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PRACA MAGISTERSKA

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**PRZETWARZANIE I ANALIZA DANYCH
MULTIMEDIALNYCH W ŚRODOWISKU
ROZPROSZONYM**

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OŚWIADCZENIE AUTORA PRACY

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PODPIS

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DEPARTMENT OF APPLIED COMPUTER SCIENCE



MASTER OF SCIENCE THESIS

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**PROCESSING AND ANALYSIS OF MULTIMEDIA IN
DISTRIBUTED SYSTEMS**

SUPERVISOR:

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Acknowledgements...

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say why akka was selected...	9
finish describing the analyser	12
scale it to more nodes...	15
nothing said about results yet...	16
add some cool images so it's visual...	16
conclude stuff...	17

1. Introduction

1.1. Goals of this work

The primary goal of this work is to research how to efficiently work with humongous amounts of multimedia data in a distributed setting, and whether this approach is the right one.

In order to guarantee that recommendations and measurements made during this research are applicable in the „real world”, outside of laboratory or „experiment” environments, I have defined a series of problems (described in the next section) and implemented a system which is able to solve those problems as well as easily adapt to any new requirements benefiting from the use of parallel access to hundreds of gigabytes of reference video material.

1.2. Targeted use cases

As stated in the introduction section, in order to be able reliably verify criteria such as responsiveness, cost-efficiency, performance and of course scalability of distributed systems, there must be some reference problem and solution the measurements will be made on.

For the sake of this paper I propose a „video material analysis platform” from here on referred to as the „*Oculus*” system. In the following two sub sections I will explain the use cases (thus - requirements) this system will aim to solve, which while being a very interesting topic of research by itself, will provide me a platform to measure the usefulness of the selected distributed system building blocks used for it.

1.2.1. Near-duplicate detection

One of the simplest use cases in which this system might be used is *near-duplicate detection* of video files. Note the term „near-duplicate” here, as exact duplicates are not the biggest problem – and the designed system must also be able to identify „almost identical” material.

It might be easier to imagine the below use-cases if we think of a system like *youtube.com* ??, where vast amounts of content are uploaded *each second*. An example of why „almost identical” material in this setting would be a movie trailer, which has just been released and

many fans want to put it online on youtube, in order to share this trailer. It is very likely that they would add slight modifications, such as their own voice-over with comments, or resize the video for example. It is also fairly common that users apply malicious modifications to the video material in order to make 1:1 identification with copyrighted material harder - such modifications are typically „mirroring” the video material, or slightly brightening every frame. The system proposed in this work identifies content properly even after such modifications have been applied to the source content.

1.2.2. Data extraction

Another, less copyright focused, goal of the presented system is to be able to extensively mine data directly from the uploaded video content. Here the canonical example would be a *TOP 10 Movies of All Time*” video, which obviously contains video material from at least 10 movies, usually in the order of 10th, 9th ... until the 1st (best) movie of all time. If we would be able to match parts of each video to their corresponding reference materials, we would be able to get meta data about the now recognised movies and even mine out the data what is the best / worst movie of all time, even without it being written per se – only by looking at the frames in the video.

While talking about extracting data from movies one cannot skip extracting text from images which seems both one of the most valuable things we can extract as well as with existing open source solutions for text recognition should not be hard to enable, given all the previous work which will be required to fulfil the above use case.

1.3. Paper structure

In section 1 I will describe the architecture of the system, and briefly go over how this architecture benefits future extension.

In section 2 I will focus in the technical challenges encountered and solved during implementing the reference system.

In the last section I will summarise the findings.

2. Selected technologies

As the core of this work will focus on analysing and benchmarking usage of popular distributed system stacks, it is only fair to begin with introducing the selected components from which the system consist.

This chapter should be treated as a brief introduction into the selected technologies, as very detailed explanations and and implementation details will be provided throughout chapters 3 through 4.

2.1. Hadoop DFS

As the system will require the storage of many gigabytes (hundreds) of data the core of the system will be pretty much dominated by writing and reading to / from a datastore that contains all our reference video material.

Hadoop's ?? Distributed File System was designed with such thoughts in mind, and is able to scale an abstract file system over many servers, yet providing tools to make it visible as if it was one file system.

2.2. Akka

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3. System and design overview

The system, from here to be referred to by the name „*Oculus*”, is designed with an asynchronous as well as distributed approach in mind. In order to achieve high asynchronicity between obtaining new reference data, and running jobs such as „*compare video1 with the reference database*”, the system was split into two primary components:

- **loader** – which is responsible for obtaining more and more reference material. It persists and initially processes the videos, as well as any related metadata. In a real system this reference data would be provided by partnering content providers, yet for this
- **analyser** – which is responsible for preparing and scheduling job pipelines for execution on top of the Hadoop cluster and reference databases.

