How To Deploy a Go Web Application with Docker

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While most Go applications compile to a single binary, web applications also ship with templates, assets and configuration files; these can get out of sync and cause faulty deployments.

Docker lets us create a self-contained image with everything our application needs to work. In this tutorial, you will learn how to deploy a Go web application with Docker, and how Docker can help improve your development workflow and deployment process.

Goals

By the end of this article, you will:

- Have a basic understanding of Docker,
- Find out how Docker can help you while developing a Go application,
- Learn how to create a Docker container for a Go application for production, and
- Know how to use Continuous Integration and Delivery (CI/CD) to automatically build a Docker image.

Prerequisites

For this tutorial, you will need:

- Docker installed on your machine.
- A free Docker Hub account.
- A Semaphore account.

You can find all the code for this tutorial in the golang-mathapp repository.

TomFern / golang-mathapp

Understanding Docker

Docker helps you create a single deployable unit for your application. This unit, also known as a container, has everything the application needs to work. This includes the code (or binary), the runtime, the system tools and libraries.

Packing all the requirements into a single unit ensures an identical environment for the application, wherever it is deployed. It also helps to maintain identical development and production setups.

Containers also eliminate a whole class of issues caused by files being out of sync or due to subtle differences in the production environments.

Advantages over Virtual Machines

Containers offer similar resource allocation and isolation benefits as virtual machines. However, the similarity ends there.

A virtual machine needs its own guest operating system while a container shares the kernel of the host operating system. This means that containers are much lighter and need fewer resources. A virtual machine is, in essence, an operating system within an operating system. Containers, on the other hand, are just like any other application in the system. Basically, containers need fewer resources (memory, disk space, etc.) than virtual machines, and have much faster start-up times than virtual machines.

Benefits of Docker During Development

Some of the benefits of using Docker in development include:

- A standard development environment used by all team members,
- Updating dependencies centrally and using the same container everywhere,
- An identical environment in development to that of production, and
- Fixing potential problems that might appear only in production.

Why Use Docker with a Go Web Application?

Most Go applications are simple binaries. This begs the question—why use Docker with a Go application? Some of the reasons to use Docker with Go include:

- Web applications typically have templates and configuration files. Docker helps keep these files in sync with the binary.
- Docker ensures identical setups in development and production. There are times when an application works in development, but not in production. Using Docker frees you from having to worry about problems like these.
- Machines, operating systems, and installed software can vary significantly across a large team. Docker provides a mechanism to ensure a consistent development setup. This makes teams more productive and reduces friction and avoidable issues during development.

Creating a Simple Go Web Application

We'll create a simple web application in Go for demonstration in this article. This application, which we'll call *MathApp*, will:

- Expose routes for different mathematical operations,
- Use HTML templates for views,
- Use a configuration file to customize the application, and
- Include tests for selected functions.

Visiting `/sum/3/6` will show a page with the result of adding 3 and 6. Likewise, visiting `/product/3/6` will show a page with the product of 3 and 6.

In this article, we used the Beego framework. Note that you can use any framework (or none at all) for your application.

Final Directory Structure

Upon completion, the directory structure of MathApp will look like:

```
MathApp
    ├── Dockerfile
    ├── Dockerfile.production
    └── src
        ├── conf
        │   └── app.conf
        ├── go.mod
        ├── go.src
        ├── main.go
        ├── main_test.go
        ├── vendor
        └── views
            ├── invalid-route.html
            └── result.html
```

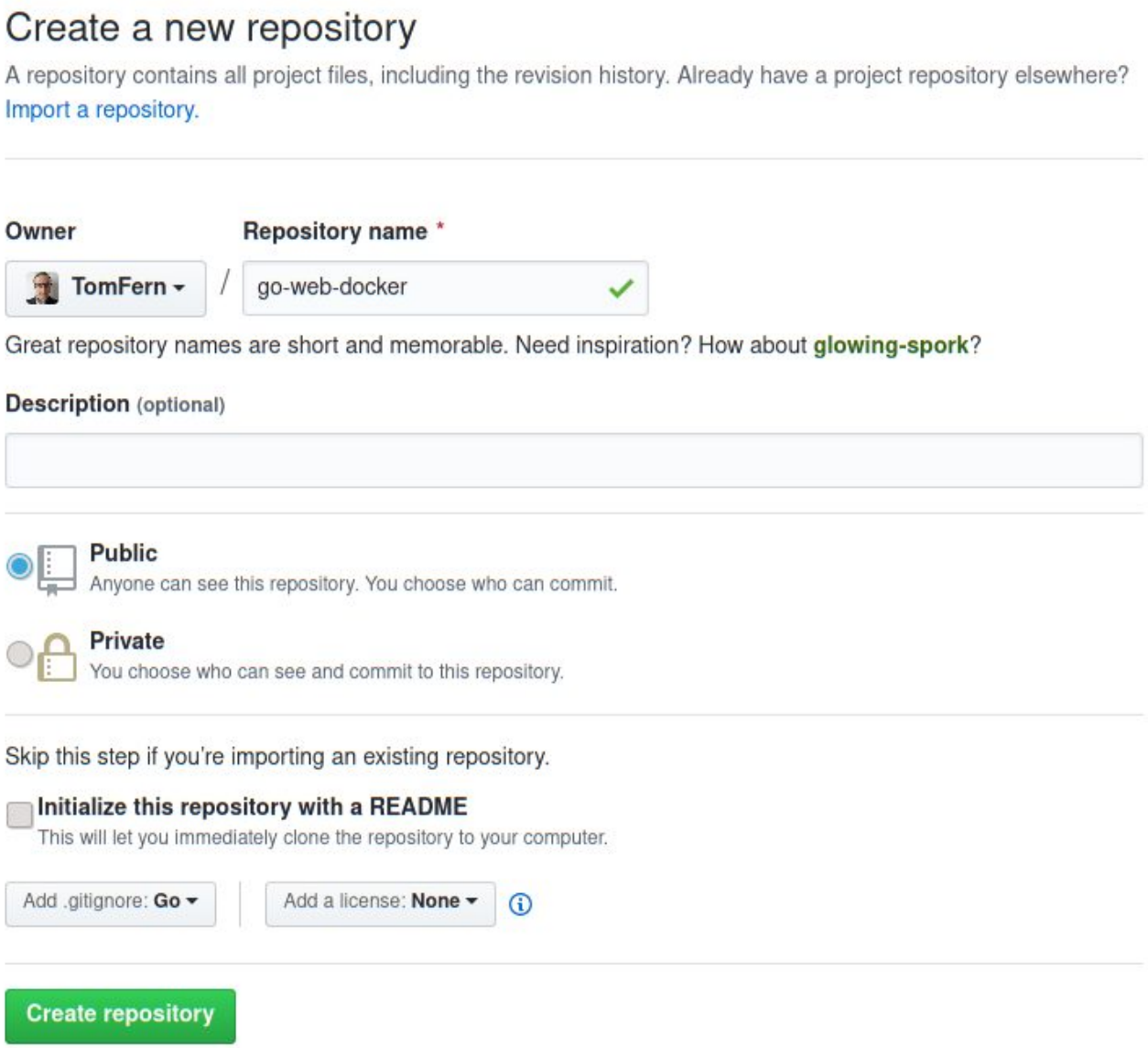
The main application file is `main.go`, located at the `src` directory. This file contains all the functionality of the app. Some of the functionality from `main.go` is tested using `main_test.go`.

The `views` folder contains the view files `invalid-route.html` and `result.html`. The configuration file `app.conf` is placed in the `conf` folder. Beego uses this file to customize the application.

Create the GitHub Repository

We'll use Go mod, the official module manager, to handle Go modules in a portable way without having to worry about GOPATH.

We'll start by creating a GitHub repository and cloning it to your machine.



