Head Count Detection Using Apache Mesos

Anurag Kumar Jain[1,*], Pratik Sushil Jain[1,*], and Ronak Parekh[1,*]

[1] School of Informatics and Computing, Bloomington, IN 47408, U.S.A.
[*] Corresponding authors: jainanur@iu.edu, jainps@iu.edu, parekhr@iu.edu

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Apache Mesos can be used for scaling of applications and providing highly available clusters. It provides the functionality to use resources from multiple agents and execute the application using the offered resources. Deployment of a custom face detection application is done using Ansible on Apache Mesos and analysis of the deployments are benchmarked. The face detection application was created using OpenCV. Ansible playbooks are used to deploy Apache Mesos on virtual machines created on chameleon cloud. For benchmarks, deployment of Mesos on different systems and different sizes of virtual machines were carried out.

Keywords: Cloud, I524, Apache Mesos, OpenCV, Face detection, Mesospehere, Ansible, Big Data, Zookeeper, Marathon, Haar Cascade

Report: https://github.com/cloudmesh/sp17-i524/tree/master/project/S17-IR-P011/report/report.pdf
Code: https://github.com/cloudmesh/cloudmesh.mesos

1. INTRODUCTION

There are a number of applications which require the counting of people in an image. The application for detecting headcount in an image can be in the field of attendance management and tagging images on social media. The purpose of this project is to deploy a head count detection framework on Apache Mesos to enable distributed processing of image data over the cloud. Apache Mesos is built using the same principles as the Linux kernel but at a different level of abstraction. It runs on every machine and provides applications with API's for resource management and scheduling across different cloud infrastructures [1]. Ansible is used to automate the deployment of the head count detection application on Apache Mesos which will be deployed on Chameleon cloud. The VGG face detection dataset is used for benchmarking the performance of Mesos on different versions of the Linux Operating System. The head count detection is restricted to detection of the number of frontal faces in an image [2]. This is due to the field of face detection and image processing being vast and thus the head count detection is restricted to detecting faces based on simple criteria. The performance benefits of Apache Mesos in terms of high availability, scalability and fault tolerance are leveraged by deploying the application on a virtual machine which offers its computing resources to Mesos for fast computation.

2. WHY MESOS?

Mesos can be used to implement a decentralized scheduling approach. In this approach, each framework decides which offers to accept or reject. There are many incentives that are provided by any decentralized system. The incentives provided by Apache Mesos system includes short tasks, no minimum allocation, scale down and not accepting unknown resources [3].

3. WHAT IS MESOS?

Mesos is built using the same principles as the Linux kernel. However, it is at a different level of abstraction. The Mesos kernel runs on every machine and provides applications such as Hadoop, Spark, Kafka, Elastic Search with API's for resource management and scheduling across entire cloud environments and data center [3].

3.1. Design Philosophy

Mesos aims to provide a resilient core to enable various frameworks for efficient cluster sharing. As cluster frameworks are rapidly evolving and highly diverse, this overriding design philosophy focussing on defining a minimal interface enabling efficient resource sharing across frameworks and otherwise push control of task scheduling and execution to the frameworks. Pushing control to the frameworks has two benefits. It allows frameworks to implement diverse approaches to various problems in the cluster and to evolve these solutions independently. This also keeps Mesos simple and minimizes the rate of change required, which makes it easier to keep Mesos scalable and robust. Higher level libraries implementing common functionality are built on top of Mesos even though Mesos provides a low-level interface. Including the functionality in libraries rather than in Mesos allows it to remain small and flexible and lets the libraries evolve independently.

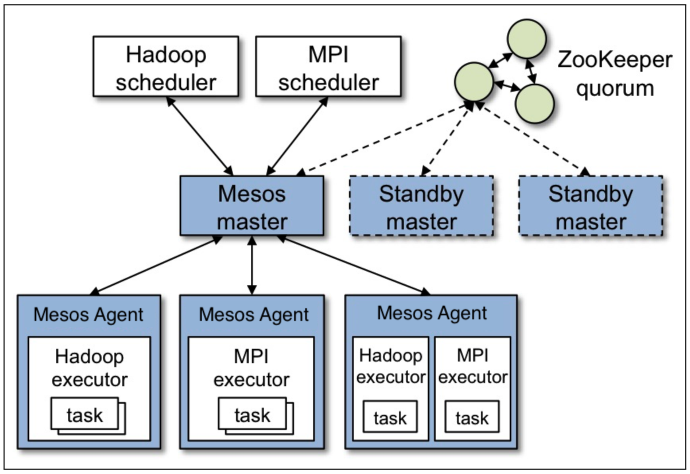

Fig. 1. Mesos architecture [4].

