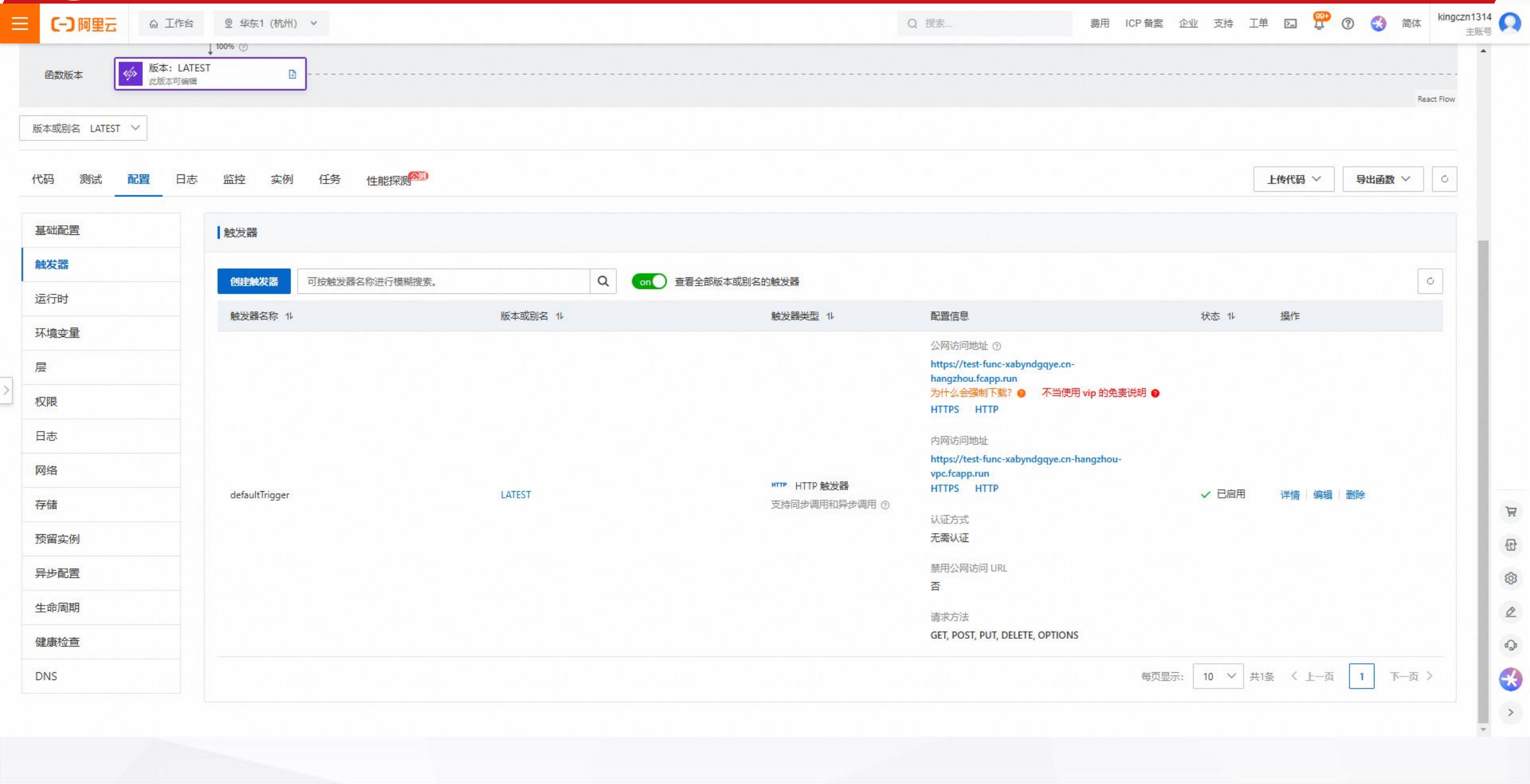
函数创建（2）


阿里云
工作台
华东1（杭州）
搜索...
费用
ICP 备案
企业
支持
工单
99+
简体
kingczn1314
主账号
函数计算 FC / 函数 / 创建函数
返回函数计算 2.0
自助问题排查
钉钉答疑群
帮助文档
创建函数
事件函数
选择事件触发如 OSS 触发器、Kafka 触发器、SLS 触发器等方式，按照函数计算定义的接口编写程序
Web 函数
选择流行 Web 框架如 Flask、ThinkPHP、Express、SpringBoot 等方式，按照框架定义的接口编写程序
任务函数
选择任务模式处理异步请求，每个任务都将追踪状态且允许手动启停，推荐在定时任务、音视频处理、数据处理等离线场景使用
GPU 函数
选择流行 AI 项目如 Stable Diffusion WebUI、ComfyUI、RAG、TensorRT 等方式，推荐以镜像方式部署至函数计算
基本设置
函数代码
高级配置
环境变量
创建
取消

函数创建（3）


阿里云
工作台
华东1（杭州）
搜索...
费用
ICP 备案
企业
支持
工单
简体
kingczn1314
主账号
函数计算 FC / 函数 / test_func_1216
返回函数计算 2.0
自助问题排查
钉钉答疑群
帮助文档
test_func_1216
删除函数
函数详情
别名管理
版本管理
配额管理
触发器
触发器：defaultTrigger
HTTP 触发器
别名
100%
函数版本
版本：LATEST
此版本可编辑
React Flow
版本或别名 LATEST
代码
测试
配置
日志
监控
实例
任务
性能探测
公测
上传代码
导出函数
测试函数
实时日志
部署代码
运行环境 自定义运行时（Debian10）
Python 3.10
代码大小 1.07 KB
编辑环境变量
编辑层
配置 WebIDE
File
Edit
Selection
View
Go
Run
Terminal
Help
app.py - code - OpenVSCode Server
全屏模式
EXPLORER
CODE
app.py
HELP.md
app.py
app.py > ...
@app.route('/', defaults={'path': ''})
@app.route('/<path:path>', methods=['GET', 'POST', 'PUT', 'DELETE'])
def hello_world(path):
rid = request.headers.get(REQUEST_ID_HEADER)
print("FC Invoke Start RequestId: " + rid)
data = request.stream.read()
print("Path: " + path)
print("Data: " + str(data))

