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Chapter 1

Software Platform Cloud Computing

(In collaboration with Mr Yuan Feng)
1.1 Chapter Summary and Highlights

Described in this chapter are details of accessing and using Real-ESSI Simulator using remote computers, the so-called "cloud" computational resources. Current focus is on using Amazon Web Services (AWS) computers.

1.2 Real-ESSI Cloud Computing Overview

Cloud computing refers to the accessing and computing over the Internet rather than on local computers. Cloud computing is a model for enabling on-demand access to a shared pool of configurable computing resources, which can be setup and released rapidly.¹

Using Real-ESSI Cloud Service, users can get computing instances on demand without requiring a lot of maintenance and financial resources a common, local parallel computer, cluster would require. In addition, users do not need to go through the installation of the dependent libraries, source-code compilation and the installation of other related software, for example, preprocessing and post-processing environment. The complete Real-ESSI Simulator system is pre-configured and built within the image such that Real-ESSI Simulator system is portable over the cloud. A stable, release version of Real-ESSI is built and can be used anywhere and anytime.

There are two ways to obtain a Real-ESSI image on Amazon Web Services (AWS):

- Obtain a Real-ESSI private image from Prof. Boris Jeremić, see Section 1.3.1 on page 7.
- Use a public image of Real-ESSI on AWS marketplace, as described in Section 1.3.2 on page 19.

After a Real-ESSI image is launched, a Real-ESSI EC2 instance is generated on AWS. The instance can be accessed through a X2GO client. The procedures are written in Section 1.4 on page 19.

When the simulation on the Real-ESSI instance is finished and all the output result files are fetched, remember to terminate the running instance so that AWS would not keep charging you. Section 1.5 on page 22 describes how to terminate a running Real-ESSI instance. See Section 1.8 on page 25 for more information about the cost of AWS cloud computing services.

1.2.1 Real-ESSI Cloud Service Content

One image is built for a single-machine setup, which contains

- Ubuntu 16.04 LTS Desktop and X2GO Server
- Real-ESSI sequential program

¹This is an excerpt from Jeremić et al. (1989-2020)
- Real-ESSI parallel program
- Real-ESSI 3C seismic motion developments (SW4)
- Real-ESSI pre-processing (gmESSI)
- Real-ESSI post-processing (PVESSIReader)
- Real-ESSI Editor, Sublime plug-ins
- Real-ESSI Documentation
- Real-ESSI Examples
1.3 Launch Real-ESSI Instance on AWS

A Real-ESSI instance can be launched either from the private image with authorization of Prof. Boris Jeremić or from the public image on AWS market place.

1.3.1 Launch Real-ESSI Instance from AWS Private Images

Follow the steps below to launch instances from Real-ESSI Private Image.

1. Create an AWS account.

AWS is the most widely used cloud service provider. If you do not have one, creating an AWS account is easy. You can create an AWS account through their website https://aws.amazon.com/. After you login, you can see the services on AWS Console Home as follows.

![AWS Console Home](image)

Figure 1.1: AWS Console Home.
2. Request the Real-ESSI image.

Real-ESSI image is currently a private Amazon Machine Images (AMI). After you get the 12-digit AWS account ID, email the AWS account ID to Prof. Boris Jeremić to obtain the Real-ESSI image. From AWS Console Home, go to Services → EC2.

![AWS Services](Figure 1.2: AWS Services.)
From EC2 Dashboard, go to AMIs to check the Real-ESSI image.

![Figure 1.3: AWS EC2 Dashboard AMIs.](image)

If users cannot find the Real-ESSI image, please make sure you are in the same AWS region with Prof. Boris Jeremić, the region is shown in the top-right corner on EC2 dashboard. The current Real-ESSI AMIs region are in both North California and Oregon.
3. Launch the Real-ESSI image.

![AWS EC2 Private AMIs](image)

Figure 1.4: AWS EC2 Private AMIs.
Follow the steps below to launch instances from the Real-ESSI image.