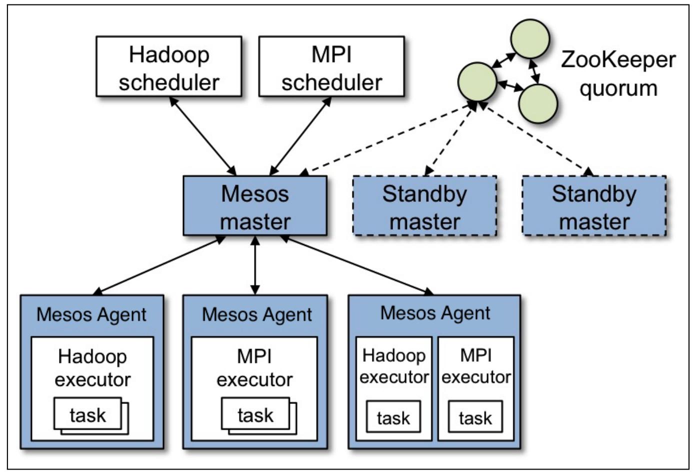

Fig. 2. Example Flow [4].

3.2. Architecture

Mesos consists of a master daemon through which an agent running on each cluster node is managed. It also consists of a Mesos Framework that runs tasks on these agents. The master enables the fine-grained sharing of resources including CPU and RAM across all the frameworks by making resource offers. Each resource offer contains a list of <agent ID, resource1:amount1, resource2: amount2,...> [4]. The master decides how many resources to offer to each framework based on an organizational policy such as strict priority or fair sharing. A diverse set of policies is supported by employing a modular architecture that makes it easy to add new allocation modules via a plug-in mechanism [1].

A framework running on top of Mesos consists of two components: an executor process that can be launched on agent nodes to run framework tasks and a scheduler that registers with the master to the resource offered. While the master determines how many resources are offered to each framework, the framework scheduler selects which of the offered resources to use. When a framework accepts offered resources, the description is passed to Mesos [4].

The sequence of events in the figure are as follows:

1. Agent 1 reports to the master that it has 4 CPU's and 4GB of memory free. An allocation policy module is invoked by the master which tells it that framework 1 should be offered all available resources [4].

2. The master sends a resource offer to framework 1 which includes details of which resources are available on agent 1.

3. A reply is sent back to the master by the frameworks scheduler with information regarding two tasks to run on the agent, using <2CPU's, 1 GB RAM> for the first task, <1CPU and 2 GB RAM> for the second task [4].

4. Finally the master sends the task to the agent which allocates appropriate resources to the frameworks executor which in turn launches the two tasks. The allocation module may now offer the unallocated resources to framework 2 [4].

The resource offer process repeats when new resources become free or when tasks are finished.

4. MESOS FRAMEWORK

A Mesos Framework is used to manage tasks. A Mesos framework is highly available only if it continues to manage tasks correctly in the presence of a variety of failure scenarios. There are failure conditions which the framework should consider. The conditions are as follows:

- A framework scheduler which is connected to a Mesos master might fail. It may be due to crashing or losing network connectivity. If the master has been configured to use the high availability mode, this will promote a replica of another Mesos master to become the new leader. In this case, the scheduler re-registers with the new master and ensure the task state is consistent [5].

- A host may fail where a framework scheduler is running. While creating the framework, the framework authors should ensure that multiple copies of the scheduler run on different nodes and a backup copy is promoted to become the new leader where a previous leader fails. This is done to ensure that the framework remains available and can continue to run new tasks [5].

- The host might fail on which a task is running. The node might not have failed but the Mesos agent on the node might be unable to communicate with the Mesos master due to a network partition [5].

4.1. Internal Working of Framework

When the agents are connected to the Mesos master, they offer resources to the Mesos master in terms of CPU's, RAM and disk space. These resources are available for the master to use till the agents are in the active state. There can be multiple states for the Mesos agents such as Active state, Deactivated state and Unreachable state. When an agent is successfully able to connect to the master, it is in the active state. When an agent is not able to advertise its IP address to the master, the agent state is changed to deactivated. If there are network outages and the agent is unable to reach the master, it goes in the unreachable state. The master is able to use the resources offered by the agent only if the agent is in the active state. When the face detection framework is started on Mesos master, the master searches for any available resource offers from the active agents. It breaks the execution of the framework into multiple tasks and uses the resource offers to execute the task. The task runs on multiple CPU's if available, and after completion of each task a status update is sent to the Mesos master. Each individual task is assigned a unique task id. If an agent doesn't update the status of the task due to network outage or failure of the agent, the Mesos master persists the task id and it assigns the task id to a new agent which has resources available and the task is resumed. The framework state changes to active when the tasks of the framework are running and changes to completed when the execution of the framework is finished.

4.2. Highly Available Frameworks

Mesos provides unreliable messaging between components by default: Messages are delivered at most once by default. Framework authors should take into consideration that the messages they sent might not be received and should be prepared to take corrective action. Timeouts are used to detect whether a message is lost. There are situations where the framework attempts to launch a task but the message does not reach the Mesos master [5]. To address such issues a framework scheduler should set a timeout after attempting to launch a new task. The scheduler should take corrective action if the scheduler does not receive a status update and thereby launching a new copy of the task [4].