函数创建（4）


阿里云
工作台
华东1（杭州）
搜索...
费用
ICP 备案
企业
支持
工单
简体
kingczn1314
主账号
函数版本
版本：LATEST
此版本可编辑
React Flow
版本或别名 LATEST
代码
测试
配置
日志
监控
实例
任务
性能探测
公测
上传代码
导出函数
基础配置
触发器
运行时
环境变量
层
权限
日志
网络
存储
预留实例
异步配置
生命周期
健康检查
DNS
触发器
创建触发器
可按触发器名称进行模糊搜索。
on
查看全部版本或别名的触发器
触发器名称
版本或别名
触发器类型
配置信息
状态
操作
defaultTrigger
LATEST
HTTP 触发器
支持同步调用和异步调用
公网访问地址
https://test-func-xabyndgqye.cn-hangzhou.fcapp.run
为什么会强制下载？
不当使用 vip 的免责说明
HTTPS
HTTP
内网访问地址
https://test-func-xabyndgqye.cn-hangzhou-vpc.fcapp.run
HTTPS
HTTP
已启用
详情
编辑
删除
认证方式
无需认证
禁用公网访问 URL
否
请求方法
GET, POST, PUT, DELETE, OPTIONS
每页显示：
10
共1条
上一页
1
下一页

函数测试

- **(1) 界面测试**
- **(2) 浏览器测试**
- **(3) 专用调试工具测试**
  - Postman
  - API Fox
- **(4) 代码测试**
  - Python `requests`库

