

Getting Started with the Cloud

Software Architecture

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Aside

Github Classroom links for this practical can be found on Edstem <https://edstem.org/au/courses/21491/discussion/2429006>

Before Class

Install Terraform¹ before your practical class. Also install the Terraform plugin for your IDE.

¹<https://developer.hashicorp.com/terraform/tutorials/aws-get-started/install-cli>

1 This Week

Our goal is to get acquainted with AWS Academy Learner Lab. We use the lab to learn how to deploy and manage infrastructure with AWS. Additionally, Learner Lab will be used to develop the Cloud Infrastructure assignment. If you have not already enrolled in the AWS Academy courses, you need to do so now.

- [Introduction to AWS Academy notes²](#) describes how to accept your invitation to enrol and login to AWS Academy.
- [Introduction to AWS Academy: Learner Lab notes³](#) describes how to access and use Learner Lab.

You will learn how to:

- Enter the AWS Console from a Learner Lab.
- Provision an EC2 instance that deploys a simple static website.

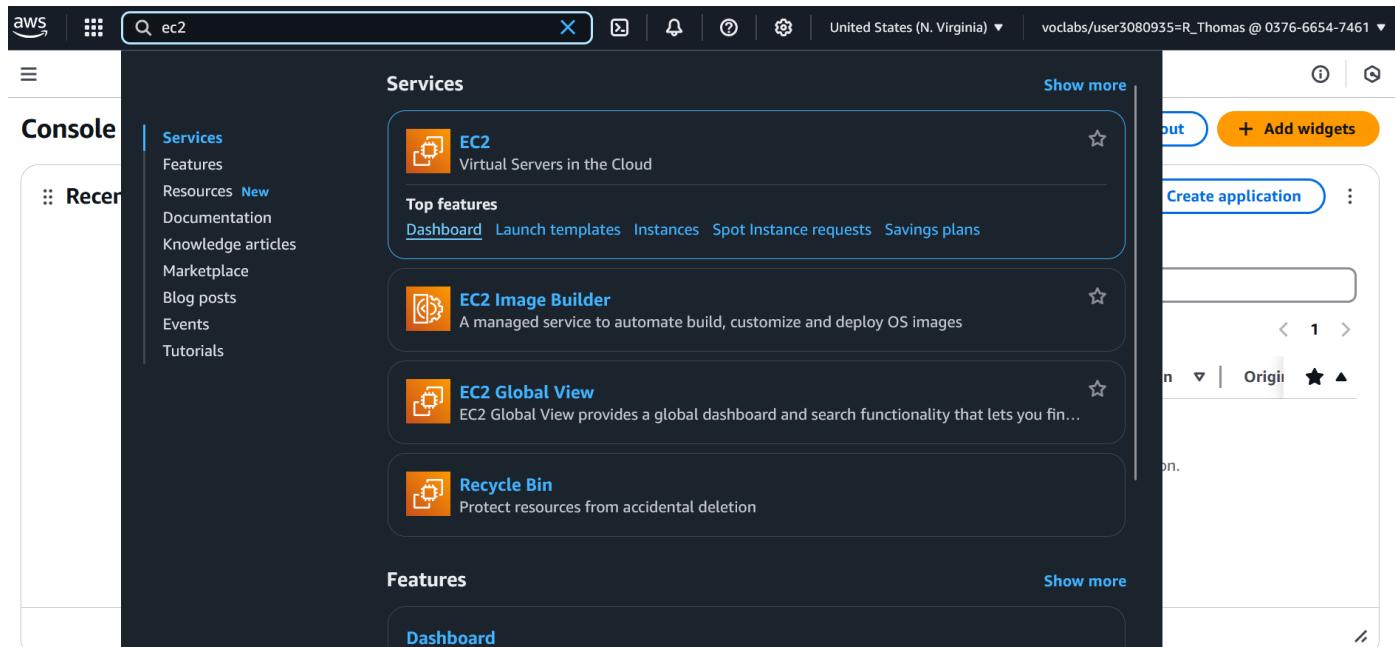
We will then start using an Infrastructure as Code tool (Terraform) to deploy the static website instead of using the AWS Console. You will also learn how to:

- Authenticate Terraform to use the AWS Learner Lab.
- Configure a single server website in Terraform and deploy.
- Create a Terraform module for deploying arbitrary single server websites.