(a) Choose AMI.

![EC2 Launch Steps: Choose AMI](image)

Figure 1.5: EC2 Launch Steps: Choose AMI.
(b) Choose Instance Type

From AMIs, users can launch any number and type of instances and choose the desired EC2 configurations. In order to have the best experiences, the compute-optimized instances (C4, C5 as the latest one, as of early 2019) are recommended.

![EC2 Launch Steps: Choose Instance Type.](image1)

Figure 1.6: EC2 Launch Steps: Choose Instance Type.
(c) Configure Instance

![Configure Instance Diagram]

Figure 1.7: EC2 Launch Steps: Configure Instance.
(d) Add Storage

Figure 1.8: EC2 Launch Steps: Add Storage.
(e) Add Tags

Figure 1.9: EC2 Launch Steps: Add Tags.
(f) **Configure Security Group.**

Please keep the default Security Group setting.

(g) **Review**

You may be asked to create a key-pair for later access of the instance you created. The key-pair can be reused later if you created other instances. Besides, the key-pair is portable across other machines. Last but not least, the key-pair cannot be recreated after you launch the instance, so please make sure you save the key-pair in a safe place.

![EC2 Launch Steps: Review](image)

Figure 1.10: EC2 Launch Steps: Review.
4. Check the launched instances

After the launch, you can view the running instance through EC2 Dashboard $\rightarrow$ Instances

![EC2 Running Instances](image)

Figure 1.11: EC2 Running Instances.

You can login to your instances either by `ssh` or by using X2GO client 1.4. Please note that every time when you restart the instances, the public IP address will change.
5. Fix Public IP Address (Optional)

The public IP address of Real-ESSI instances change for each reboot. If users want to have a fixed public IP address for every login, users can allocate one elastic IP address and associate the IP address to a Real-ESSI instance such that users can have a fixed public IP address for each login.
6. Attach more Storage (Optional)

The Real-ESSI Image holds 30GB Hard disk and already uses 15GB. In the case of a real large simulations, this size hard drive might not be enough for the full output. Users can attach more storage through elastic block store.

### 1.3.2 Launch Real-ESSI Instance from AWS Market Place

This section gives a quick start guide for using Real-ESSI on AWS market place.

Real-ESSI Simulator system (pre processing, main Real-ESSI program, post processing) is available on Amazon Web Services MarketPlace. Point your web browser to the Amazon Web Services Market Place, and search for ”Real ESSI", ”Real-ESSI" or ”MS ESSI”.

In summary, a quick guide to launching an instance from AWS Market Place is:

- Go to the ESSI Cloud Product Page.
- Click **Continue** to go to Launch ESSI from the Cloud.
- Click **Manual Launch** (use **1-Click Launch**, if comfortable with settings).
- Click **Launch from the EC2 Console** for your **preferred region**.
- Select your **preferred instance** from the table, e.g. t2.micro.
- Click **Review and Launch**.

### 1.4 Connect to Real-ESSI Instance on AWS

#### 1.4.1 Install X2GO Client

Before connecting to the Real-ESSI cloud, users should install the client-side of X2GO. X2Go is a remote desktop software that can visualize the launched Real-ESSI instance. Installation of X2GO for different operating systems is fairly straightforward, and users can find installation instructions on their own or follow installation instructions below.

**Installing X2GO client on Ubuntu Linux.**

User can directly install X2GO client by using debian install utility, to install x2goclient.

**Installing X2GO client on Apple Mac.**

Users can download the package through this link: [http://code.x2go.org/releases/X2GoClient_latest_macosx_10_9.dmg](http://code.x2go.org/releases/X2GoClient_latest_macosx_10_9.dmg).
Installing X2GO client on Windows.

Users can download the package through this link: http://code.x2go.org/releases/X2GoClient_latest_mswin32-setup.exe.