In general, distributed systems cannot distinguish between 'lost' messages and messages that are delayed. There might be a case where the scheduler might see a status update for the attempt of the first task launch immediately after its timeout has fired but it has already begun to take corrective action. Mesos provides ordered message delivery between any pair of processes. If a framework sends a message M1 and M2 to the master, then the master might not receive any messages, or it may receive only M1 or, only M2 or, M1 followed by M2. But it will never receive messages in the order M2 followed by M1 [5]. Mesos also provides reliable delivery of the task status updates. The agent persists task status updates to disk and then forwards them to the master. The master sends status updates to the appropriate framework scheduler. When a scheduler acknowledges a status update, the master forwards the acknowledgment back to the agent, which allows the stored status update to be garbage collected. If the agent does not receive an acknowledgment for a task status update within a specific amount of time, it will repeatedly resend the status update to the master, which will again forward the update to the scheduler. Hence, task status updates will be delivered "at least once", assuming that the agent and the scheduler both remain available [5].

The information about the active tasks and registered frameworks is stored by the Mesos master in memory. Persistent storage is not used and it does not ensure that the information is preserved even after the master is failed. This feature helps the Mesos master to scale to large clusters with many tasks and frameworks [5]. If all the Mesos masters are unavailable or crashed, the cluster should continue to operate. The existing Mesos agents and user tasks should continue running but new tasks cannot be scheduled and frameworks will not receive resource offers or status updates about previously launched tasks. Mesos does not dictate how frameworks should be implemented and does not try to assume responsibility for how frameworks should deal with failures [5].

4.3. Designing Highly Available Frameworks

The patterns followed for designing highly available networks are as follows:

- Frameworks run multiple scheduler instances to tolerate scheduler failures. Only one of the scheduler instances is the leader at any particular given point in time. This instance is connected to the Mesos master, it receives resource offers and task status updates and launches new tasks. The other available scheduler replicas are followers. They are used only when the leader fails and in that case one of the followers is chosen to become the new leader via polling [5].
- The election of a new leader is done via a mechanism and schedulers need that mechanism when the scheduler has failed. This mechanism is typically provided using a coordination service. This coordination service can be Apache ZooKeeper [5].
- After election is conducted and a new leading scheduler is elected, the new leader should reconnect to the Mesos master. When the master is registered, the framework should set the id field in its FrameworkInfo to the ID that was assigned to the failed scheduler instance. This ensures that a new session is not started by the master and the master recognizes the connection. Thus, it will continue the session used by the failed scheduler instance.
- After connecting to the Mesos master, the newly elected leading scheduler should maintain the consistency of its local state with the current state of the cluster. If the previous leading scheduler attempted to launch a new task and then failed immediately, the task might have launched successfully and the newly elected leader will start to receive updates regarding it [5]. Frameworks typically use a consistent distributed data store to record information about active and pending tasks. The coordination service that is used to elect the master can be used for this purpose. Mesos replicated logs can also be used to achieve this. The data store is used to record the actions that the scheduler intends to take, before it takes them. If a scheduler intends to launch a task, it first writes this intent to its data store. It then sends a launch task message to the Mesos master. This helps in cases when the instance of the scheduler fails and a new scheduler is promoted to become the leader, the newly elected leader then consults the data store to find all the possible tasks that might be running on the cluster.

  The approach is called as write-ahead logging pattern. The key aspects of this approach can be summarized as one when the scheduler must persist its intent before launching task. If the task is launched and then the scheduler fails before it can write to the data store, the new scheduler instance is unaware of the new task. In this case, the new scheduler instance will begin receiving the task status updates for a task it has no knowledge of. Another aspect is that the scheduler should ensure that its intent has been durably recorded in the data store before it continues to launch the task [5].

5. LIFE CYCLE OF A TASK

A Mesos task transitions through a sequence of states. The agent is the actual source from which the state of a task can be determined. The agent on which the task is running provides information regarding the actual state of the task. The framework scheduler learns about the current state of the task by communicating with the Mesos master [4]. It does learn by listening for task status updates and performing task state reconciliation. The task states are represented by the frameworks using a state machine. It can have one initial state and possibly several terminal states [5].

TASK_STAGING state is the first state of the task. The task begins in the TASK_STAGING state and is in this state when the framework sends the request to the master. The master receives the request to launch the task but the task has not yet started to run [5].

TASK_STARTING state is intended to be used by executor which are custom implemented. This state can be used to describe that a custom executor is aware of the task and might have started fetching its dependencies but it hasn't yet started [5].

TASK_RUNNING is the state when a task transitions to after it has begun running successfully. The framework should perform reconciliation when it attempts to launch a task but does not receive a status update within a particular timeout interval. For unknown tasks, the master will reply with the TASK_LOST status. The framework uses this to distinguish between the tasks that are slow to launch and the tasks that the master is unaware about [5].