2 AWS EC2

Today we are focussing on using AWS's EC2 service. Elastic Compute Cloud (EC2) is the primary compute service offered by AWS. It allows you to create virtual machines on Amazon's infrastructure. You have full control over this machine and can configure it for whatever purpose you need.

Navigate to the search bar in the top left and find the EC2 service. You might find this interface overwhelming. It is important to note that since EC2 is one of the primary services offered by AWS, many smaller services we do not need are bundled into this service.



²<https://csse6400.uqcloud.net/handouts/aws-academy.pdf>

³<https://csse6400.uqcloud.net/handouts/learner-lab.pdf>

Today, we only need the Instances dashboard. Navigate to there and select “Launch instance”.

The screenshot shows the AWS EC2 Instances dashboard. On the left, a sidebar menu includes: Dashboard, Instances (with sub-options like Instances, Instance Types, Launch Templates, etc.), Images, Elastic Block Store, Network & Security, and Load Balancing. The main content area has several sections: 'Resources' (listing Instances (running) 0, Auto Scaling Groups 0, Capacity Reservations 0, Dedicated Hosts 0, Elastic IPs 0, Instances 0, Key pairs 1, Load balancers 0, Placement groups 0, Security groups 1, Snapshots 0, Volumes 0), 'Launch instance' (with 'Launch instance' and 'Migrate a server' buttons), 'Service health' (AWS Health Dashboard, Region: United States (N. Virginia), Status: This service is operating normally), 'Zones' (listing Zone names and Zone IDs: us-east-1a (use1-az1), us-east-1b (use1-az2), us-east-1c (use1-az4), us-east-1d (use1-az6), us-east-1e (use1-az3), us-east-1f (use1-az5)), 'Explore AWS' (Get Up to 40% Better Price Performance, Enable Best Price-Performance with AWS Graviton2, Amazon GuardDuty Malware Protection), and 'Additional information' (Getting started guide). Top navigation includes: Search, [Alt+S], United States (N. Virginia), and user info: voclabs/user3080935=R_Thomas @ 0376-6654-7461.

2.1 EC2 AMI

First we need to select an Amazon Machine Image (AMI). An AMI is the template that provides instructions on how an instance should be provisioned. Amazon offers a range of built-in AMIs. There are also community AMIs or you can create your own. As we just want a simple server today, we will use one of the built-in AMIs.

We will use the Amazon Linux 2023 AMI today, it is considered one of the fundamental images. Every AMI has a unique AMI code, which is `ami-08b5b3a93ed654d19` for the Amazon Linux 2023 AMI.

Launch an instance [Info](#)

Amazon EC2 allows you to create virtual machines, or instances, that run on the AWS Cloud. Quickly get started by following the simple steps below.

Name and tags [Info](#)

Name
e.g. My Web Server [Add additional tags](#)

Application and OS Images (Amazon Machine Image) [Info](#)

An AMI is a template that contains the software configuration (operating system, application server, and applications) required to launch your instance. Search or Browse for AMIs if you don't see what you are looking for below.

Search our full catalog including 1000s of application and OS images

Quick Start

Amazon Linux macOS Ubuntu Windows Red Hat SUSE [Browse more AMIs](#)
Including AMIs from AWS, Marketplace and the Community

Amazon Machine Image (AMI)

Amazon Linux 2023 AMI
Free tier eligible
ami-053a45ffff0a704a47 (64-bit (x86), uefi-preferred) / ami-0c518311db5640eff (64-bit (Arm), uefi)
Virtualization: hvm ENA enabled: true Root device type: ebs

Description
Amazon Linux 2023 is a modern, general purpose Linux-based OS that comes with 5 years of long term support. It is optimized for AWS and designed to provide a secure, stable and high-performance execution environment to develop and run your cloud applications.