Installing X2GO client on other operating systems. If you are using a different operating system, please refer to X2GO website for the installation. The X2GO website for client installation is https://wiki.x2go.org/doku.php/download:start
1.4.2 Configure the Client-Side of X2GO

For all operating systems, users will see the same session when they open the x2goclient new-session, as shown in Fig. 1.12.

Figure 1.12: Configuration of X2GO client.

1. Users can name their own session.
2. AWS IP address is to be copied from EC2 management console, from the description TAB of launched instance, at the bottom of the page. This is IPv4 Public IP... it goes into Host: ...
3. AWS User Name is “ubuntu”.
4. AWS ssh-key is the one saved from before, in .ssh directory
5. Please check the auto-login.
6. Please change the session type to XFCE.
7. Click OK to finish the configuration.

In addition to the Desktop login, users can also use ssh to login the Real-ESSI Terminal.

```
1  chmod 400 your_ssh_key.pem
2  ssh -i your_ssh_key.pem ubuntu@your_AWS_public_IP_address
```
1.4.3 Connect to the Launched Instance

Click the configured session to connect to the ESSI instance. You should see a virtual desktop pop up on your local machine, as shown in Fig. 1.13. Now you have successfully connected to the Real-ESSI Simulator instance on AWS. You can now use Real-ESSI Simulator within the virtual desktop.

![Connected to the already launched Real-ESSI instance.](image)

Figure 1.13: Connected to the already launched Real-ESSI instance.

1.5 Terminate Real-ESSI Instance on AWS

Once the Real-ESSI simulation on AWS is finished, the user can transfer output files to the local computer, or leave them on AWS, preferably on cheap S3 storage Section 1.8 on page 25 provides detailed description of storage and transfer options and costs. **NOTE:** Users need to terminate the running Real-ESSI instance on AWS to avoid additional charges. The terminate operation is done on AWS console that is the same place where you launch the Real-ESSI instance. As shown Fig. 1.14, following steps are required:

1. Click ‘Instances’ from the sidebar to see all your running instances on AWS.

2. Choose the instance you want to terminate.

3. Click ‘Actions’.

4. Click ‘Instance State’
5. Click ‘Terminate’

![Figure 1.14: Terminate a Real-ESSI Simulator instance.](image)

### 1.6 Adding Permission for Private Real-ESSI Image to User AWS Accounts

- login to AWS
  - sign in to console
  - go to image in a region, say N, California
  - then go to EC2
  - go to AMIs on left side
  - select image to be shared
  - go to Actions
  - go to Modify Image Permissions and put user account number then click Add Permission and then Save...
1.7 Real-ESSI Instructional Videos Cloud Computing

This section presents few short instructional videos about how to use Real ESSI on Amazon Web Services (AWS) computers.

**Installing X2GO for Windows:** Youtube instructional video.

**Installing X2GO for Macintosh:** Youtube instructional video.

**Installing X2GO for Linux:** Youtube instructional video.

**Launch AWS Marketplace:** Youtube instructional video.

**Access Running Instance on AWS:** Youtube instructional video.

**Start Real-ESSI Program on AWS:** Youtube instructional video.

**Run Real-ESSI Example Model on AWS:** Youtube instructional video.

**Visualize Real-ESSI Example Model on AWS:** Youtube instructional video.

**Post-Process, Visualize Real-ESSI Results on AWS:** Youtube instructional video.
1.8 Cost of AWS EC2

The cost breakdown for using Real-ESSI on AWS (EC2) is:

- **AWS computer cost**

  There are 3 ways to pay for AWS computer cost (EC2 instances)

  - **On-Demand instance**, offers a real, instant pay-per-use model. On-Demand instance is sold at a fixed price, and AWS computer availability is guaranteed (within the limits of the service-level agreement). **Running Real-ESSI On-Demand Instance**: User prepares simulation runs, and then can simulate problems at hand immediately.