02

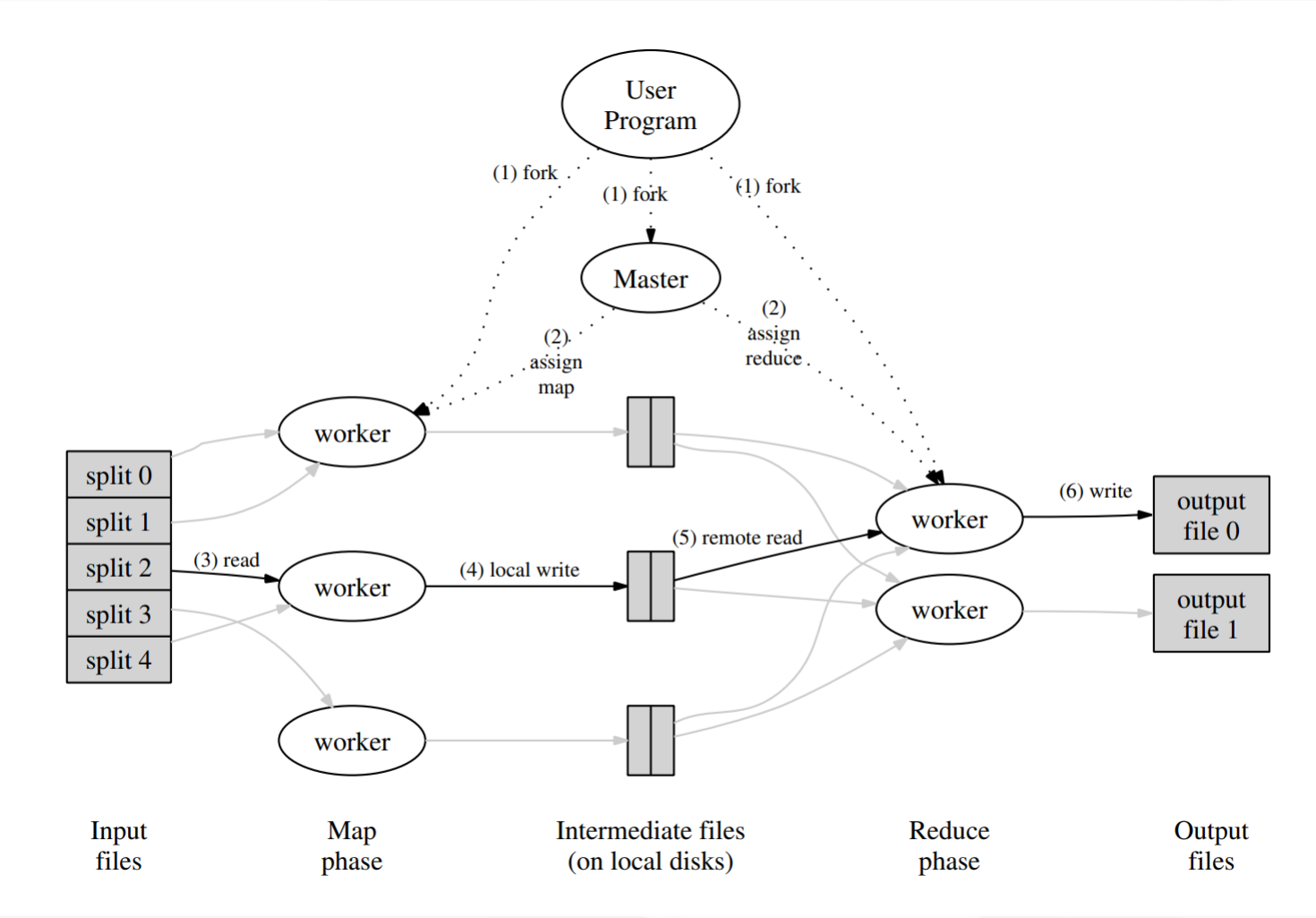
基于 serverless 平台的 MapReduce

- MapReduce

MapReduce Introduction

- MapReduce: Simplified Data Processing on Large Clusters (OSDI)
- https://www.usenix.org/legacy/events/osdi04/tech/full_papers/dean/dean.pdf
- MapReduce is a programming model and an associated implementation for processing and generating large data sets. Users specify a _map_ function that processes a key/value pair to generate a set of intermediate key/value pairs, and a _reduce_ function that merges all intermediate values associated with the same intermediate key. Many real world tasks are expressible in this model, as shown in the paper.
- Programs written in this functional style are automatically parallelized and executed on a large cluster of commodity machines. The run-time system takes care of the details of partitioning the input data, scheduling the program's execution across a set of machines, handling machine failures, and managing the required inter-machine communication. This allows programmers without any experience with parallel and distributed systems to easily utilize the resources of a large distributed system.
- Our implementation of MapReduce runs on a large cluster of commodity machines and is highly scalable: a typical MapReduce computation processes many terabytes of data on thousands of machines. Programmers find the system easy to use: hundreds of MapReduce programs have been implemented and upwards of one thousand MapReduce jobs are executed on Google's clusters every day.

MapReduce Framework



Programming Model

map_reduce.py > ...

```python
import minio


def main(params):
    role = params['role']

    if role == 'map':
        do_map(params)
    elif role == 'reduce':
        do_reduce(params)
    elif role == 'master':
        do_master(params)
    else:
        print('error role')

    return {}


def do_map(params):...


def do_reduce(params):...


def do_master(params):...
```

Requirements

- **Implement a map-reduce framework to handle word frequency task.**
- **How many map and reduce functions do you set? How do they affect the completion time?**
- **Can you make a summary of the function execution time and communication time ratio?**
- **What is the memory consumption of each function?**
- **How the memory/cpu parameter influences the execution time?**
  - Design an automatic algorithm to find the minimal cost: 贝叶斯优化、机器学习、启发式算法

03

基于 serverless 平台的高维矩阵运算

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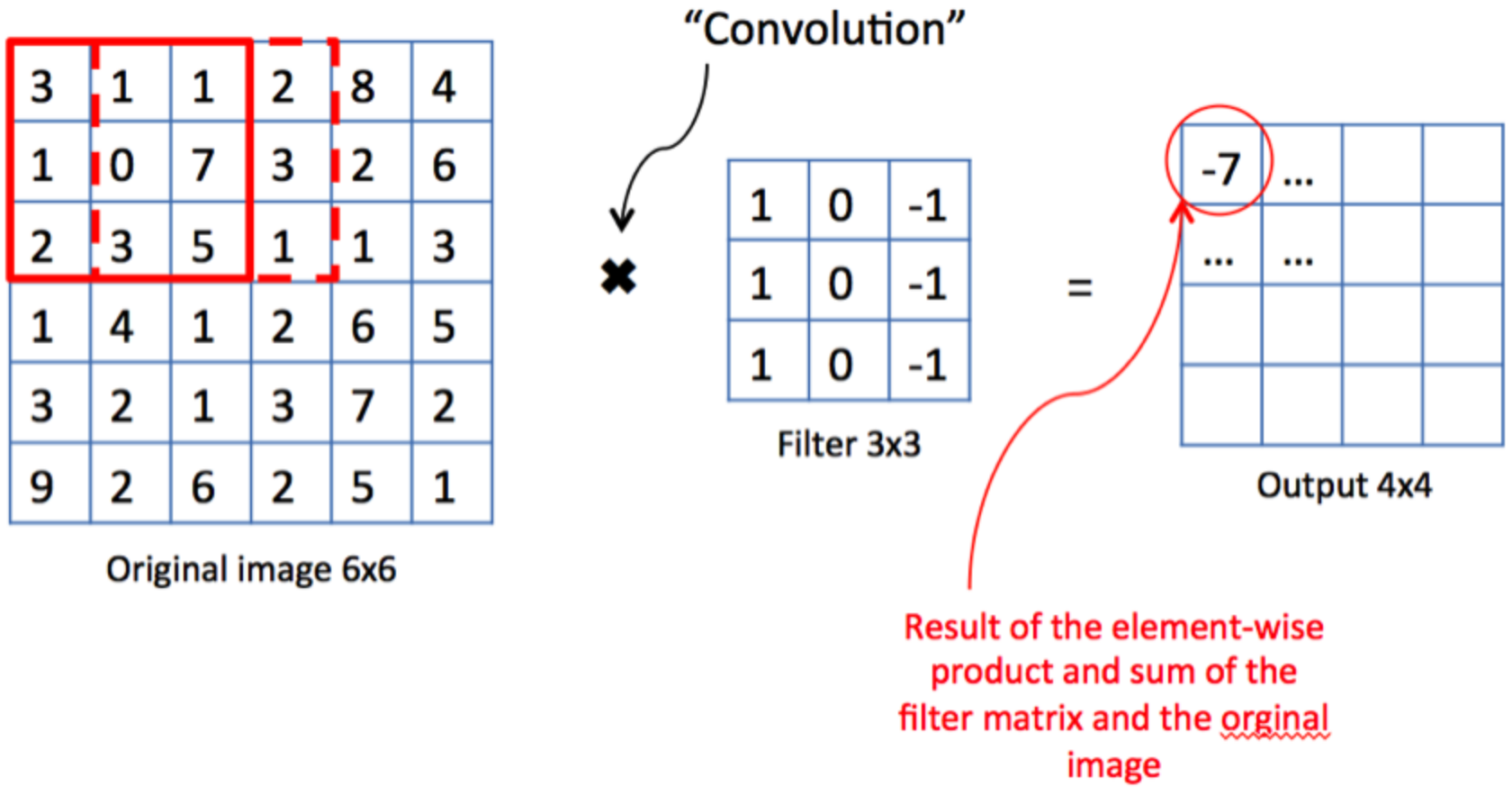
矩阵运算