Amazon Linux 2023 AMI 2023.6.20250211.0 x86_64 HVM kernel-6.1

Architecture	Boot mode	AMI ID	Username	Verified provider
64-bit (x86)	uefi-preferred	ami-053a45ffff0a704a47	ec2-user	

Instance type [Info](#) | [Get advice](#)

Instance type
t2.micro Free tier eligible
Family t2 1 vCPU 1 GiB Memory Current generation: true

Summary

Number of instances [Info](#)
1

Software Image (AMI)
Amazon Linux 2023 AMI 2023.6.2... [read more](#)
ami-053a45ffff0a704a47

Virtual server type (instance type)
t2.micro

Firewall (security group)
New security group

Storage (volumes)
1 volume(s) - 8 GiB

Free tier: In your first year includes 750 hours of t2.micro (or t3.micro in the Regions in which t2.micro is unavailable) instance usage on free tier AMIs per month, 750 hours of public IPv4 address usage per month, 30 GiB of EBS storage, 2 million I/Os, 1 GB of snapshots, and 100 GB of bandwidth to the internet.

[Cancel](#) [Launch instance](#) [Preview code](#)

2.2 Instance Settings

The settings to configure your instance are:

1. Add a 'Name' tag. Call it the name of your website, e.g. hextris.
2. Select an appropriate AMI, i.e. Amazon Linux 2023 AMI, ami-053a45ffff0a704a47.
3. Select a 64-bit (x86) architecture.
4. The instance type defines the computing, memory, networking and storage capabilities of your instance. We do not need a large server, choose t2.micro.
5. Select the existing vockey (Type: RSA) key pair option.
6. In network settings, choose 'Create security group' and select to allow SSH traffic from anywhere, and HTTPS and HTTP access from the internet.
7. Keep the 'Configure storage' settings as default.
8. Do not worry about the 'Advanced details' options for now.
9. You can now launch the instance to start your server.

3 Accessing the Instance

Return to the Instances dashboard. You should see that a new instance has been created. Its instance state might not yet be Running, if not, wait.

The screenshot shows the AWS EC2 Instances dashboard. On the left, there's a sidebar with navigation links for Dashboard, EC2 Global View, Events, Instances (selected), Instance Types, Launch Templates, Spot Requests, Savings Plans, Reserved Instances, Dedicated Hosts, Capacity Reservations, Images, AMIs, and AMI Catalog. Below these are sections for Elastic Block Store (Volumes, Snapshots, Lifecycle Manager), Network & Security (Security Groups, Elastic IPs, Placement Groups, Key Pairs, Network Interfaces), Load Balancing (Load Balancers, Target Groups, Trust Stores), and Auto Scaling (Auto Scaling Groups). At the bottom of the sidebar is a Settings link. The main content area shows a table of instances with one row selected: 'hextris' (Instance ID: i-0e4a4edee40a78ee5, State: Running, Type: t2.micro, Status: Initializing, Availability Zone: us-east-1c, Public IPv4 DNS: ec2-3-90-102-7). Below the table is a detailed view for the selected instance, showing sections for Instance summary, Instance details, and Platform details. The Instance summary section includes fields like Instance ID, IPv6 address, Hostname type, Answer private resource DNS name, Auto-assigned IP address, IAM Role, IMDSv2, Operator, and more. The Instance details section includes fields like AMI ID, AMI name, Monitoring, Allowed image, and Platform details (Linux/UNIX). The Platform details section also indicates Termination protection is managed and false.

Note the public IPv4 address, as we will need to use this to connect to the server. You will also need this address to test that installation of Hextris in section 4 worked.