TASK_KILLING state is an optional state which is intended to indicate that the request has been received by the executor but the corresponding task has not yet been killed. This might be useful for tasks to be killed smoothly. Executors should not generate this state unless the framework has the TASK_KILLING_STATE capability [5].

There are several terminal states such as TASK_FINISHED which depicts when a task is completed successfully, TASK_FAILED indicates that the task is aborted with an error, TASK_KILLED indicates that a task was killed by the executor, TASK_LOST depicts that the task was running on an agent that has lost contact with its master and TASK_ERROR indicates that a task is launched but its attempt to launch the task has failed because of an error in the task specification [5].

6. COMPARISON OF MESOS, DOCKER AND KUBERNETES

Mesos, Kubernetes and Docker fall into DevOps infrastructure management tools known as Container Orchestration Engines(COEs) [6]. An abstraction layer of protocols are provided by COEs between a pool of resources and the containers of application that run on these resources. COEs also solve the problem of taking multiple discrete resources in the cloud and combine them into a single pool. This pool can be used to deploy a variety of applications. These tools provide a set of features such as Container scheduling, High Availability, Health checks, Service discovery and Load balancing. Container scheduling comprises of performing functions which start and stop containers, distributing containers amongst pooled resources, failure recovery of containers, rebalancing containers from hosts that are failed to hosts that are healthy and scaling of applications [6]. High availability of application and container is provided by these tools. The health checks are used to determine the container and application health while service discovery is used to determine the services which are located on a network [6].

6.1. Kubernetes Container Orchestration Capailities

Kubernetes project originated to resolve the issue of running containers at a massive scale. Kubernetes uses YAML-based deployment model. It is used to manage the scheduling the containers on host machines. It also includes features such as built-in auto-scaling, secrets management, load balancing and volume management. It requires less third party software than Mesos and Swarm. It consists of a concept of pods which are groups of containers that are scheduled together to form a service. It doesn't support single node master installations with highly available clusters. The learning curve of Kubernetes is steeper than Swarm.

6.2. Swarm Container Orchestration Capabilities

Docker Swarm is a native Docker Container Orchestration Engine. Swarm is tightly integrated with the Docker API which makes it extremely suitable for its use with Docker. Swarm uses the same primitives as applicable to single host docker cluster. It simplifies managing container infrastructure as there is no need to configure a different orchestration engine. Swarm also uses a YAML-based deployment model using Docker Compose. Its main features includes auto-healing of clusters, overlay networks with DNS, and usage of multiple masters for high availability. Swarm does not support native auto-scaling as well as external load balancing. Swarm includes the capability of ingress load balancing but it requires a third party load balancer for external load balancing.

6.3. Mesos Container Orchestration Capabilities

Apache Mesos takes a more distributed approach to managing datacenter and cloud resources. Mesos uses Zookeeper to manage multiple masters and form a high-availability cluster. Other container management frameworks can be run on top of Mesos including Kubernetes, Apache Aurora, Chronos, and Mesosphere Marathon. The Mesosphere DC/OS, distributed datacenter operating system is based on Apache Mesos. Mesos takes a modular approach to managing containers which allow flexibility in the type of applications that can be run on Mesos and also the scale to which the applications can be run. It can scale upto tens of thousands of nodes and is used by Twitter, Airbnb, Yelp and eBay. The most important features are multiple types of container engines including Docker and its own Containerizer which comes along with a web UI, and its ability to run on multiple Oses including Linux, OS X and even Windows. Due to its complexity and flexibility, Mesos has a steeper learning curve than Docker Swarm.

7. ANSIBLE

Ansible is an open source automation engine which can be used to automate cloud provisioning, configuration management, and application deployment [7]. It is designed to be minimal in nature, secure, consistent, and highly reliable [8]. In many respects, it is unique from other management tools and aims to provide large productivity gains. It has an extremely low learning curve and seeks to solve major unsolved IT challenges under a single banner [7].

7.1. Architecture

One of the primary differences between Ansible and many other tools in the space is its architecture. Ansible is an agentless tool, it doesn't require any software to be installed on the remote machines to make them manageable. By default it manages remote machines over SSH or WinRM, which are natively present on those platforms [9].

Like many other configuration management softwares, Ansible distinguishes two types of servers: controlling machines

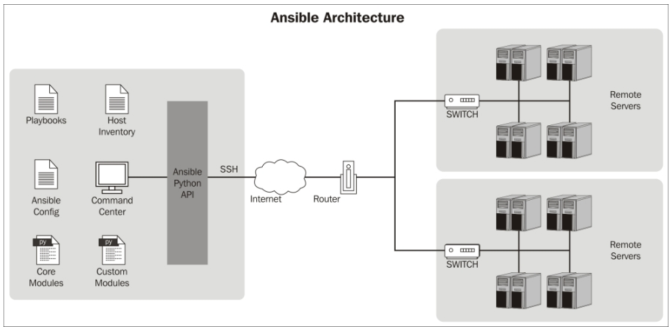

Fig. 3. Ansible Architecture [10].

and nodes. Ansible uses a single controlling machine where the orchestration begins. Nodes are managed by a controlling machine over SSH. The location of the nodes is described by the inventory of the controlling machine [8].