  - **Spot instance**, uses spare AWS computers that users can bid for. Prices for those spot instances fluctuate based on the supply and demand of available AWS computers. When a user makes a bid for a Spot instance, a spot instance is launched when the bid exceeds the current Spot market price, and continues until terminated by the user. The user is charged the Spot market price, not the bid price while the instance runs. Spot instances can offer substantial savings over On-Demand instances, as shown in the AWS Spot Bid Advisor. **Running Real-ESSI using Spot instance**: User can prepare simulation runs, and then bid on computer hardware and run simulations at later time, when cost is acceptable.

  - **Reserved instance**, uses spare AWS computers during scheduled, later time as determined by AWS and reserved by the user. **Running Real-ESSI using Reserved Instance**: User prepares simulation runs, and then reserves AWS computer to simulate problem at hand at predetermined/reserved time.

- **AWS data storage cost**

  Input data/files and output data/files are stored using:

  - **Amazon Elastic Block Store (EBS)**, attached to a AWS computer (EC2 instance) during simulation run. Storage cost is charged by the size of storage in GB per month, pro-rated to the hour, until the storage is released. The cost of EBS is typically $0.10 per GB per month. When running Real-ESSI program on AWS computer, the storage is used during simulation, while the data (input and output) is transferred out of the AWS computer, to other type of storage that is less expensive (the so called S3 storage, see below), or to user’s desktop computer, before AWS computer/instance is terminated and storage released.

  - **Amazon Simple Storage Service (S3)**, offers better value for longer term data storage. S3 pricing varies by region and frequency of access. Cost of S3 storage is typically between $0.0125 are $0.03 per GB per month.
- **Amazon Glacier**, provides storage at an even lower cost of $0.007 per GB per month for data archiving.

- **AWS data transfer cost**
  
  Data transfer charges are listed as part of the On-Demand EC2 pricing. Transfer is typically charged at $0.09 per GB beyond the first 1GB of data and up to the first 1TB of a given month. After the first TB, price drops down.

- **Real-ESSI program cost**
  
  Use of Real-ESSI for educational purposes is free. For commercial use of Real-ESSI, please contact Prof. Jeremić or one of the commercial companies that offer access to Real-ESSI on AWS.
1.8.1 Cost of Running Real-ESSI on AWS

Small Size Real-ESSI Example

Imposed Motion  Real-ESSI modeling and simulation on AWS summary:

- DOFs in the Model: 5,000
- Number of Time Step: 210
- Running Time: 30 Second
- Disk Space: 25 MB.
- Recommended Machine: Free Instance Amazon EC2 t2.micro

The Real-ESSI input files for this example are available HERE. The compressed package of input files is HERE.

The Modeling parameters are listed below

- Elastic Material Properties
  - Mass density, $\rho$, $2000 \text{ kg/m}^3$
  - Shear wave velocity, $V_s$, $500 \text{ m/s}$
  - Young’s modulus, $E$, $1.1 \text{ GPa}$
  - Poisson’s ratio, $\nu$, $0.1$

The thickness of the shell structure is 2 meters. The simulation model is shown below.

The simulation results:

- The time series of simulation results is shown in Fig. 1.17.
- The response spectrum of motion is shown in Fig. 1.18.
Figure 1.15: Simulation Model.

Figure 1.16: Simulation Results.
Figure 1.17: Simulation Results: Acceleration Time Series with 1C imposed motion.
Figure 1.18: Simulation Results: Response Spectrum of Structure Top with 1C imposed motion.
**Eigen Analysis**  Real-ESSI modeling and simulation on AWS summary:

- DOFs in the Model: 5,000
- Number of Eigenmodes: 10
- Running Time: 3 Second
- Disk Space: 25 MB.
- Recommended Machine: Free Instance Amazon EC2 t2.micro

The Real-ESSI input files for this example are available [HERE](#). The compressed package of input files is [HERE](#).

The thickness of the shell structure is 2 meters. The simulation model is shown below.