1. Return to the AWS Learner Lab interface.
2. In the terminal window run the following, replacing 127.0.0.1 with the public IP address of your instance. This command uses the vockey | RSA key pair to gain SSH access to the machine.

```
$ ssh -i ~/.ssh/labsuser.pem ec2-user@127.0.0.1
```

For example:

```
eee_W_2897588@runweb113237:~$ ssh -i ~/.ssh/labsuser.pem ec2-user@3.95.132.33
The authenticity of host '3.95.132.33 (3.95.132.33)' can't be established.
ECDSA key fingerprint is SHA256:BArUeylQormBYN/FANocVRnn+HM9n8X+cn0BRn7hNiE.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added '3.95.132.33' (ECDSA) to the list of known hosts.

          _#
 ~\_\_ #####_      Amazon Linux 2023
 ~~ \#####\
 ~~  \###|
 ~~   \#/ __ https://aws.amazon.com/linux/amazon-linux-2023
 ~~   V~' '-'>
 ~~    /
 ~~.._ /_
 /_/_/
 /m/'

[ec2-user@ip-172-31-80-172 ~]$ []
```

You can also access the instance by selecting it from the list of instances in the dashboard and clicking the “Connect” button. This will open a new tab in your browser with terminal access to your instance.

4 Installing Hextris

Hextris [1] is very simple to install. Using an EC2 interface is perhaps overkill for it. It is an entirely client-side/static web application, which means we just have to serve the static files.

First, we will need to enable serving of static files. We can install and start the `httpd` service to do this. The AMI we have picked uses the `yum` package manager, so to install `httpd` we run:

```
> sudo yum install httpd
Last metadata expiration check: ...
Dependencies resolved
.....
Total download size: 2.3 M
Installed size: 6.9 M
Is this ok [y/N] :

# enter y to install
.....
Complete!
> sudo systemctl enable httpd
Created symlink from /etc/systemd/system/multi-user.target.wants/httpd.service to /
  usr/lib/systemd/system/httpd.service.
> sudo systemctl start httpd
```

All files in the `/var/www/html` directory will now be served when accessed via **HTTP**. Navigate to the public IP address of your EC2 instance in the browser. You should see an “It works!” landing page.

Change to the `/var/www/html` directory and notice that it is currently empty. We need to download the static files to this directory so that they can be served. We can use `git` for this (though it is not the most suited tool), but first `git` needs to be installed on the machine.

```
$ sudo yum install git
```

Finally, confirm that we are in the `/var/www/html` directory.

```
$ cd /var/www/html
```

And clone the repository into that directory.

```
$ sudo git clone https://github.com/Hextris/hextris .
```

Now if you navigate to the **http** address of the public IP address (e.g. <http://18.208.165.253>), you should be able to see your newly deployed website. Congratulations!

Notice

If you are having timeout issues, one problem could be using `https` to connect rather than `http`.

5 Switching to Terraform

For the remainder of the practical we will use Terraform to provision the same instance we just created.

1. First, delete any running instances in your AWS account using the AWS Console.
2. Next, navigate to the GitHub Classroom link for this practical provided at the start of this document. This will create a new repository where we can work with Terraform.

6 Using Terraform in AWS Learner Labs

We will redeploy our Hextris application using Infrastructure as Code (IaC). You will need to keep your lab running for the next steps. (Now is a good time to click start to refresh your 4 hour time limit.)

1. Click on “AWS Details” to display information about the lab.

The screenshot shows the AWS Academy Learner Lab interface. On the left is a sidebar with icons for Account, Dashboard, Courses, Calendar, Inbox, History, and Help. The main navigation bar shows the path: ALLv1EN-LT13-73527 > Modules > AWS Academy Learner ... > Launch AWS Academy Learner Lab. The top right shows usage details: Used \$0 of \$100, 01:55, and buttons for Start Lab, End Lab, AWS Details, Readme, and Reset. The central area has a terminal window showing the command [ec2-user@ip-172-31-88-93 html]\$. To the right is the "Cloud Access" panel, which displays AWS CLI status (Show), Cloud Labs session info (Remaining session time: 01:55:16(116 minutes), Session started at: 2024-02-15T20:09:23-0800, Session to end at: 2024-02-16T00:09:23-0800), accumulated lab time (02:04:00 (124 minutes)), and a note that no running instance exists. It also includes SSH key, Cloud SSO, and download buttons for PEM and PPK. At the bottom are fields for AWSAccountID (058264123001) and Region (us-east-1).