Modules are deployed by Ansible over SSH. These modules are temporarily stored in the nodes and communicate with the controlling machine through a JSON protocol over the standard output [9].

The design goals of Ansible includes consistency, high reliability, low learning curve, security and to be minimalistic in nature. The security comes from the fact that Ansible doesn't require users to deploy agents on nodes and manage remote machines using SSH or WinRM. If needed, Ansible can connect with LDAP, Kerberos, and other centralized authentication management systems [11].

7.2. Advanced Features

The Ansible Playbook language includes a variety of features which allow complex automation flow, this includes conditional execution of tasks, the ability to gather variables and information from the remote system, ability to spawn asynchronous long running actions, ability to operate in either a push or pull configuration, it also includes a check mode to test for pending changes without applying change, and the ability to tag certain plays and tasks so that only certain parts of configuration can be applied [8]. The features allow your applications and environments to be modeled simply and easily, in a logical framework that is easily understood. Ansible has low overhead and is much smaller when compared to other tools like Puppet [12].

7.3. Playbook and Roles

Playbook is what Ansible uses to perform automation and orchestration. They are Ansible's configuration, deployment, and orchestration language. They can be used to describe policy you need your remote systems to enforce, or a set of steps in a general IT process [13].

At a basic level, playbooks can be used to manage configurations and deployments to remote machines. While at an advanced level, they can be utilized to sequence multi-tier rollouts which involve rolling updates, and can also be used to delegate actions to other hosts, interacting with monitoring servers and load balancers at the same time.

Playbooks consist of series of plays, which are used to define automation across a set of hosts, known as the 'inventory'. These 'play' generally consists of multiple 'tasks', that can select one, many, or all of the hosts in the inventory where each task is a call to an Ansible module - a small piece of code for doing a specific task. The tasks may be complex, such as spinning up an entire cloud formation infrastructure in Amazon EC2 or Chameleon. Ansible includes hundreds of modules which help it perform a vast range of tasks [9].

Similar to many other languages Ansible supports encapsulating Playbook tasks into reusable units called 'roles'. These roles can be used to easily apply common configurations in different scenarios, such as having a common web server configuration role which can be used in development, test, and production automation. The Ansible Galaxy community site contains thousands of customizable rules that can be reused used to build Playbooks.

Playbook can be used to combine multiple tasks to achieve complex automation [13]. Playbook and Ansible can be easily used in implementing a cluster-wide rolling update that consists of consulting a configuration/settings repository for information about the involved servers, configuring the base OS on all machines and enforcing the desired state. It can also be used in signaling the monitoring system of an outage window prior to bringing the servers offline and signaling load balancers to take the application servers out of a load balanced pool [9].

7.4. Integration Of Cloud And Infrastructure

Ansible can easily deploy workloads to a variety of public and on-premise cloud environments. This capability includes cloud providers such as Amazon Web Services, Microsoft Azure, Rackspace, Cloudmesh, and Google Compute Engine, and local infrastructure such as VMware, OpenStack, and CloudStack. This includes not just compute provisioning, but storage and networks as well and the capability doesn't end here. As noted, further integrations are easy, and more are added to each new Ansible release. As Ansible is open source, anyone can make his/her contributions [9].

8. OPENCV

OpenCV stands for Open Source Computer Vision Library. It is an extensively used open source machine learning and computer vision software library. OpenCV was built with a motive to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial products. Being an open source library licensed under BSD-licensed product, OpenCV makes it easy for anyone to utilize and modify the code [14].

The library has a number of optimized algorithms, which includes a comprehensive set of both classic and advanced computer vision and machine learning algorithms. The algorithms can be used for a variety of purposes ranging from face detection, object identification, classification of human actions to tracking moving objects, extracting 3D models of objects. It has C++, C, Python, Java and MATLAB interfaces and supports Windows, Linux, Android and Mac OS. OpenCV leans mostly towards real-time vision applications and takes advantage of single instruction, multiple data (SIMD) and Streaming SIMD Extensions instructions when available [14].

9. FACE DETECTION

Face detection is a specific case of object-class detection. In object-class detection, the task is to find the locations and sizes of all objects in an image that belong to a given class. Face-detection algorithms focus on the detection of frontal human faces. It is analogous to image detection in which the image of a person is matched bit by bit. Image matches with the image stored in database. Any facial feature changes in the database will invalidate the matching process [15].