![Simulation Model](image_url)

**Figure 1.19: Simulation Model.**

The eigen results:
Figure 1.20: Eigen Results (Eigen Mode 1 to 3 from left to right).

Figure 1.21: Eigen Results (Eigen Mode 4 to 6 from left to right).
Medium Size Real-ESSI Example

**Elastic Material**  The compressed package of input files is available [HERE](#).

Real-ESSI modeling and simulation on AWS summary:

- **DOFs in the Model:** 132,000
- **Number of Time Steps:** 210
- **Running Time:** 10 minutes
- **Disk Space:** 3GB
- **Recommended Machine:** Amazon EC2 c4.2xlarge instance 8 cores
- **Estimated Bill in AWS Region Oregon/Ohio/Northern Virginia:**
  - For simulation time: $0.398 \times 10/60 = $0.07
  - For General Purpose (SSD) Storage: $0.1 \times 3 = $0.3 (monthly)
  - For S3 Storage: $0.023 \times 3 = $0.069 (monthly)

The Modeling parameters are listed below

- **Elastic Material Properties**
  - Mass density, $\rho$, 2000 $kg/m^3$
  - Shear wave velocity, $V_s$, 500 $m/s$
  - Young’s modulus, $E$, 1.1 GPa
  - Poisson’s ratio, $\nu$, 0.1

The illustration results of the simulation is shown in Fig. 1.23. It is noted that outside the DRM layer, there are no outgoing waves.

**von-Mises Armstrong-Frederick Material**  The compressed package of input files is available [HERE](#).

Real-ESSI modeling and simulation on AWS summary:

- **DOFs in the Model:** 132,000
- **Number of Time Steps:** 210
- **Running Time:** 46 minutes
Figure 1.22: Simulation Model.

Figure 1.23: Simulation Model.
• Disk Space: 3GB

• Recommended Machine: Amazon EC2 c4.2xlarge instance 8 cores.

• Estimated Bill in AWS Region Oregon/Ohio/Northern Virginia:
  - For simulation time: $0.398 \times 46/60 = $0.31
  - For General Purpose (SSD) Storage: $0.1 \times 3 = $0.3 (monthly)
  - For S3 Storage: $0.023 \times 3 = $0.069 (monthly)

The Modeling parameters are listed below

• von-Mises nonlinear hardening material model
  - Mass density, $\rho$, 2000 kg/m$^3$
  - Shear wave velocity, $V_s$, 500 m/s
  - Young’s modulus, $E$, 1.1 GPa
  - Poisson’s ratio, $\nu$, 0.1
  - von Mises radius, $k$, 60 kPa
  - Nonlinear kinematic hardening, $H_a$, 30 MPa
  - Nonlinear kinematic hardening, $C_r$, 60
  - Shear strength ($\approx \sqrt{2/3} \frac{H_a}{C_r}$), $S_u$, 408 kPa
  - Isotropic hardening rate, $K_{iso}$, 0 Pa

SIMULATION TIME: With 8 cores on AWS EC2 c4.2xlarge instance, the running time for this example is 46 minutes.
Large Example

Elastic Simulation  The Real-ESSI input files for this example are available HERE. The compressed package of Real-ESSI input files for this example is available HERE.

Real-ESSI modeling and simulation on AWS summary:

- DOFs in the Model: 210,000
- Number of Time Steps: 2065
- Running Time: 17 hours
- Disk Space: 45GB
- Recommended Machine: Amazon EC2 c4.8xlarge instance 36 cores.
- Estimated Bill in AWS Region Oregon/Ohio/Northern Virginia:
  - For simulation time: $1.591 \times 17 = $27.05
  - For General Purpose (SSD) Storage: $0.1 \times 45 = $4.5 \text{ (monthly)}
  - For S3 Storage: $0.023 \times 45 = $1.035 \text{ (monthly)}
  - For Network Bandwidth if transfer: $0.09 \times 45 = $4.05

SIMULATION TIME: With 32 cores on AWS EC2 c4.8xlarge instance, the running time for this example is 17 hours.