2. Click on the first 'Show' button next to 'AWS CLI'. This will display a text block starting with [default].
3. Within your repository create a `credentials` file and copy the contents of the text block into the file. **Do not share this file contents — do not commit it.** This file is added to the `.gitignore` of your repository by default.
4. Create a `main.tf` file in the same directory with the following contents:

```
» cat main.tf

terraform {
  required_providers {
    aws = {
      source = "hashicorp/aws"
      version = "~> 5.0"
    }
  }
}

provider "aws" {
  region = "us-east-1"
  shared_credentials_files = ["./credentials"]
  default_tags {
    tags = {
      Environment = "Dev"
      Course = "CSSE6400"
      StudentID = "<Your Student ID>"
    }
  }
}
```

The `terraform` block specifies the required external dependencies, here we need to use the AWS provider above version 5.0. The `provider` block configures the AWS provider, instructing it which region to use and how to authenticate (using the `credentials` file we created). We also include some tags to add to any resource made by this provider, these are useful for keeping track of resources in the console.

5. We need to initialise Terraform, which will download the required dependencies. This is done with the `terraform init` command.

```
$ terraform init
```

This command will create a `.terraform` directory which stores providers and a provider lock file, `.terraform.lock.hcl`.

6. To verify that we have setup Terraform correctly, use `terraform plan`.

```
$ terraform plan
```

As we currently have no resources configured, it should find that no changes are required. Note that this does not ensure our credentials are correctly configured, as Terraform has no reason to try authenticating yet.

7 Deploying Hextris

First, we will need to create an EC2 instance resource. The AWS provider calls this resource an `aws_instance`⁴. Get familiar with the documentation page. Most Terraform providers have reasonable documentation. Reading the argument reference section helps to understand what a resource is capable of doing.

We will start off with the basic information for the resource. Configure it to use a specific Amazon Machine Instance (AMI), and chose the `t2.micro` size. We will also give it a name so that it is easy to find. Add the following basic resource block to `main.tf`:

```
» cat main.tf

resource "aws_instance" "hextris-server" {
    ami = "ami-08b5b3a93ed654d19"
    instance_type = "t2.micro"
    key_name = "vokey"

    tags = {
        Name = "hextris"
    }
}
```

To create the server, invoke `terraform apply`, which will first do `terraform plan` and prompt us to confirm if we want to apply the changes.

```
$ terraform apply
```

You should be prompted with something similar to the output below.

Terraform used the selected providers to generate the following execution plan.

Resource actions are indicated with the following symbols:

+ create

Terraform will perform the following actions:

```
# aws_instance.hextris-server will be created
+ resource "aws_instance" "hextris-server" {
    + ami = "ami-08b5b3a93ed654d19"
    (omitted)
    + instance_type = "t2.micro"
    (omitted)
    + tags = {
```

⁴<https://registry.terraform.io/providers/hashicorp/aws/latest/docs/resources/instance>

```
+ "Name" = "hextris"
}
(omitted)
}
```

Plan: 1 to add, 0 to change, 0 to destroy.

Do you want to perform these actions?
Terraform will perform the actions described above.
Only 'yes' will be accepted to approve.

Enter a value:

If the plan looks sensible enter yes to enact the changes.

Enter a value: yes

```
aws_instance.hextris-server: Creating...
aws_instance.hextris-server: Still creating... [10s elapsed]
aws_instance.hextris-server: Still creating... [20s elapsed]
aws_instance.hextris-server: Still creating... [30s elapsed]
aws_instance.hextris-server: Still creating... [40s elapsed]
aws_instance.hextris-server: Creation complete after 47s [id=i-08c92a097ae7c5b18]
```

Apply complete! Resources: 1 added, 0 changed, 0 destroyed.

You can now check in the AWS Console that another EC2 instance with the name hextris has been created. Now that we have a server, we should try to configure it to serve Hextris. We will use the user_data field, which configures commands to run when launching the instance. First we need a script to provision the server, if we combine all our commands from section 4, we will produce this script:

```
» cat serve-hextris.sh
#!/bin/bash
yum install -y httpd
systemctl enable httpd
systemctl start httpd

yum install -y git
cd /var/www/html
git clone https://github.com/Hextris/hextris .
```

Now we can add the following field to our Terraform resource. It uses the Terraform file function to load the contents of a file named serve-hextris.sh, relative to the Terraform directory. The contents of that file is passed to the user_data field.

```
user_data = file("./serve-hextris.sh")
```

If you run the `terraform plan` command now, you will notice that Terraform has identified that this change will require creating a new EC2 instance. Where possible, Terraform will try to update a resource in-place but since this changes how an instance is started, it needs to be replaced. Go ahead and apply the changes.