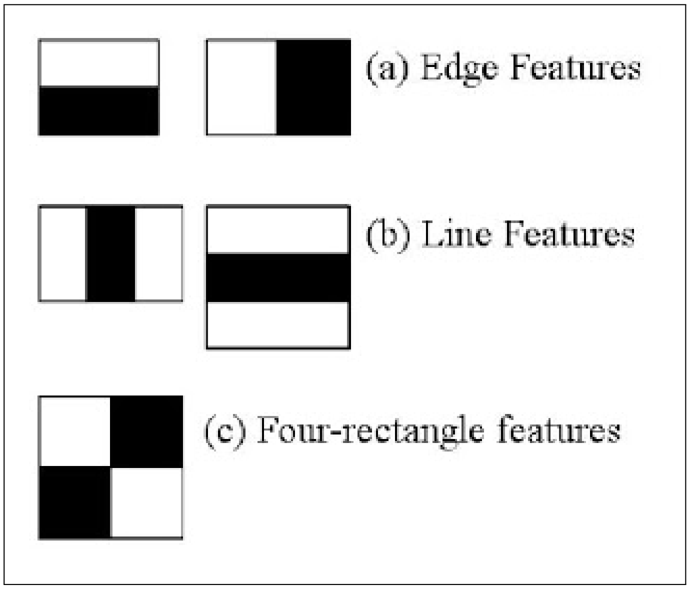

Fig. 4. Features [15].

A number of approaches are used but the most common one which our project utilized is a method where the possible human eye regions are detected by testing all the valley regions in the gray-level image. The basic idea is eyes (white) is separated by darker shades (skin color) above and below it. Then the genetic algorithm is used to generate all the possible face regions which include the eyebrows, the iris, the nostril and the mouth corners [15].

Each possible face candidates is normalized to reduce lightning effect caused due to uneven illumination and the shirring effect due to head movement. The fitness value of each candidate is measured based on its projection on the eigen-faces. After a number of iterations, all the face candidates with a high fitness value are selected for further verification. At this stage, the face symmetry is measured and the existence of the different facial features is verified for each face candidate.

We have utilized face detection Haar cascade provided by OpenCV. The Haar cascade is a classifier achieved using machine learning algorithm known as AdaBoost [16]. Initially, the AdaBoost algorithm required a lot of positive images (images of faces) and negative images (images without faces) to train the face detection classifier. Then the features are extracted from it. Each feature is a single value obtained by subtracting sum of pixels under imaginary white rectangle from sum of pixels under black rectangle [15].

All possible sizes and locations of each kernel are used to calculate plenty of features. For each feature calculation, we need to find sum of pixels under white and black rectangles. Among all the features generated, most of them are irrelevant. To select best features, they are applied to each and every feature on all the training images. For each feature, it finds the best threshold which will classify the faces to positive and negative. There will be errors or misclassifications but when results from all the features are combined the results are excellent. Out of all the features, the features with the minimum error rate, are the features that best classifies the face and non-face images.

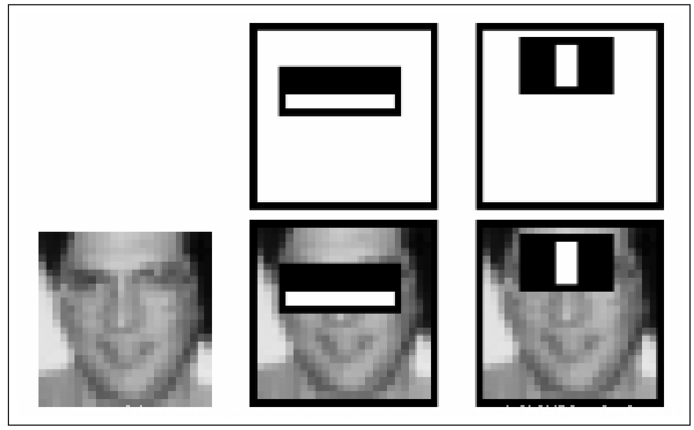

Fig. 5. Basic idea behind features [15].

Final classifier is a weighted sum of these weak classifiers/features. It is considered as weak classifier because it can't classify the image alone, but together with other classifiers, forms a strong classifier. The combined results obtained from all the features help to identify if a face is present in the image, and if it is then the classifier also tells the user about the dimensions of the rectangle and the starting x, y coordinate of that rectange on the image [16].

10. IMPLEMENTATION

In our implementation, we used Ansible version 2.2.1.0, Mesos version 1.2.0, Python version 2.7.12 and OpenCV version 3.2. The deployment was done on chameleon cloud. Firstly, cloudmesh client is set up on the local machine and ansible is installed. A new security is created and the ports 5050 and 5051 are exposed. The default security group was also included which exposed ports 22, 80 and 443. Port 22 is used for accessing the remote machine. The virtual hardware template(flavor) used is m1.medium and the image used was CC-Ubuntu16.04-20161214. A virtual hardware template defines the size of RAM, disk size, and number of cores. The flavor m1.medium specifies 2 VCPU's used, 40 GB root disk, 4096 MB RAM. The cluster was setup to have 3 virtual machines(nodes). Amongst the 3 virtual machines, one was used as Mesos master and the remaining two were used as Mesos agents(slaves). The profile details for cloudmesh client have been set up. The cloudmesh client setup was validated. The system has been deployed using Ansible roles. For the deployment, the system has been divided into multiple roles such as inventory role(r_inventory) , role for create swap file(r_swap), mesos(r_mesos) role, master(r_master) role, agent(r_agent) role, role for copying framework(r_copy_framework) and role for running framework(r_run_framework).