Matrix multiplication

$$\begin{bmatrix} a_1 & a_2 & a_3 \\ a_4 & a_5 & a_6 \\ a_7 & a_8 & a_9 \end{bmatrix} \begin{bmatrix} b_1 & b_2 & b_3 \\ b_4 & b_5 & b_6 \\ b_7 & b_8 & b_9 \end{bmatrix} = \begin{bmatrix} c_1 & c_2 & c_3 \\ c_4 & c_5 & c_6 \\ c_7 & c_8 & c_9 \end{bmatrix}$$

矩阵计算

Convolution / Pooling



Programming Model

```python
import numpy as np


def main(params):
    pass


def worker(params):
    pass


def master(params):
    pass
```

Requirements

- Implement a matrix multiplication and convolution framework.
- How many worker functions do you set? How do they affect the completion time?
- Can you make a summary of the function execution time and communication time ratio?
- What is the memory consumption of each function?
- How the memory/cpu parameter influences the execution time?

04

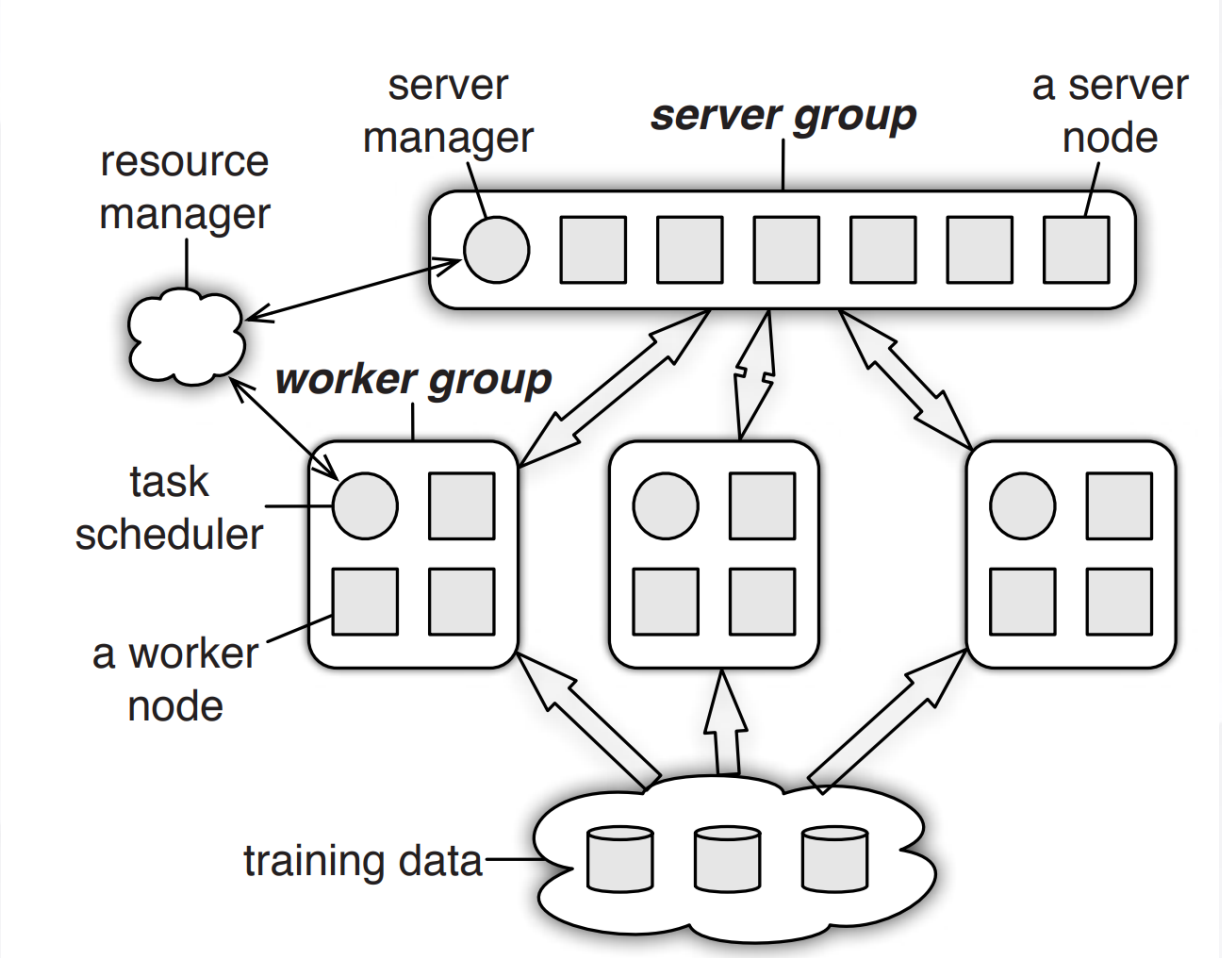
基于 serverless 平台的分布式机器学习训练

请在此输入文字说明

Parameter Server

- Scaling Distributed Machine Learning with the Parameter Server
- https://www.usenix.org/system/files/conference/osdi14/osdi14-paper-li_mu.pdf
- We propose a parameter server framework for distributed machine learning problems. Both data and workloads are distributed over worker nodes, while the server nodes maintain globally shared parameters, represented as dense or sparse vectors and matrices. The framework manages asynchronous data communication between nodes, and supports flexible consistency models, elastic scalability, and continuous fault tolerance.
- To demonstrate the scalability of the proposed framework, we show experimental results on petabytes of real data with billions of examples and parameters on problems ranging from Sparse Logistic Regression to Latent Dirichlet Allocation and Distributed Sketching.