Now, in theory, we should have deployed Hextris to an EC2 instance. But how do we access that instance? We could go to the AWS Console and find the public IP address. However, it turns out that Terraform already knows the public IP address. In fact, if you open the Terraform state file (`terraform.tfstate`), you should be able to find it hidden away in there. But, we do not want to go hunting through this file all the time. Instead we will use the `output` keyword.

We can specify certain attributes as 'output' attributes. Output attributes are printed to the terminal when the module is invoked directly but as we will see later, they can also be used by other Terraform configuration files.

```
> cat main.tf

output "hextris-url" {
  value = aws_instance.hextris-server.public_ip
}
```

This creates a new output attribute, `hextris-url`, which references the `public_ip` attribute of our `hextris-server` resource. Note that resources in Terraform are addressed by the resource type (`aws_instance`) followed by the name of the resource (`hextris-server`).

If you apply the changes, it should tell you the public IP address of the instance resource.

```
$ terraform apply
```

```
aws_instance.hextris-server: Refreshing state... [id=i-043a61ff86aa272e0]
```

Outputs:

```
hextris-url = "3.82.225.65"
```

You can apply this plan to save these new output values to the Terraform state, without changing any real infrastructure.

So let's try and access that URL, hmm. That is strange. Something has gone wrong.

8 Security Groups

When we setup our EC2 instance using the AWS Console, it helpfully created a new security group for us. We specified that this security group should allow SSH, HTTP, and HTTPS traffic by allowing traffic from ports 22, 80, and 443 respectively. When configuring with Terraform, security groups and their attachment to EC2 instances are separate resources. Refer back to the Terraform documentation for details or, as is normally quicker, [Google "terraform aws security group"](#).

First, let us create an appropriate security group. Recall that in the AWS Console configuration, ingress SSH access (port 22) and all egress⁵ traffic were automatically configured and we just added ingress port 80. In Terraform the whole state must be configured so we specify two ingress blocks, one for HTTP (port 80) and one for SSH access (port 22).⁶ Additionally, we will create egress for all outgoing traffic.

```
resource "aws_security_group" "hextris-server" {
  name = "hextris-server"
  description = "Hextris HTTP and SSH access"

  ingress {
    from_port = 80
    to_port = 80
    protocol = "tcp"
    cidr_blocks = ["0.0.0.0/0"]
  }

  ingress {
    from_port = 22
    to_port = 22
    protocol = "tcp"
    cidr_blocks = ["0.0.0.0/0"]
  }

  egress {
    from_port = 0
    to_port = 0
    protocol = "-1"
    cidr_blocks = ["0.0.0.0/0"]
  }
}
```

Note the following:

- `from_port` and `to_port` are the start and end of a range of ports rather than incoming or outgoing. In this example our range is 80-80.
- `protocol` set to “-1” is a special flag to indicate all protocols.
- Explaining `cidr` is outside the scope of the course, but the specified block above means to apply to all IP addresses.

You may now apply the changes to create this new security group resource.

Next, we will attach the security group to the EC2 instance. Return to the `aws_instance.hextris-server` resource and include the following line:

```
security_groups = [aws_security_group.hextris-server.name]
```

⁵Ingress and egress in networking just means incoming and outgoing respectively.

⁶We do not actually need SSH access as all the server configuration is done when the machine is provisioned, thanks to the `user_data`, but we are trying to create a new instance that is identical to the original AWS Console in section 4.

Note that EC2 instances can have multiple security groups. Once again notice the structure of resource identifiers in AWS.

Now apply the changes. If you now try to access via the IP address (the IP address may have changed), you should be able to view the Hextris website.