Use the repository name to initialize the project:

```
$ mkdir src
$ cd src
$ export GOFLAGS=-mod=vendor
$ export GO111MODULE=on
$ go mod init github.com/YOUR_GITHUB_USER/YOUR_REPOSITORY_NAME
# (example: go mod init github.com/tomfern/go-web-docker)
```

From now on, we can use these commands:

```
$ go mod download
$ go mod vendor
$ go mod verify
```

To download the required dependencies in the `vendor/` folder (instead of downloading them in the GOROOT, this will come in handy later).

Application File Contents

Before continuing, let's create the file structure:

```
$ mkdir conf views
```

The main application file (`main.go`) contains all the application logic. The contents of this file are as follows:

```
// main.go

package main

import (
    "strconv"

    "github.com/astaxie/beego"
)


func main() {
    /* This would match routes like the following:
       /sum/3/5
       /product/6/23
       ...
    */
    beego.Router("/:operation/:num1:int/:num2:int", &mainController{})
    beego.Run()
}

type mainController struct {
    beego.Controller
}


func (c *mainController) Get() {

    //Obtain the values of the route parameters defined in the route above
    operation := c.Ctx.Input.Param(":operation")
    num1, _ := strconv.Atoi(c.Ctx.Input.Param(":num1"))
    num2, _ := strconv.Atoi(c.Ctx.Input.Param(":num2"))

    //Set the values for use in the template
```

```
    c.Data["operation"] = operation
    c.Data["num1"] = num1
    c.Data["num2"] = num2
    c.TplName = "result.html"

    // Perform the calculation depending on the 'operation' route parameter
    switch operation {
    case "sum":
        c.Data["result"] = add(num1, num2)
    case "product":
        c.Data["result"] = multiply(num1, num2)
    default:
        c.TplName = "invalid-route.html"
    }
}

func add(n1, n2 int) int {
    return n1 + n2
}

func multiply(n1, n2 int) int {
    return n1 * n2
}
```

In your application, this might be split across several files. However, for the purpose of this tutorial, I like to have everything in one place.

Test File Contents

The `main.go` file has some functions which need to be tested. The tests for these functions can be found in `main_test.go`. The contents of this file are as follows:

```
// main_test.go

package main

import "testing"

func TestSum(t *testing.T) {
    if add(2, 5) != 7 {
        t.Fail()
    }
    if add(2, 100) != 102 {
        t.Fail()
    }
    if add(222, 100) != 322 {
        t.Fail()
    }
}

func TestProduct(t *testing.T) {
    if multiply(2, 5) != 10 {
```

```
        t.Fail()
    }
    if multiply(2, 100) != 200 {
        t.Fail()
    }
    if multiply(222, 3) != 666 {
        t.Fail()
    }
}
```

Testing your application is particularly useful if you want to do Continuous Deployment. If you have adequate testing in place, then you can make stress-free deployments anytime, any day of the week.

View Files Contents

The view files are HTML templates; these are used by the application to display the response to a request. The content of `views/result.html` is as follows:

```
<!-- views/result.html -->
<!doctype html>
<html>
    <head>
        <title>MathApp - {{.operation}}</title>
    </head>
    <body>
     The {{.operation}} of {{.num1}} and {{.num2}} is {{.result}}
    </body>
</html>
```

The content of `views/invalid-route.html` is as follows:

```
<!-- invalid-route.html -->
<!doctype html>
<html>
    <head>
        <title>MathApp</title>
                <meta  name="viewport"  content="width=device-
width, initial-scale=1">
        <meta charset="UTF-8">
    </head>

    <body>
        Invalid operation
    </body>
</html>
```

Configuration File Contents

The `conf/app.conf` file is read by Beego to configure the application. Its content is as follows:

```
appname = mathapp
runmode = "dev"
httpport = 8010
```

In this file:

- **appname**: is the name of the process that the application will run as,
- **httpport**: is the port on which the application will be served, and
- **runmode**: specifies which mode the application should run in. Valid values include `dev` for development and `prod` for production.

Finally, if you haven't yet done so, install the Go modules with:

```
$ go mod download
$ go mod vendor
$ go mod verify
```

Using Docker During Development

This section will explain the benefits of using Docker during development, and walk you through the steps required to use Docker in development.

Configuring Docker for Development

We'll use a `Dockerfile` to configure Docker for development. The setup should satisfy the following requirements for the development environment:

- We will use the application mentioned in the previous section,
- The files should be accessible both from inside and outside of the container,
- We will use the `bee` tool, this will be used to live-reload the app (inside the Docker container) during development,
- Docker will expose the application on port `8010`,
- In the Docker container, the application is located at `/home/app`,
- The name of the Docker image we'll create for development will be `mathapp`.

Step 1 – Creating the Dockerfile

Go back to the top level of your project:

```
$ cd ..
```

The following Dockerfile should satisfy the above requirements.

```
FROM golang:1.18-bullseye

RUN go install github.com/beego/bee/v2@latest

ENV GO111MODULE=on
ENV GOFLAGS=-mod=vendor

ENV APP_HOME /go/src/mathapp
RUN mkdir -p "$APP_HOME"

WORKDIR "$APP_HOME"
EXPOSE 8010
CMD ["bee", "run"]
```

The first line:

```
FROM golang:1.18-bullseye
```

References the official image for Go as the base image. This image comes with Go 1.18 pre-installed.

The second line:

```
RUN go install github.com/beego/bee/v2@latest
```

Installs the `bee` tool globally (Docker commands run as root by default), which will be used to live-reload our code during development.

Next, we configure the environment variables for Go modules:

```
ENV GO111MODULE=on
ENV GOFLAGS=-mod=vendor
```

The next lines:

```
ENV APP_HOME /go/src/mathapp
RUN mkdir -p "$APP_HOME"
WORKDIR "$APP_HOME"
```

Creates a folder for the code and makes it active.

The next to last line tells Docker that port `8010` is of interest.

```
EXPOSE 8010
```

The final line:

```
CMD ["bee", "run"]
```

Uses the `bee` command to start our application.

Step 2 – Building the Image

Once the Docker file is created, run the following command to create the image:

```
$ docker build -t mathapp-development .
```

Executing the above command will create an image named `mathapp`:

- **-t mathapp**: sets the tag name for the new image, we can reference the image later as `mathapp:latest`
- Don't forget to type the last dot (.) in the command, otherwise you'll get an error.

This command can be used by everyone working on this application. This will ensure that an identical development environment is used across the team.

To see the list of images on your system, run the following command:

```
$ docker images
```

Note that the exact names and number of images might vary. However, you should see at least the `golang` and `mathapp` images in the list:

```
REPOSITORY              TAG             IMAGE ID            CREATED
golang                  1.18            25c4671a1478        2 weeks ago
mathapp-development     latest          8ae092824585        60 seconds ago
```

Step 3 – Running the Container

Once you have `mathapp`, you can start a container with:

```
$ docker run -it --rm -p 8010:8010 -v $PWD/src:/go/src/mathapp mathapp-development
```

Let's break down the above command to see what it does.

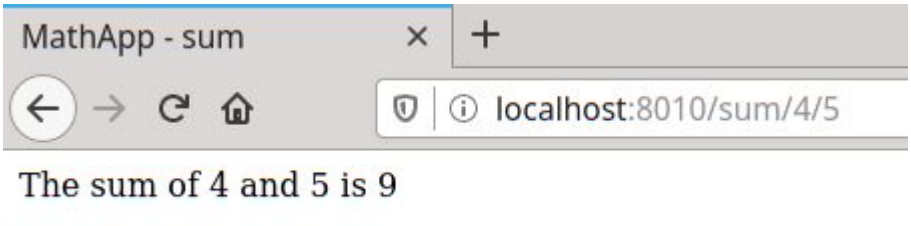
- The `docker run` command is used to run a container from an image,
- The `-it` flag starts the container in an interactive mode (tie it to the current shell),
- The `--rm` flag cleans out the container after it shuts down,
- The `--name mathapp-instance` names the container `mathapp-instance`,
- The `-p 8010:8010` flag allows the container to be accessed at port `8010`,
- The `-v $PWD/src:/go/src/mathapp` is more involved. It maps the `src/` directory from the machine to `/go/src/mathapp` in the container. This makes the development files available inside and outside the container, and
- The `mathapp` part specifies the image name to use in the container.