Framework


server
manager
server group
a server
node
resource
manager
worker group
task
scheduler
a worker
node
training data

Serverless Framework

- https://arxiv.org/abs/2105.07806

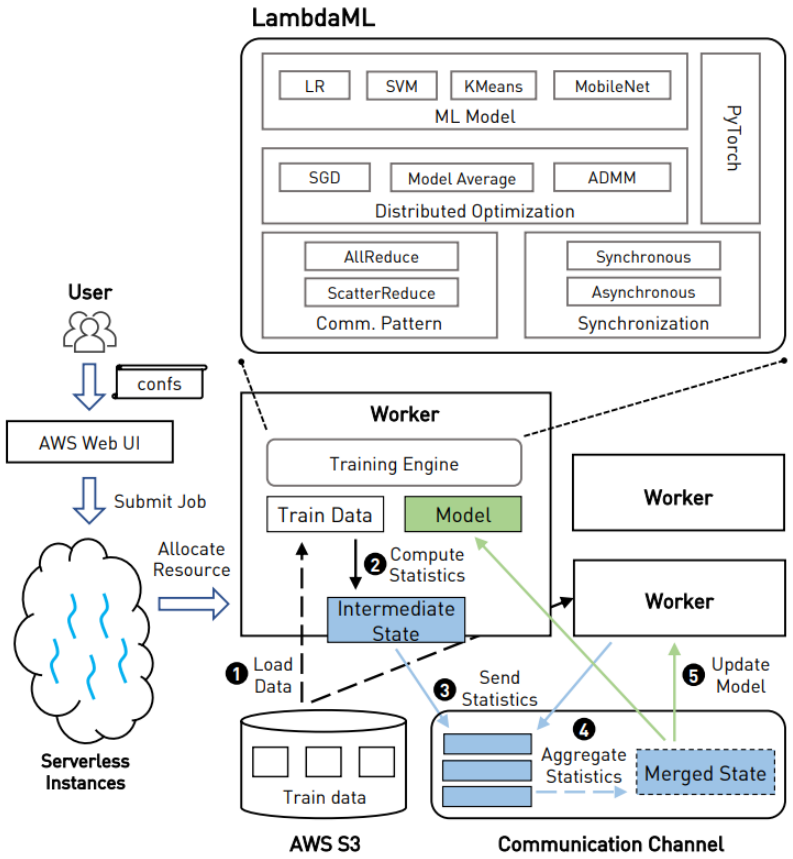


Figure 2: Framework of LambdaML.

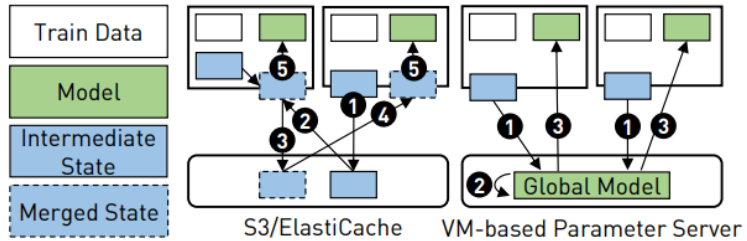


Figure 3: An FaaS-based data aggregation.

Requirements

- Implement a serverless distributed training framework.
- How many worker functions do you set? How do they affect the completion time?
- Can you make a summary of the function execution time and communication time ratio?
- What is the memory consumption of each function?
- How the memory/cpu parameter influences the execution time?

05

基于serverless平台的机器学习推理任务

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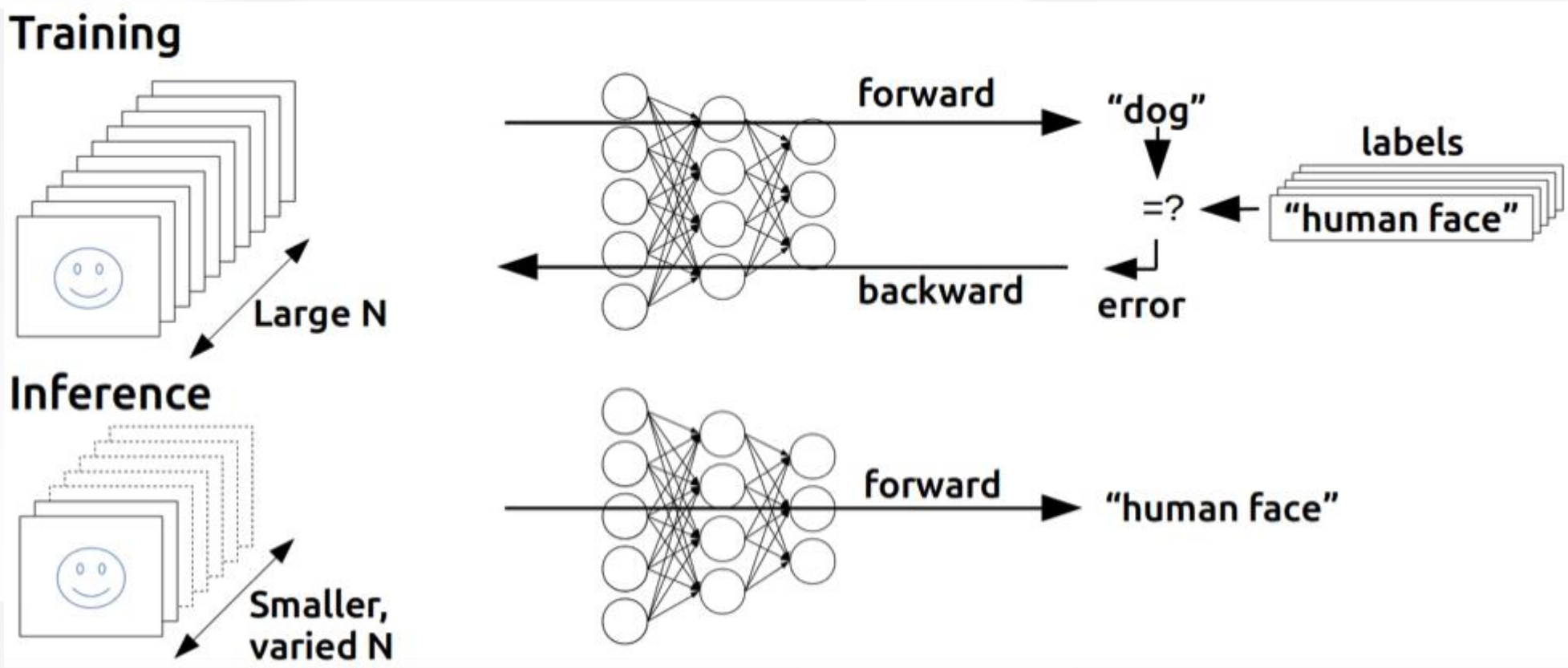
ML Inference