9 Tearing Down

One of the important features of Infrastructure as Code (IaC) is all the configuration we just did is stored in a file. This file can, and should be, version controlled and subject to the same quality rules of code files. It also means that if we want to redeploy Hextris at any point, we can easily just run the IaC to deploy it.

To try this out, let us first take everything down. We can do this with:

```
$ terraform destroy
```

You should be prompted to confirm that you want to destroy all of the resources in the state. Once Terraform has finished taking everything down, confirm that you can no longer access the website and that the AWS console says the instances have been destroyed.

Now go ahead and apply the changes to bring everything back:

```
$ terraform apply
```

Confirm that this brings the website back exactly as before (with a different IP address). You can now start any lab you want and almost instantly spin back up the website you have configured. That is the beauty of Infrastructure as Code!

Hint: Destroy everything again before you finish.

10 Automated Testing

A quick note about automated testing. As with all the practicals thus far, this practical has automated tests enabled on your repository.

From within your repository, you can run the tests locally with:

```
$ .csse6400/bin/unittest.sh
```

While the emails saying that the tests failed can be annoying, these automated tests allow us to ensure that everyone is keeping up with the practical content.

If fixing the test failures is not too hard, please try to do so. If you are repeatedly not passing the practicals, we may reach out to ensure that you are not being left behind in the content.

11 Extension

Info

This section is for students who have completed the practical and want to extend their knowledge.

Since CSSE6400 runs this practical every year, sometimes the AMI that we were using is out of date or does not exist any more. For this practical, we could instead query AWS for the latest AMI and use that in our Terraform.

To do this we introduce a new data source, `aws_ami`. Data sources fetch or query data from the provider, rather than creating something.

Add the following to your `main.tf` file:

```
data "aws_ami" "latest" {
  most_recent = true
  owners = ["amazon"]

  filter {
    name = "name"
    values = ["al2023-ami-2023*"]
  }

  filter {
    name = "root-device-type"
    values = ["ebs"]
  }

  filter {
    name = "virtualization-type"
    values = ["hvm"]
  }

  filter {
    name = "architecture"
    values = ["x86_64"]
  }
}
```

The `aws_ami` data source will find the latest Amazon Linux 2023 AMI for 64 bit x86, which is what is running on our EC2 instance.

To use the data source we need to change the `ami` attribute of the `aws_instance` resource to use the data source. This is done as so:

```
resource "aws_instance" "hextris-server" {
  ami = data.aws_ami.latest.id
  instance_type = "t2.micro"
  key_name = "vokey"
  security_groups = [aws_security_group.hextris-server.name]
  user_data = file("./serve-hextris.sh")
```

```

tags = {
  Name = "hextris"
}

```

And now, if we run `terraform plan`, we will see that it wants to destroy and recreate the EC2 instance. This is because the AMI has changed since this practical was first updated for this year.

References

- [1] L. Engstrom, G. Finucane, N. Moroze, and M. Yang, “Hextris.” <https://github.com/hextris/hextris/>, 2014.
- [2] “Aws global infrastructure.” <https://aws.amazon.com/about-aws/global-infrastructure/>, March 2025.

A AWS Networking Terminology

AWS Regions Regions are the physical locations of AWS data centres. When applying Terraform, the changes are made to one region at a time. In our case we specified the region `us-east-1`. Often you do not need to deploy to more than one region, however, it can help decrease latency and reduce risk from a major disaster. Generally, pick a region and stick with it. We have picked `us-east-1` because it is the least expensive.



Figure 1: AWS Regions as of March 2025 [2]

Availability Zones An AWS Region will consist of availability zones, normally named with letters. For example, the AWS Region located in Sydney, ap-southeast-2 has three availability zones: ap-southeast-2a, ap-southeast-2b, and ap-southeast-2c. An availability zone is a collection of resources which run on separate power supplies and networks. Reducing the risk that multiple availability zones would fail at once.

VPC Virtual Private Clouds, or VPCs, are virtual networks under your control, if you have managed a regular network before it should be familiar. VPCs are contained within one region but are spread across multiple availability zones.