Executing the above command starts the Docker container. This container exposes your application on port `8010`. It also rebuilds your application automatically whenever you make a change. You should see the following output in your console:

```
_______
|  ___ \
|  |_/ /  ___   ___
|  ___ \ / _ \ / _ \
|  |_/ /|  __/|  __/
\____/  \___| \___| v2.0.2
```

```
2022/05/10 13:39:29 INFO    ▶ 0003 Using 'mathapp' as 'appname'
2022/05/10 13:39:29 INFO      ▶ 0004 Initializing watcher...
2020/03/17 14:43:24.912 [I] [asm_amd64.s:1373]  http server Running on h
```

To check the setup, visit `http://localhost:8010/sum/4/5` in your browser. You should see something similar to the following:



Note: This assumes that you're working on your local machine.

To try the live-reload feature, make a modification in any of the source files. For instance, edit `src/main.go`, replace this line:

```
c.Data["operation"] = operation
```

To something like this:

```
c.Data["operation"] = "real " + operation
```

Bee should pick up the change, even inside the container, and reload the application seamlessly:

```
______
| ___ \
| |_/ /  ___   ___
| ___ \ / _ \ / _ \
| |_/ /|  __/|  __/
\____/  \___| \___| v2.0.2
2022/05/10 13:39:29 INFO     ▶ 0003 Using 'mathapp' as 'appname'
2022/05/10 13:39:29 INFO     ▶ 0004 Initializing watcher...
2022/05/10 13:39:29 INFO.   [asm_amd64.s:1373]  http server Running on http://:801
```

Now reload the page on the browser to see the modified message:

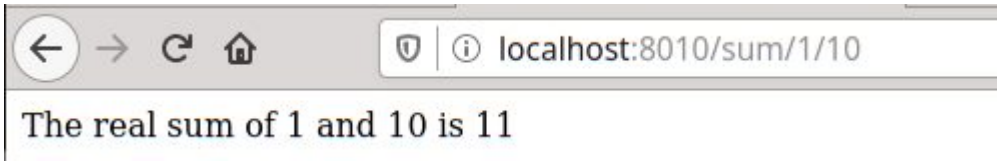


Figure 1: img

Using Docker in Production

This section will explain how to deploy a Go application in a Docker container. We will use Semaphore to do the following:

- Automatically build after changes are pushed to the git repository,
- Automatically run tests,
- Create a Docker image if the build is successful and if the tests pass, and
- Push the Docker image to Docker Hub.

Creating a Dockerfile for Production

We'll write a new Dockerfile to create a complete, self-contained image; without external dependencies.

Enter the following contents in a new file called `Dockerfile.production`:

```
# Dockerfile.production

FROM registry.semaphoreci.com/golang:1.18 as builder

ENV APP_HOME /go/src/mathapp

WORKDIR "$APP_HOME"
COPY src/ .

RUN go mod download
RUN go mod verify
RUN go build -o mathapp

FROM registry.semaphoreci.com/golang:1.18

ENV APP_HOME /go/src/mathapp
RUN mkdir -p "$APP_HOME"
WORKDIR "$APP_HOME"

COPY src/conf/ conf/
COPY src/views/ views/
COPY --from=builder "$APP_HOME"/mathapp $APP_HOME

EXPOSE 8010
CMD ["./mathapp"]
```

Let's take a detailed look at what each of these commands does. The first command:

```
FROM registry.semaphoreci.com/golang:1.18 as builder
```

Tells us this is a multi-stage build; it defines an intermediate image that will only have one job: compile the Go binary.

You might have noticed that we're not pulling the image from Docker Hub, the default image registry. Instead, we're using the Semaphore Docker Registry, which is more convenient, faster, and pulls don't count against your Docker Hub rate limits.

The following commands:

```
ENV APP_HOME /go/src/mathapp

WORKDIR "$APP_HOME"
COPY src/ .
```

Creates the application folder for the app and copies the source code.

The last commands in the intermediate image download the modules and build the executable:

```
RUN go mod download
RUN go mod verify
RUN go build -o mathapp
```

Next comes the final and definitive container, where we will run the services.

```
FROM registry.semaphoreci.com/golang:1.18
```

We use the `COPY` command to copy files into the image, the `--from` argument let us copy the generated binary from the `builder` stage.

```
COPY src/conf/ conf/
COPY src/views/ views/
COPY --from=builder $APP_HOME/mathapp $APP_HOME
```

We finalize by exposing the port and starting the binary:

```
EXPOSE 8010
CMD ["./mathapp"]
```

To build the deployment image:

```
$ docker build -t mathapp-production -f Dockerfile.production .
```

You can run it with:

```
$ docker run -it -p 8010:8010 mathapp-production
```

Notice that we don't need to map any directories, as all the source files are included in the container.

Continuous Integration with Semaphore

Docker is a great solution to package and deploy Go applications. The only downside is the additional steps required to build and test the image. This hurdle is easily is best dealt with Continuous Integration and Continuous Delivery (CI/CD).

A Continuous Integration (CI) platform can test our code on every iteration, on every push and every merge. Developers adopting CI no longer have to fear of merging branches, nor be anxious about release day. In fact, CI lets developers merge all the time and make safe releases any day of the week. A good CI setup will run a series of comprehensive tests, like the ones we prepared so far, to weed out any bugs.

Once the code is ready, we can extend our CI setup with Continuous Delivery (CD). CD can prepare and build the Docker images, leaving them ready to deploy at any time.

Push the Code to GitHub

Let's push our modifications to GitHub:

- Open `.gitignore` and uncomment the `vendor/` line, so vendored modules are not committed:

```
# Dependency directories (remove the comment below to include it)
vendor/

# Build artifact
src/mathapp
```

- Push all the code with git:

```
$ git add Dockerfile*
$ git add src
$ git add .gitignore
$ git commit -m "initial commit"
$ git push origin master
```

Adding the Repository to Semaphore

We can add CI to our project for free in just a few minutes:

- Go to Semaphore and sign up using the **Sign up with GitHub** button. This will link up both accounts.
- Click on the **+ Create New** to create a new project:

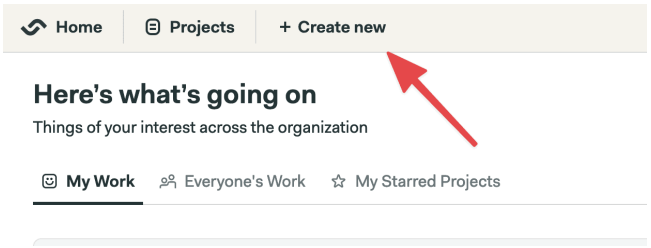


Figure 2: Create new project

- Find your GitHub repository and click on **Choose**:

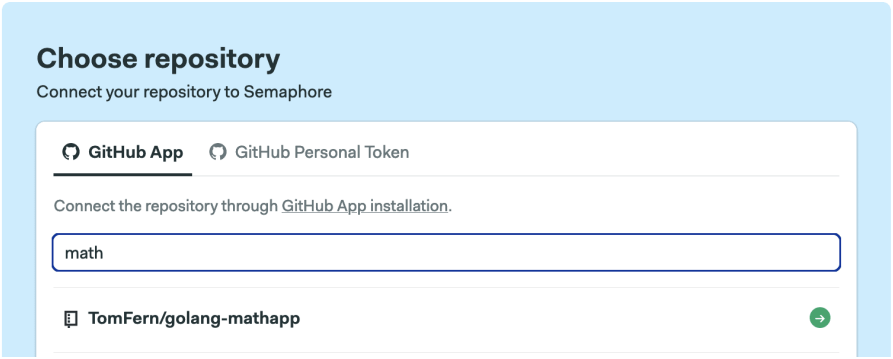


Figure 3: Grab your repository

- Select the **Go** starter workflow. Click on **Customize it first**:

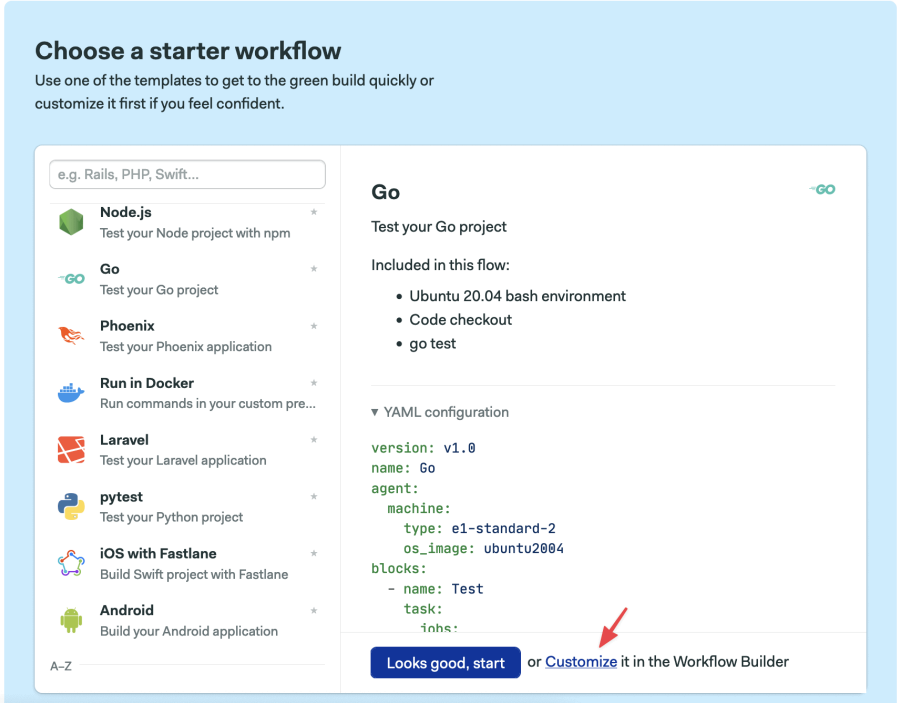


Figure 4: create a Dockerize Go workflow

You'll get the **Workflow Editor**. Here's an overview of how it works:

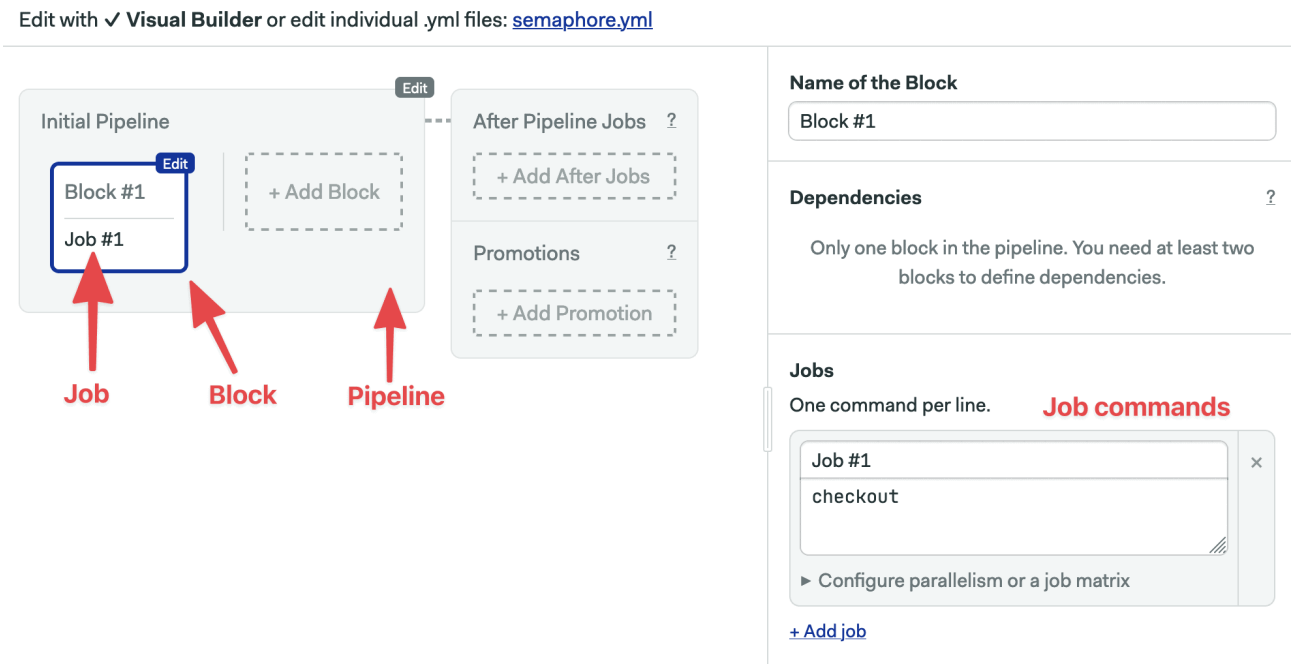


Figure 5: Semaphore workflow editor

- **Pipeline**: A pipeline has a specific objective, e.g. building or testing. Pipelines are made of blocks that are executed from left to right in an agent.
- **Agent**: The agent is the virtual machine that powers the pipeline. We have three machine types to choose from. The machine runs an optimized Ubuntu 20.04 image with build tools for many languages.
- **Block**: blocks group jobs that can be executed in parallel. Jobs in a block usually have similar commands and configurations. Once all jobs in a block complete, the next block begins.
- **Job**: jobs define the commands that do the work. They inherit their configuration from their parent block.

Coming back to our setup. The started workflow expects the code at the project's root, but our code is inside the `src` directory so we need to make a small modification:

- Click on the **Test** block.
- On the right side, you'll find the job's commands, change them so they look like this:

```
sem-version go 1.18
export GO111MODULE=on
export GOPATH=~/go
export PATH=/home/semaphore/go/bin:$PATH
checkout
cd src
go get ./...
go test ./...
go build -v .
```