11. ROLES

The functionality of the Ansible roles are explained as below:

11.1. Inventory

The role r_inventory was used for inventory setup on the local machine. Firstly, the operating cluster was selected and its node details were obtained. These nodes were added to the known hosts file under the ssh directory. The inventory was created selecting two nodes as Mesos agents and one as Mesos master and were tagged accordingly in the inventory file.

11.2. Create Swap file

Swap space in Linux is used when the amount of physical memory is full. If the system needs more memory resources and the RAM is full, inactive pages in memory are moved to the swap space. Initially, the built was unsuccessful when attempts were made with RAM size of 2GB, 4GB and 8GB. It was observed, the virtual machines created had no swap space defined. The swap size was increased to 2GB after which Mesos was successfully installed. All these observations led to the conclusion that for successfully installing Mesos on a virtual machine minimum of 2GB swap space is required. The playbook r_create_swap successfully creates a swap file of 5GB on all the remote machines.

11.3. Mesos

The Mesos package is downloaded from the Mesos website. The latest version of Apache Mesos is 1.2.0 and it is uncompressed on the virtual machines. All the existing softwares on the virtual machines are updated. The dependencies required for Mesos 16.04 are openjdk-8-jdk, python-dev, build-essential, python-virtualenv, libcurl4-nss-dev, libsasl2-dev, libsasl2-modules, maven, libapr1-dev, libsvn-dev, zlib1g-dev, git. These packages are specific to different distribution and versions of OSes. Now, the dependencies required for face detection framework are installed. The dependencies include python-pip, numpy and opencv-python to support face detection framework. In Mesos, applications are deployed as frameworks. Mesos is configured using the configure command. In order to install Mesos on the virtual machines, the make and make check commands are executed.

11.4. Mesos Master

The Mesos master is run on the host which was selected as the Mesos master in the inventory file. The working directory for Mesos is selected. The IP address of this virtual machine is advertised using the tag –advertise_ip. The Mesos master runs on default port 5050. The Mesos master can be validated by entering the IP address followed by the port number of the Mesos master in a Web browser on a local machine.

11.5. Mesos Agent

The Mesos agent is run on the hosts which were selected as the Mesos agents in the inventory file. The working directory for Mesos is selected. The IP address of the Mesos agents are advertised and the IP address of the master to which the agents will be connected is specified. In the inventory role, the IP address of the master node was saved in a separate file which is copied to the remote agents in this role and the IP address of the master will be used by the agents to connect to the master node. The agent runs on the default port 5051.

11.6. Copy and Run framework

The face detection framework files are copied from the local machine to all the remote virtual machines including both the Mesos master node and Master agent nodes and are placed in their respective directories. The face detection framework is then run on the master node.

12. FRAMEWORK IMPLEMENTATION

The test framework provided by mesos have been modified to run face detection application. The framework initializes all the requirements through face_detection_framework file after which face_detection_executor runs. The executor creates threads which then run on agents. The executor is designed such that it can be easily modified to support another python application by just changing the call to the main function in run_task.

The variable dataset and database_url are the only variables that need to be modified to change the dataset from which the images need to extracted and head counts need to be taken. Here, the dataset variable tells the dataset name and the dataset_url tells the location from where the zip folder can be downloaded. The program downloads and unzips the folder to home directory of the user and this default path can be changed by changing the global_path variable. After unzipping the files, the program removes the zip folder as it is no longer required.

Once the dataset is extracted, the file list is given to the face detection program implemented using OpenCV library. The OpenCV library uses cascade files, where the cascade files are simply classifiers which can identify faces in an image or dogs in an image or any other object depending on the cascade file used. For our application, face detection cascade has been used and the link to cascade file is given in cascase_url. One can easily change this cascade file and change the way this program functions, i.e. one can just provide the hyperlink in the variable cascade_url depending on the cascade file user wants to use and the function will identify dogs, cats, eyes or any other object which the cascade file is trained to identify. The user can find these cascade files online, easily or could train and create one if required.

The program identifies faces, marks them in a rectangle and saves the output in the output folder. The number of images has been restricted to 50 for testing purposes but this can easily be changed by updating the no_files and images_per_file variable as per the requirement. After the results have been obtained the dataset folder is deleted. The results obtained contains images with faces marked in blue square and the count is maintained in results.txt file. These results are saved on the agent machines which is then copied to local machine using fetch command automatically.