![Simulation Model](image)

Figure 1.24: Simulation Model.

The Modeling parameters are listed below
- Soil
  - Unit weight, $\gamma$, 21.4 kPa
  - Shear velocity, $V_s$, 500 m/s
  - Young’s modulus, $E$, 1.3 GPa
  - Poisson’s ratio, $\nu$, 0.25
  - Shear strength, $S_u$, 650 kPa
  - von Mises radius, $k$, 60 kPa
  - kinematic hardening, $H_a$, 30 MPa
  - kinematic hardening, $C_r$, 25

- Structure
  - Unit weight, $\gamma$, 24 kPa
  - Young’s modulus, $E$, 20 GPa
  - Poisson’s ratio, $\nu$, 0.21

The input motion is a 3C wave from SW4.
Inelastic Simulation  The Real-ESSI input files for this example are available HERE. The compressed package of Real-ESSI input files for this example is available HERE.

Real-ESSI modeling and simulation on AWS summary:

- DOFs in the Model: 210,000
- Number of Time Steps: 2065
- Running Time: 30 hours
- Disk Space: 45GB
- Recommended Machine: Amazon EC2 c4.8xlarge instance 36 cores.
- Estimated Bill in AWS Region Oregon/Ohio/Northern Virginia:
  - For simulation time: $1.591 \times 30 = \$47.73$
  - For General Purpose (SSD) Storage: $0.1 \times 45 = \$4.5$ (monthly)
  - For S3 Storage: $0.023 \times 45 = \$1.035$ (monthly)
  - For Network Bandwidth if transfer: $0.09 \times 45 = \$4.05$

SIMULATION TIME: With 32 cores on AWS EC2 c4.8xlarge instance, the running time for this example is 30 hours.

The Modeling parameters are listed below

- Soil
  - Unit weight, $\gamma$, 21.4 kPa
  - Shear velocity, $V_s$, 500 m/s
  - Young’s modulus, $E$, 1.3 GPa
  - Poisson’s ratio, $\nu$, 0.25
  - Shear strength, $S_u$, 650 kPa
  - von Mises radius, $k$, 60 kPa
  - kinematic hardening, $H_a$, 30 MPa
  - kinematic hardening, $C_r$, 25

- Structure
  - Unit weight, $\gamma$, 24 kPa
- Young's modulus, $E$, 20 GPa
- Poisson's ratio, $\nu$, 0.21

- Contact
  - Initial axial stiffness, $k_{n}^{\text{init}}$, 1e9 N/m
  - Stiffening rate, $S_{r}$, 1000 /m
  - Maximum axial stiffness, $k_{n}^{\text{max}}$, 1e12 N/m
  - Shear stiffness, $k_{t}$, 1e7 N/m
  - Axial viscous damping, $C_{n}$, 100 N·s/m
  - Shear viscous damping, $C_{t}$, 100 N·s/m
  - Friction ratio, $\mu$, 0.25

Figure 1.25: Simulation Model.
1.8.2 **AWS for Education**

Amazon Web Services provides grants for educators and students from member institution\(^2\) through AWS Educate program. AWS Educate offers cloud content, training, collaboration tools and AWS technology **at no cost**. Some of the AWS Educate program benefits:

- **For Educators**
  - $200 in AWS credits per educator - at member institutions.
  - $75 in AWS credits per educator - at non-member institutions.
  - Free AWS Technical Essentials eLearning course.
  - Free access to AWS content for classes.

- **For Students**
  - $100 in AWS credits per student - at member institutions.
  - $40 in AWS credits per student - at non-member institutions.
  - Access to AWS Technical Essentials Training Course (a $600 value).

If you have an email address from an educational institutions, you can use Real-ESSI on AWS for free through AWS Educate.

\(^2\)List of member institution is available at this [LINK](#).
1.8.3 AWS for Government

AWS GovCloud

AWS Secret Region
Bibliography