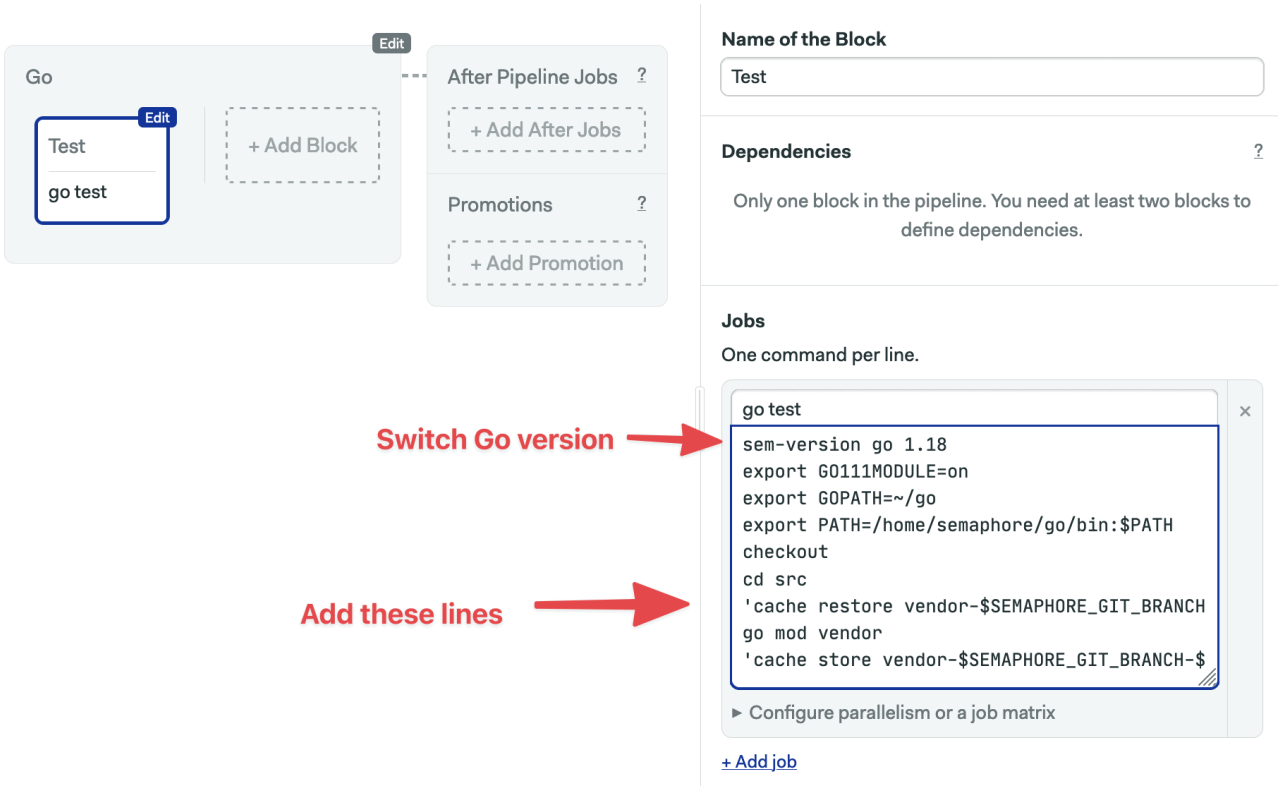


Figure 6: Go test commands

- Click on the **Run the Workflow** and then on **Start** to get the pipeline running:

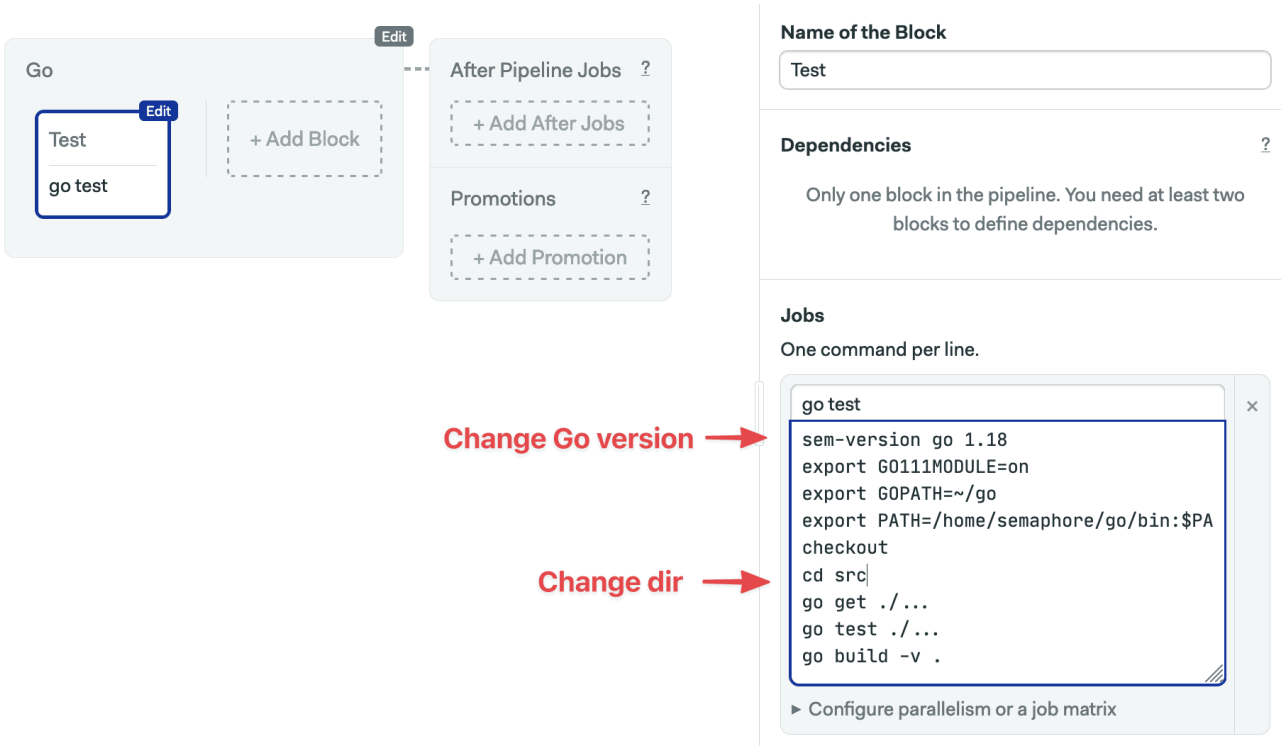


Figure 7: Switching GO version

If all goes well, after a few seconds the job should be completed without errors.

Enhancing the CI Pipeline

In this section, we'll modify the pipeline so that:

- Go dependencies are cached to having to avoid re-download on each run.
- Tests get their own block so we can scale out testing more easily.

To get started, click on the **Edit Workflow button**, then:

1. Click on the block. We'll completely replace its contents.
2. Change the name of the block and the job to "Install".
3. Type the following content in the Job command box:

```
sem-version go 1.18
export GO111MODULE=on
export GOPATH=~/go
export PATH=/home/semaphore/go/bin:$PATH
checkout
cd src
cache restore vendor-$SEMAPHORE_GIT_BRANCH-$(checksum go.mod),vendor-$SEMAPHORE_GI
go mod vendor
cache store vendor-$SEMAPHORE_GIT_BRANCH-$(checksum go.mod),vendor-$SEMAPHORE_GIT_
```

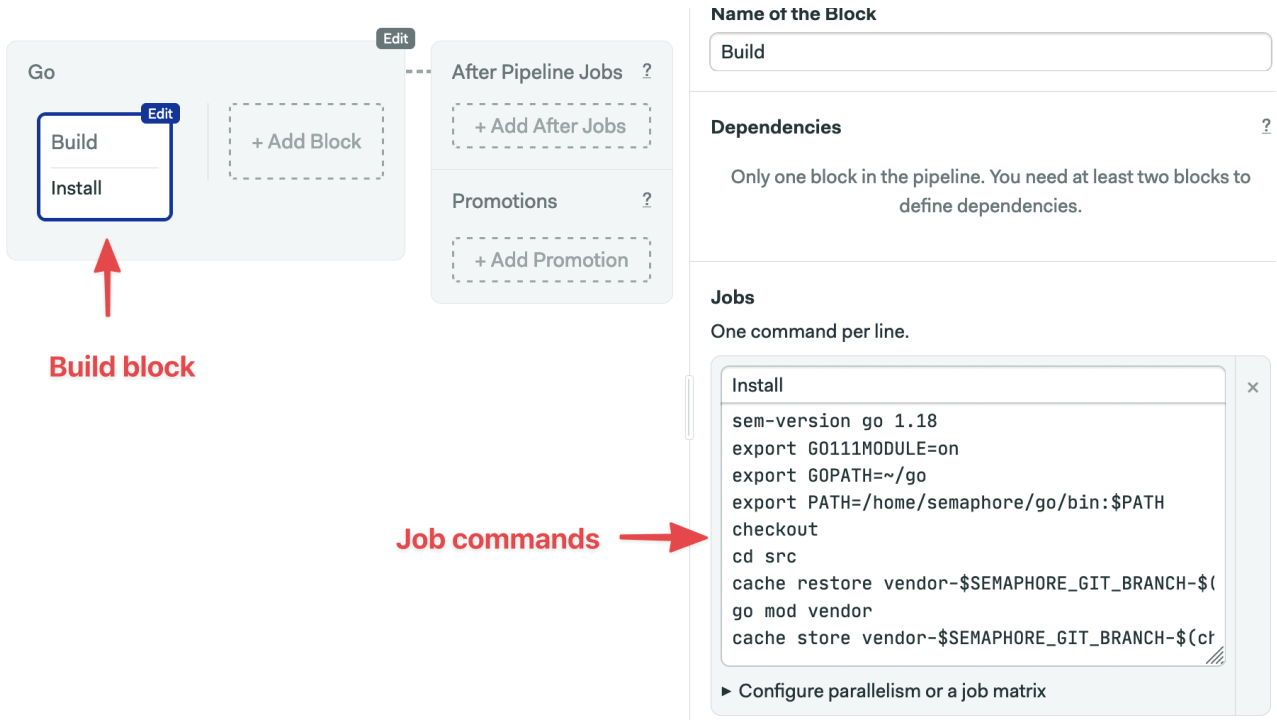


Figure 8: Build code before building a Dockerize Go pipeline

I think this is a good opportunity to learn about the Semaphore toolbox of built-in commands:

- **checkout**: the checkout commands clones the correct revision of the GitHub repository and changes the directory. It's usually the first command in a job.
- **sem-version**: with sem-version, we can switch the active version of a language. Semaphore fully supports many languages, including Go.
- **cache**: the cache is a project file storage. We'll use the cache to persist the `vendor/` directory.