Whenever new tests are run, the results are appended to results.txt file in place of just replacing the results. This has been done as a user might decide to run the application for different dataset or for different images while keeping the head counts for older datasets.

13. BENCHMARK

The benchmarks are shown in Table 1 which compare the time to run the make command and the make check on different VMs. The time required to install, setup a cluster and install prerequisites has been excluded as they are negligible and on average take 5 minutes on each VM and just vary in few seconds on average.

The results shown in table 2 were run on VM's running Ubuntu 16.04 with flavor as medium and swap size of 5 GB. The results were taken for 1 image to see how much time initialization takes. The results show that there is significant improvement when number of agents gets increased.

14. CONCLUSION

The head count detection framework is running successfully on Apache Mesos and the output is generated on the local machine which gives the source of the image and the number of head counts detected in the image along with it. Apache Mesos

Table 1. Benchmarks

Operating System	Flavor	Virtual Size Allocated	RAM CPU Cores (in GB)	Swap Size (in GB)	HDD Size (in GB)	Time to run make (in hh:mm:ss)	Time to run make install (in hh:mm:ss)
Ubuntu 14.04	small	1	2	2	20	00:43:56	00:48:07
Ubuntu 14.04	medium	2	4	5	40	00:35:23	00:42:32
Ubuntu 14.04	large	2	8	5	80	00:33:27	00:37:21
Ubuntu 16.04	small	1	2	2	20	00:40:32	00:48:32
Ubuntu 16.04	medium	2	4	2	40	00:37:56	00:46:68
Ubuntu 16.04	medium	2	4	5	40	00:19:31	00:32:16
Ubuntu 16.04	medium	2	4	7	40	00:21:47	00:29:43
Ubuntu 16.04	large	2	8	5	80	00:20:31	00:31:23

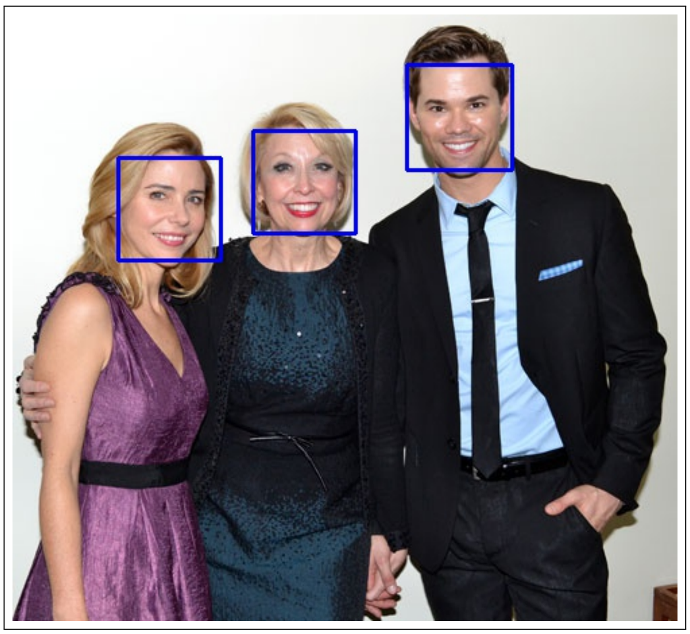

Fig. 6. Sample Output Image.

Fig. 7. Sample Result.

Table 2. Application Benchmarks

Number Of Images	Run Time with 1 Agent (in hh:mm:ss)	Run Time with 2 Agents (in hh:mm:ss)
1	00:00:28	00:00:45
50	00:01:21	00:01:15
100	00:02:12	00:01:52
500	00:05:08	00:03:25
1000	00:10:21	00:07:32

was successfully deployed on Linux 16.04 and 14.04 systems and the time required to install and deploy Mesos was successfully benchmarked. Implementation of the head count detection framework was successfully tested on Apache Mesos with a cluster of 1 master with 1 agent and 1 master with 2 agents. Ansible was used to successfully deploy Mesos on chameleon cloud and it is seen that Apache Mesos handles the containerization of the framework with ease. The future scope would include deployment of the headcount detection framework over 1,000 virtual machines and test the scalability of Apache Mesos. Along with scalability, the reliability can also be tested by running multiple masters and checking the fault tolerance of Apache Mesos.

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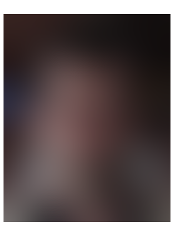
AUTHOR BIOGRAPHIES



Anurag Kumar Jain will receive his Masters (Computer Science) in 2018 from The Indiana Univeristy Bloomington. His research interests include Artificial Intelligence and Big Data.

Pratik Sushil Jain will receive his Masters (Computer Science) in 2018 from Indiana University Bloomington. His research interests include Big Data and Machine Learning.

Ronak Parekh will receive his Masters (Computer Science) in 2018 from Indiana University Bloomington. His research interests include Big Data, Cloud Computing and Machine Learning.