- Configure memory size to compare performance
- Add more workloads to observe the scaling



Gillis: Serving Large Neural Networks in Serverless Functions with Automatic Model Partitioning

- The increased use of deep neural networks has stimulated the growing demand for cloud-based model serving platforms. Serverless computing offers a simplified solution: users deploy models as serverless functions and let the platform handle provisioning and scaling. However, serverless functions have constrained resources in CPU and memory, making them inefficient or infeasible to serve large neural networks-which have become increasingly popular. In this paper, we present Gillis, a serverless-based model serving system that automatically partitions a large model across multiple serverless functions for faster inference and reduced memory footprint per function. Gillis employs two novel model partitioning algorithms that respectively achieve latency-optimal serving and cost-optimal serving with SLO compliance. We have implemented Gillis on three serverless platforms-AWS Lambda, Google Cloud Functions, and KNIX-with MXNet as the serving backend. Experimental evaluations against popular models show that Gillis supports serving very large neural networks, reduces the inference latency substantially, and meets various SLOs with a low serving cost.

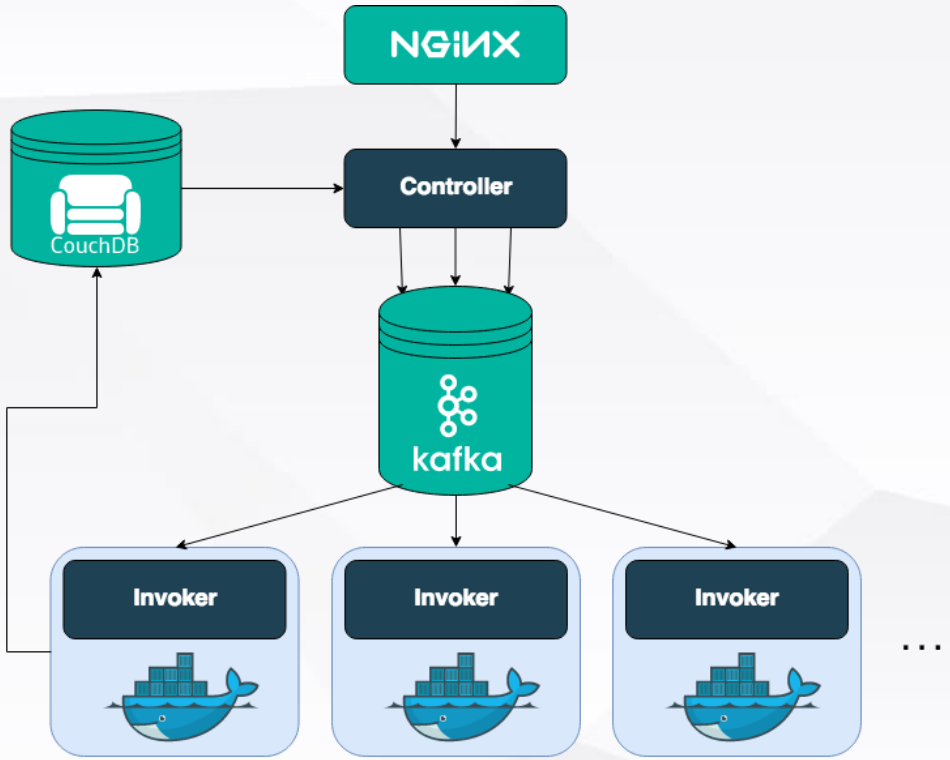
Requirements

- Implement a serverless distributed inference framework.
- How many worker functions do you set? How do they affect the completion time?
- Can you make a summary of the function execution time and communication time ratio?
- What is the memory consumption of each function?
- How the memory/cpu parameter influences the execution time?
- 1. 环境配置的问题
- 2. 选择合适的模型：ResNet、GoogleNet、XXX；大语言模型：GPT-2
- 3. 模型分割。
- 4. 并发测试。