Let's go back to our pipeline:

1. Use the **+ Add Block** dotted line button to create a new block.
2. Call the block and the job "Test".
3. Open the **Environment Variables** section and create the `GO111MODULE` and `GOFLAGS` variables like we did on the previous block.
4. Open the **Prologue** section, which executed before each job in the block, and type the following commands:

```
sem-version go 1.18
export GO111MODULE=on
export GOPATH=~/go
export PATH=/home/semaphore/go/bin:$PATH
checkout
```

```
cd src
cache restore vendor-$SEMAPHORE_GIT_BRANCH-$(checksum go.mod),vendor-
$SEMAPHORE_GIT_BRANCH,vendor-master
```

1. Type the following command in the job:

```
go test ./...
```

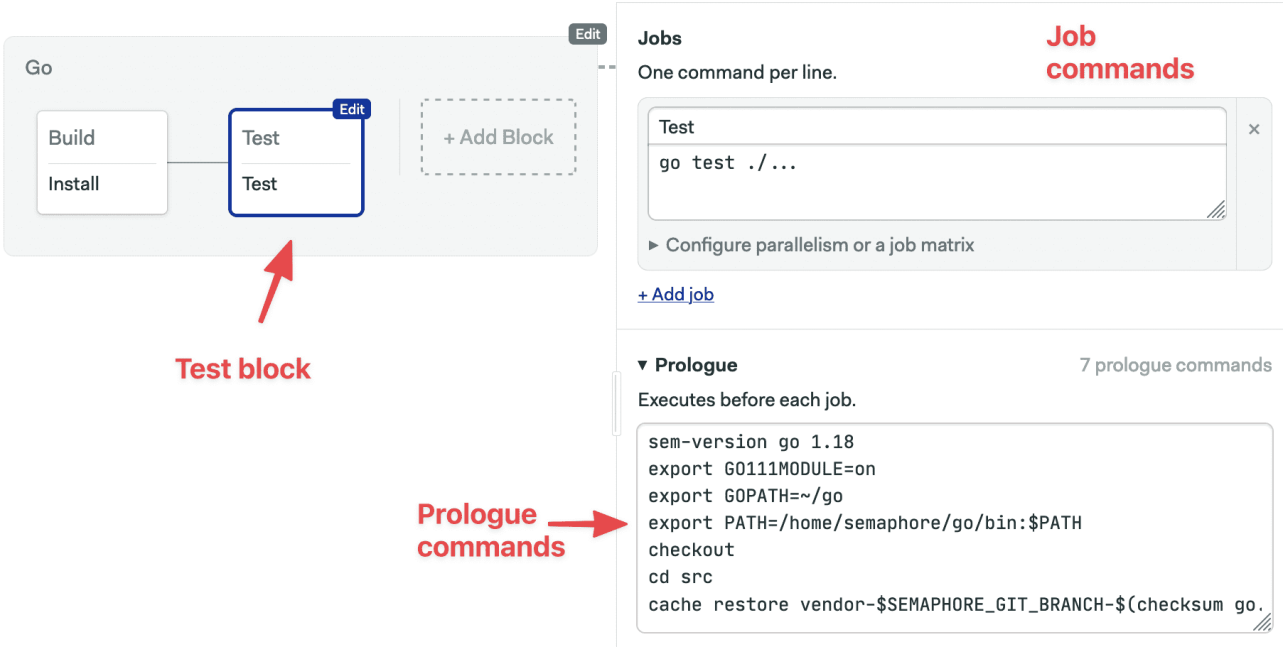


Figure 9: Test code before building a Dockerize Go pipeline

1. Click on **Run the Workflow** and **Start** to try the updated pipeline.

Building the Docker Image

So far all we did enters in the Continuous Integration category, the natural next stage is to pack the application in a Docker container.

We'll create a new delivery pipeline to:

- Build a Docker Image with our Go binary and HTML templates.
- Upload the image to Docker Hub so it's ready for deployment.

First, we have to tell Semaphore how to connect to Docker Hub:

1. On the account menu, click on **Settings**:

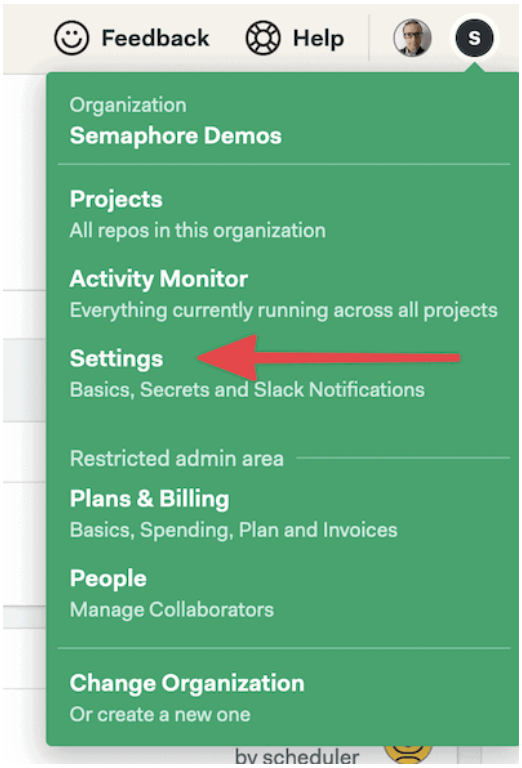


Figure 10: Settings menu

1. Click on **Secrets** and then **Create New Secret**.
2. Create two variables for your Docker Hub username and password:
    - `DOCKER_USENAME` = YOUR DOCKER USERNAME
    - `DOCKER_PASSWORD` = YOU DOCKER PASSWORD

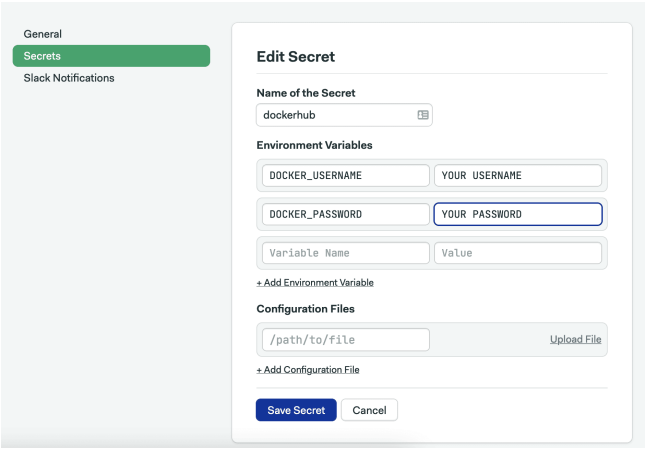


Figure 11: Docker Hub secret to Dockerize Go

1. Click on **Save**.

Going back to the pipeline:

1. Click on **Edit Workflow**.
2. Use the **+Add First Promotion** button to create a new linked pipeline:

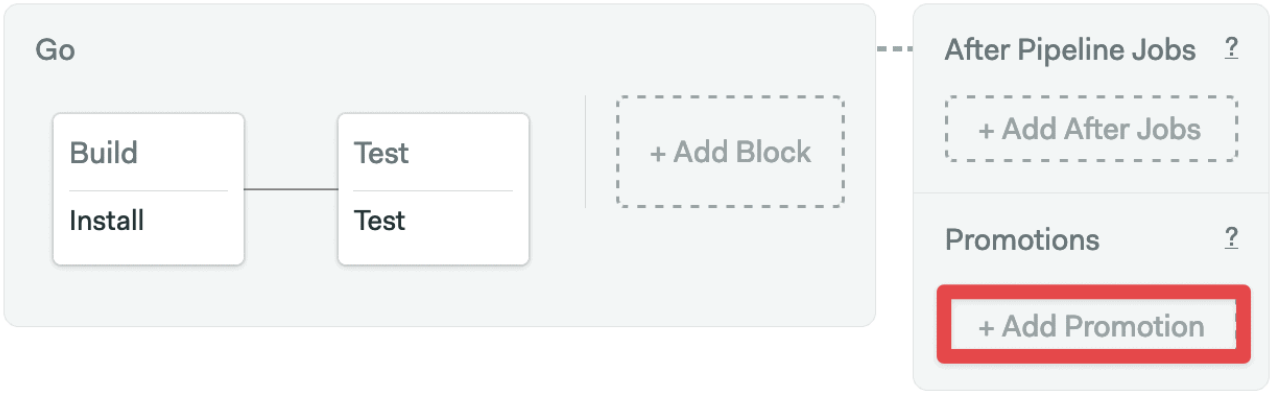


Figure 12: Add a promotion

1. Change the name of the pipeline to "Dockerize"
2. Check **Enable automatic promotion**. You can set conditions to trigger the pipeline here:

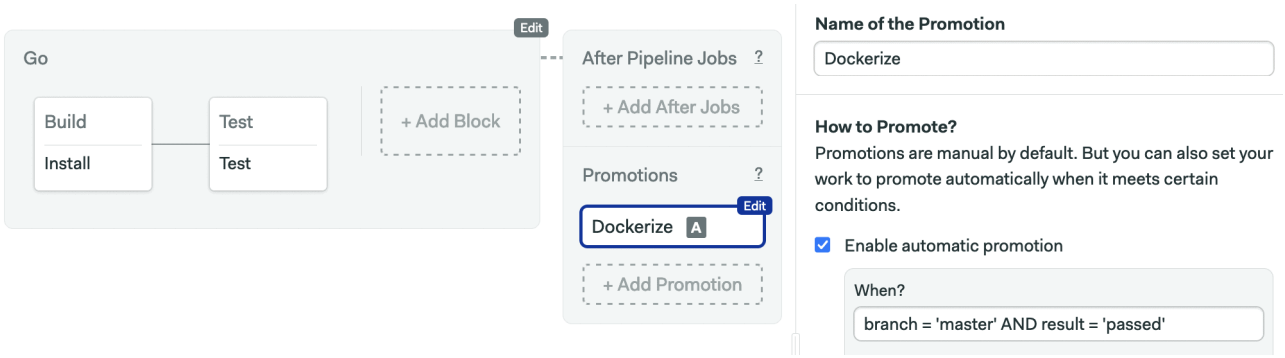


Figure 13: Dockerize Go promotion

1. Click **+Add Block**. We'll call the new block "Build"
2. Open the **Secrets** section and check the **dockerhub** box. This will import the variables we created earlier into the jobs in the block:

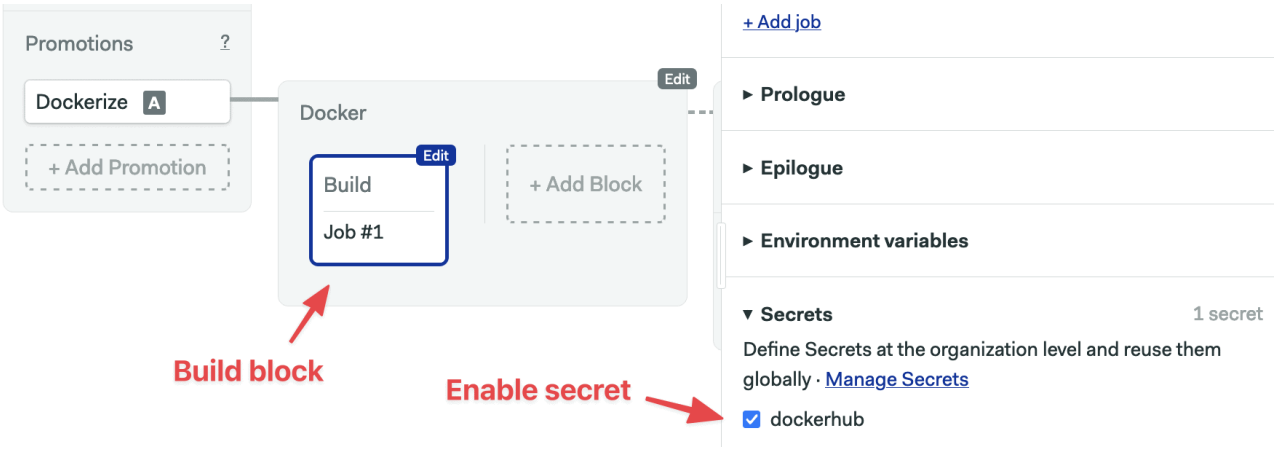


Figure 14: New block

1. Type the following commands in the job:

```
checkout
echo "$DOCKER_PASSWORD" | docker login  --username "$DOCKER_USERNAME" --password-s
docker pull $DOCKER_USERNAME/mathapp-production:latest
docker build -f Dockerfile.production --cache-from $DOCKER_USERNAME/mathapp-produc
docker push $DOCKER_USERNAME/mathapp-production:latest
```

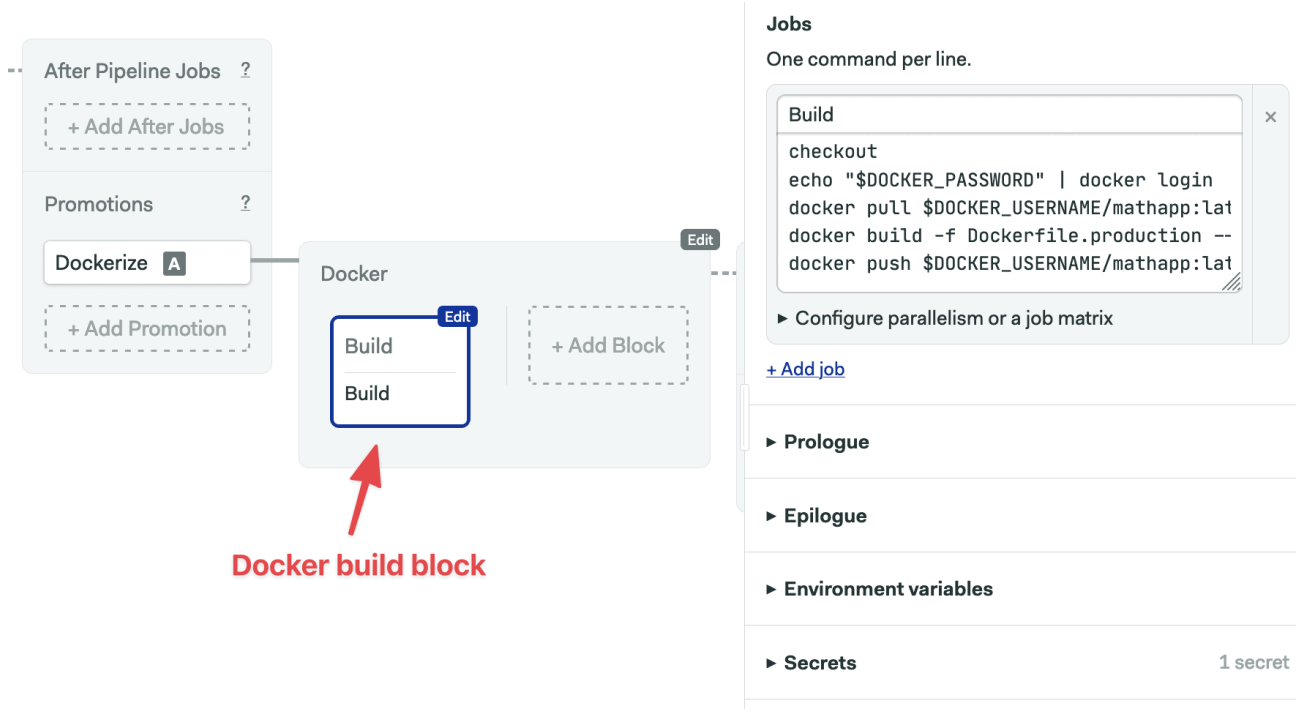


Figure 15: Dockerize Go block

1. Click on **Run the Workflow** and **Start**.
2. Once the first two blocks are done, click on the **Promote** button:

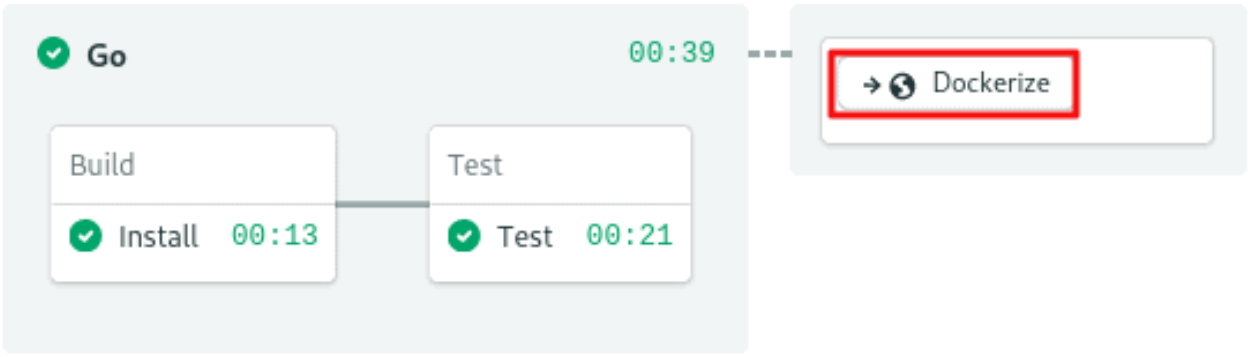


Figure 16: Dockerize Go promotion

Wait a few seconds until the Dockerize pipeline is done:

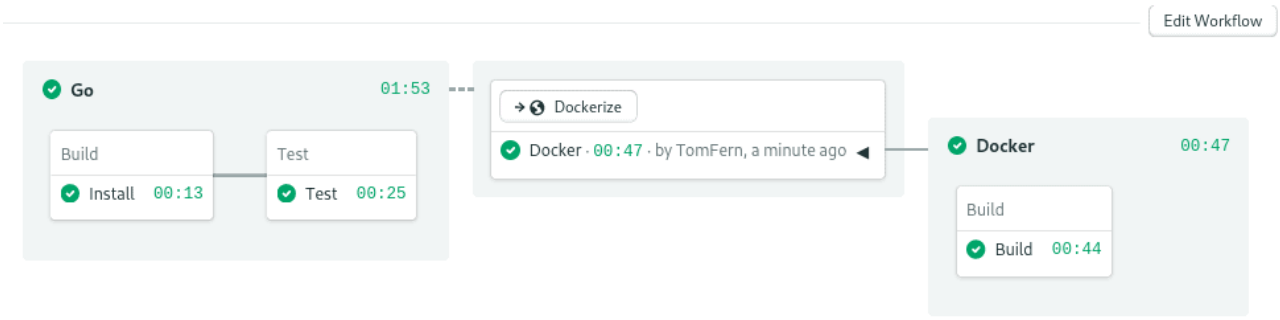


Figure 17: Dockerize Go application pipeline

Check your Docker Hub repositories, you should find the new image, ready to use:

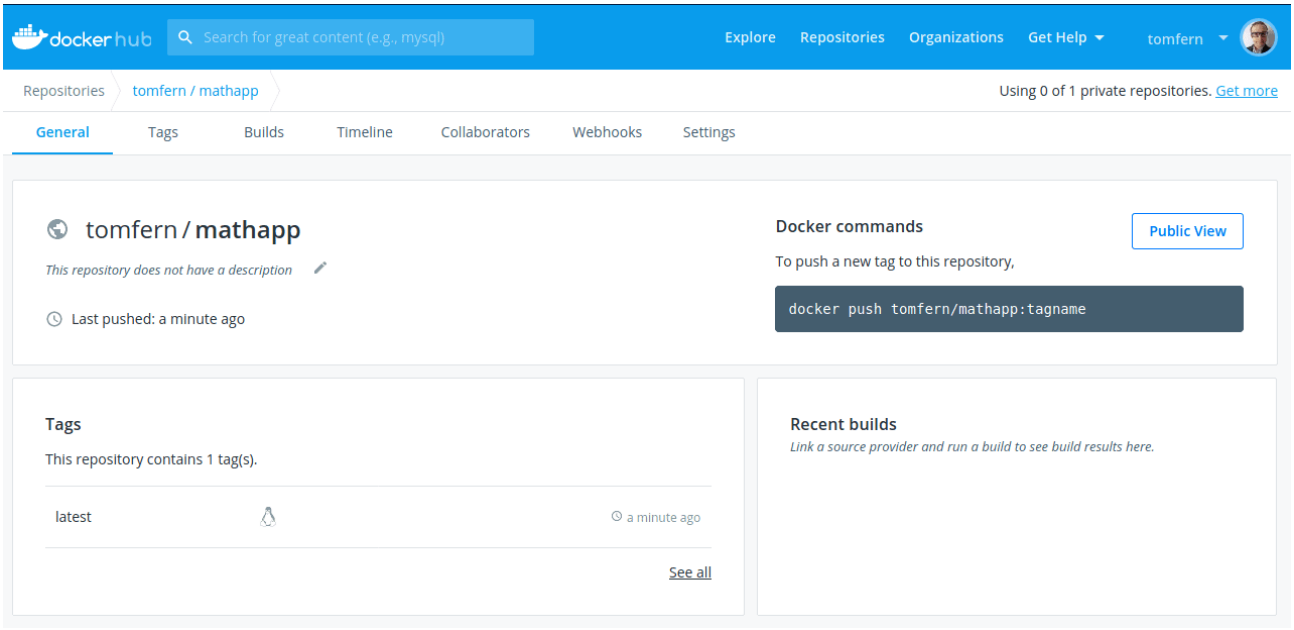


Figure 18: Dockerize Go application image

Finally, pull and test the new image in your machine:

```
$ docker pull YOUR_DOCKERHUB_USERNAME/mathapp-production
$ docker run -it -p 8010:8010 YOUR_DOCKERHUB_USERNAME/mathapp-production
```

What's Next

Docker opens up the possibilities for deployments:

- **Self-hosted**: run the image directly on a VM. With some scripting, we can integrate automatic deployment to your CI/CD setup.
- **PaaS**: many Platforms-as-a-Service offerings such as Heroku can directly run Docker containers. For more details, check the links below.
- **Kubernetes**: with Kubernetes, we can run the application at scale. Kubernetes brings a lot of features and is supported by almost every cloud provider. Checks the links below for related tutorials.

Heroku:

- Continuous Deployment of a Python Flask Application with Docker and Semaphore
- Dockerizing a PHP Application

Kubernetes:

- Download our ebook for free: CI/CD with Docker and Kubernetes
- CI/CD for Microservices on DigitalOcean Kubernetes
- A Step-by-Step Guide to Continuous Deployment on Kubernetes

- Continuous Integration and Delivery to AWS Kubernetes

Conclusion

In this tutorial, we learned how to create a Docker container for a Go application and prepare a Docker container using Semaphore.

You should now be ready to use Docker to simplify the deployment of your next Go application. If you have any questions, feel free to post them in the comments below.

P.S. Want to continuously deliver your applications made with Docker? Check out Semaphore's Docker support.

Read next:

- Dockerizing a Python Django Web Application
- Building Go Web Applications and Microservices Using Gin
- Lightweight Docker Images in 5 Steps

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