Q&A

饮 水 思 源　爱 国 荣 校

OpenWhisk




```
[zhangrenjun@Octopus ~]$ wsk

Usage:
  wsk [command]

Available Commands:
  action      work with actions
  activation  work with activations
  api         work with APIs
  help        Help about any command
  list        list entities in the current namespace
  namespace   work with namespaces
  package     work with packages
  project     The OpenWhisk Project Management Tool
  property    work with whisk properties
  rule        work with rules
  sdk         work with the sdk
  trigger     work with triggers

Flags:
      --apihost HOST         whisk API HOST
      --apiversion VERSION   whisk API VERSION
  -u, --auth KEY             authorization KEY
      --cert string          client cert
  -d, --debug                debug level output
  -h, --help                 help for wsk
  -i, --insecure             bypass certificate checking
      --key string           client key
  -v, --verbose              verbose output
```

wsk action

```
dashuju@iZuf6dmz3aabl13vvtg3myZ:~/caizinuo$ wsk action -h
work with actions
Usage:
  wsk action [command]

Available Commands:
  create      create a new action
  delete      delete action
  get         get action
  invoke      invoke action
  list        list all actions in a namespace or actions contained in a package
  update      update an existing action, or create an action if it does not exist

Flags:
  -h, --help   help for action

Global Flags:
      --apihost HOST         whisk API HOST
      --apiversion VERSION   whisk API VERSION
  -u, --auth KEY             authorization KEY
      --cert string          client cert
  -d, --debug                debug level output
  -i, --insecure             bypass certificate checking
      --key string           client key
  -v, --verbose              verbose output

Use "wsk action [command] --help" for more information about a command.
```

wsk action create

```
dashuju@iZuf6dmz3aabl13vvtg3myZ:~/caizinuo$ wsk action create -h
create a new action
Usage:
  wsk action create ACTION_NAME ACTION [flags]

Flags:
  -a, --annotation KEY VALUE   annotation values in KEY VALUE format
  -A, --annotation-file FILE   FILE containing annotation values in JSON format
  -c, --concurrency LIMIT      the maximum intra-container concurrent activation LIMIT for the action (default 1)
      --copy                   treat ACTION as the name of an existing action
      --docker string          use provided docker image (a path on DockerHub) to run the action
  -h, --help                   help for create
      --kind KIND              the KIND of the action runtime (example: swift:default, nodejs:default)
  -l, --logsize LIMIT          the maximum log size LIMIT in MB for the action (default 10)
      --main string            the name of the action entry point (function or fully-qualified method name when applicable)
  -m, --memory LIMIT           the maximum memory LIMIT in MB for the action (default 256)
      --native                 treat ACTION as native action (zip file provides a compatible executable to run)
  -p, --param KEY VALUE        parameter values in KEY VALUE format
  -P, --param-file FILE        FILE containing parameter values in JSON format
      --sequence               treat ACTION as comma separated sequence of actions to invoke
  -t, --timeout LIMIT          the timeout LIMIT in milliseconds after which the action is terminated (default 60000)
      --web string             treat ACTION as a web action, a raw HTTP web action, or as a standard action; yes | true = web action, raw = raw HTTP
 web action, no | false = standard action
      --web-secure SECRET      secure the web action. where SECRET is true, false, or any string. Only valid when the ACTION is a web action
```

```
dashuju@iZuf6dmz3aabl13vvtg3myZ:~/caizinuo$ wsk action create hello_world hello_world.py -i
ok: created action hello_world
```

wsk action invoke

```
dashuju@iZuf6dmz3aabl13vvtg3myZ:~/caizinuo$ wsk action invoke -h
invoke action
Usage:
  wsk action invoke ACTION_NAME [flags]

Flags:
  -b, --blocking          blocking invoke
  -h, --help              help for invoke
  -p, --param KEY VALUE   parameter values in KEY VALUE format
  -P, --param-file FILE   FILE containing parameter values in JSON format
  -r, --result            blocking invoke; show only activation result (unless there is a failure)
```

```
dashuju@iZuf6dmz3aabl13vvtg3myZ:~/caizinuo$ wsk action -i  invoke hello_world -p name zinuo
ok: invoked /_/hello_world with id c80ef2a5252842e58ef2a5252852e5f5
```

wsk activation

```
dashuju@iZuf6dmz3aabl13vvtg3myZ:~/caizinuo$ wsk activation -h
work with activations
Usage:
  wsk activation [command]

Available Commands:
  get         get activation
  list        list activations
  logs        get the logs of an activation
  poll        poll continuously for log messages from currently running actions
  result      get the result of an activation

Flags:
  -h, --help   help for activation
```

wsk activation list

```
dashuju@iZuf6dmz3aabl13vvtg3myZ:~/caizinuo$ wsk activation list -h
list activations
Usage:
  wsk activation list [NAMESPACE or NAME] [flags]
```

```
dashuju@iZuf6dmz3aabl13vvtg3myZ:~/caizinuo$ wsk activation list -i
Datetime            Activation ID                  Kind      Start Duration   Status          Entity
2022-07-23 20:13:44 08c7ec04c75f4e6087ec04c75f7e6019 python:3 cold  97ms       success         guest/hello_world:0.0.1
2022-07-23 20:09:30 c80ef2a5252842e58ef2a5252852e5f5 python:3 warm  0s         internal error guest/hello_world:0.0.1
```

wsk activation get

```
dashuju@iZuf6dmz3aabl13vvtg3myZ:~/caizinuo$ wsk activation get -h
get activation
Usage:
  wsk activation get (ACTIVATION_ID | --last) [FIELD_FILTER] [flags]
```

```
dashuju@iZuf6dmz3aabl13vvtg3myZ:~/caizinuo$ wsk activation get 08c7ec04c75f4e6087ec04c75f7e6019 -i
ok: got activation 08c7ec04c75f4e6087ec04c75f7e6019
{
    "namespace": "guest",
    "name": "hello_world",
    "version": "0.0.1",
    "subject": "guest",
    "activationId": "08c7ec04c75f4e6087ec04c75f7e6019",
    "start": 1658578424894,
    "end": 1658578424991,
    "duration": 97,
    "statusCode": 0,
    "response": {
        "status": "success",
        "statusCode": 0,
        "success": true,
        "result": {
            "greeting": "hello, zinuo"
        }
    },
    "logs": [],
```

success

wsk activation get

```
dashuju@iZuf6dmz3aabl13vvtg3myZ:~/caizinuo$ wsk activation get c80ef2a5252842e58ef2a5252852e5f5 -i
ok: got activation c80ef2a5252842e58ef2a5252852e5f5
{
    "namespace": "guest",
    "name": "hello_world",
    "version": "0.0.1",
    "subject": "guest",
    "activationId": "c80ef2a5252842e58ef2a5252852e5f5",
    "start": 1658578170123,
    "end": 1658578170123,
    "duration": 0,
    "statusCode": 3,
    "response": {
        "status": "whisk internal error",
        "statusCode": 0,
        "success": false,
        "result": {
            "error": "Failed to run container with image 'openwhisk/action-python-v3.7:1.17.0'."
        }
    },
    "logs": [],
```

failure

基于容器的开发环境

Build Docker Image

```
dashuju@iZuf6dmz3aabl13vvtg3myZ:~/caizinuo$ docker build -t myenv:v1 .
Sending build context to Docker daemon  122.9kB
Step 1/22 : FROM golang:1.15 AS builder_source
 ---> 40349a2425ef
Step 2/22 : RUN go env -w GO111MODULE=on && go env -w GOPROXY="https://goproxy.io,direct"
 ---> Using cache
 ---> 0a459053855d
```

Kind load docker-image

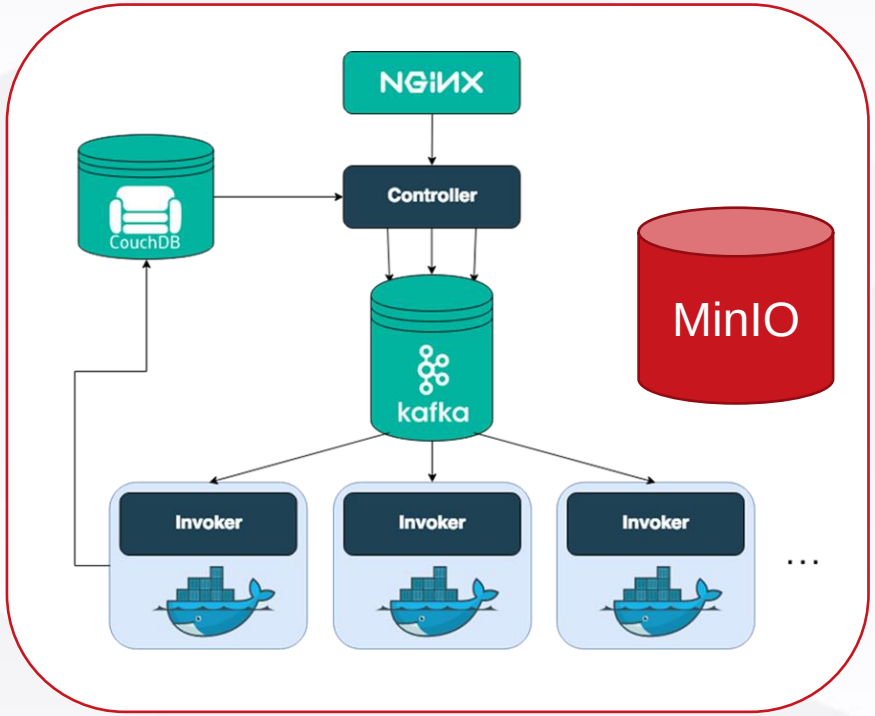
```
dashuju@iZuf6dmz3aabl13vvtg3myZ:~/caizinuo$ kind load docker-image myenv:v1
Image: "myenv:v1" with ID "sha256:c487ab5216b53320b1f681eebc3add99ee115219cf399d0d9bd90c
kind-worker", loading...
Image: "myenv:v1" with ID "sha256:c487ab5216b53320b1f681eebc3add99ee115219cf399d0d9bd90c
kind-worker2", loading...
Image: "myenv:v1" with ID "sha256:c487ab5216b53320b1f681eebc3add99ee115219cf399d0d9bd90c
kind-control-plane", loading...
```

Create function with the specified image

Invoke the function

数据交互

- export POD_NAME=$(kubectl get pods --namespace openwhisk -l "release=minio-1658640199" -o jsonpath="{.items[0].metadata.name}")
- kubectl port-forward $POD_NAME 9000 --namespace openwhisk
- IP: 127.0.0.1:9000 (out of cluster) / 10.96.136.135:9000
- Access key: `AKIAIOSFODNN7EXAMPLE`
- Secret key: `wJalrXUtnFEMI/K7MDENG/bPxRfiCYEXAMPLEKEY`



数据交互

```python
from minio import Minio


def main(params):
    minioClient = Minio('10.96.136.135:9000',
                        access_key='AKIAIOSFODNN7EXAMPLE',
                        secret_key='wJalrXUtnFEMI/K7MDENG/bPxRfiCYEXAMPLEKEY',
                        secure=False)

    buckets = minioClient.list_buckets()

    for bucket in buckets:
        print(bucket.name, bucket.creation_date)

    if minioClient.bucket_exists('test'):
        print('bucket test already exists')
    else:
        minioClient.make_bucket('test')
        print('make bucket test')

    minioClient.fput_object('test', 'hello_world', 'hello_world.py')

    return {'greeting': 'hello, world'}
```

总结

- **OpenWhisk**
- **Wsk action**
  - Create
  - Invoke
- **Wsk activation**
  - List
  - Get
- **基于容器的开发环境**
- **数据交互**