To further illustrate

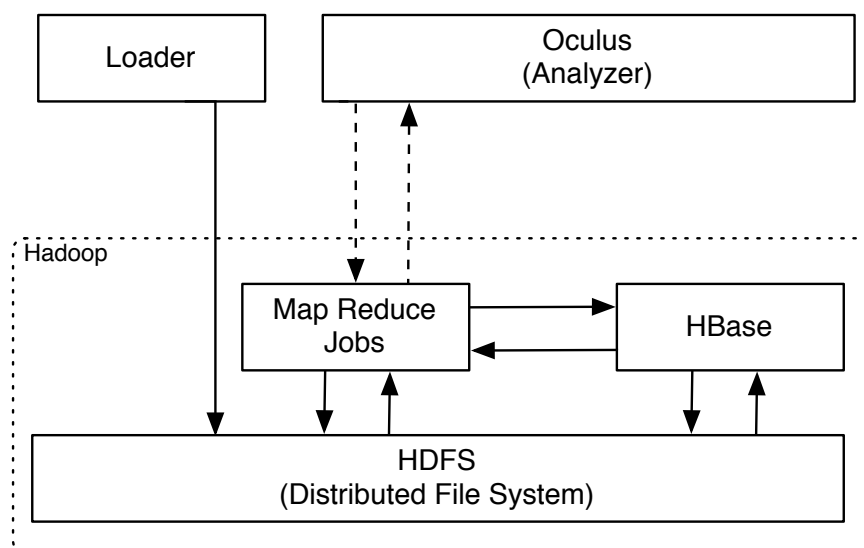


Figure 3.1: High level overview of the system's architecture

3.1. Loader

The downloader is responsible for obtaining as much as possible „reference data”, by which I mean video material – from sites such as *youtube.com* or video hosting sites.

It should be also noted that while I refer to this system as „the” downloader, in fact it is composed out of many instances of the same application, sharing the common workload of downloading and converting the input data. The deployment diagram on drawing [12] explains the interactions between the nodes.

3.1.1. Work sharing in an actor-based cluster

The Loader system is implemented following the style of „Actor model” style of concurrency [?].

This sub-system is implemented the so-called „message passing style”, which means that the work requests to the cluster come in as *messages*, and then are *routed* to an *actor*, who performs the work, and then responds with another message – in other words, all communication between Actor instances is performed via messages and there is no shared state between them. This also applies to Actor instances residing in the same JVM - for the user of an „Actor System”, the location (on which physical node the actor is actually executing) of an actor remains fully transparent - this has huge gains in terms of load balancing the message execution on the cluster - the router decides who will be notified on which message, the listing 3.1 shows a typical workflow using the so-called „smallest inbox” routing strategy ??.

Listing 3.1: smallest-inbox routing algorithm

```

                                ---> [inbox1, size = 3]
                                =>
                                YoutubeDownloadActor(1)
YoutubeCrawlerActor -- Msg(url=http://...) --> router ---/
                                \   [inbox2, size = 5]
                                =>
                                YoutubeDownloadActor(2)

                                /* because inbox1.size < inbox2.size */

```

The underlying Actor System is implemented by a project called Akka [?], and can be easiest explained as „porting Erlang concepts of the Actor Model to the JVM”. I selected the „Smallest Inbox” routing strategy instead of the other widely used „Round Robin” approach in order to guarantee not overloading any Actor with too many requests to download movies (which is a relatively slow process). Thanks to the smallest inbox routing, I can guarantee that if

some of the nodes have a faster connection to the Internet, they will get more movie download requests, than nodes located on a slower network.

As mentioned before, the system is fully distributed and *any node can perform any task* submitted to the cluster. For example let's take the first step in the processing pipeline in Oculus, which is Download video from <http://www.youtube.com/watch?v=-X9bcrJ3TjY> – such message will be emitted by the `YoutubeCrawlerActor` and sent via a `Router` instance to an `YoutubeDownloadActor` which has the „smallest inbox”.

3.2. Analyser

The job runners responsibility is at the core of the systems...

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3.2.1. Tackling the „small-files problem” on HDFS

In this section I will explain the „small-files problem” which would lead to major performance degradation of the Hadoop cluster is left undressed and how it was solved in the face of having to work with millions of small files – frames of the analysed movies.

Hadoop uses so called „blocks” as smallest atomic unit that can be used to move data between the cluster. The default block size is set to *64 megabytes* on most Hadoop distributions (including vanilla Apache Hadoop which this implementation is using).

This also means that if the DFS takes a write of one file (assuming the *replication factor* equals 1) it will use up one block. By itself this is not worrisome, because other than in traditional (local) file systems such as EXT3 for example, when we store N bytes in a block on HDFS, the the file system can still use block's unused space. Figure 3.2 shows the structure of a block storing only one frame of a movie.

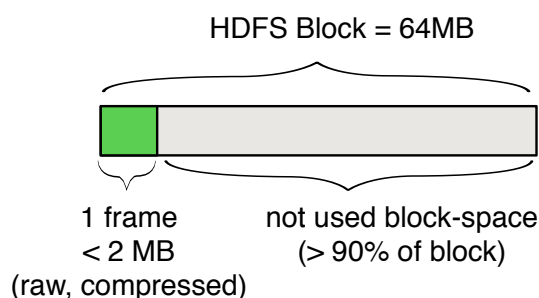


Figure 3.2: When storing a small file in HDFS, it still takes up an entire block. The grey space is not wasted on disk, but causes the *name-node* memory problems.

a movie is most often bound to access other frames of this movie we don't suffer any drawbacks from such storage format.

Another solution that could have been applied here is the use of HBase and its key-value design instead of the explicit use of Sequence Files, yet this would not yield much performance nor storage benefits as HBase stores its Table data in a very similar format as Sequence Files. The one benefit from using HBase in order to avoid the small files problem would have been random access to any frame, not to „frames of this movie”, but since I don't have such access patterns and it would complicate the design of the system I decided to use Sequence Files instead.

4. Performance and scalability analysis

In this section I will analyse the devised system on such aspects as general performance, ability (and ease) of scaling the system to support larger amounts of data or to speed-up the processing times by adding more servers to the cluster.

These measurements will be made in the previously described system and backed by measurements

4.1. Scaling Hadoop

In this section I will investigate the impact of scaling the Hadoop cluster vertically (by adding more nodes) on processing times of movies.

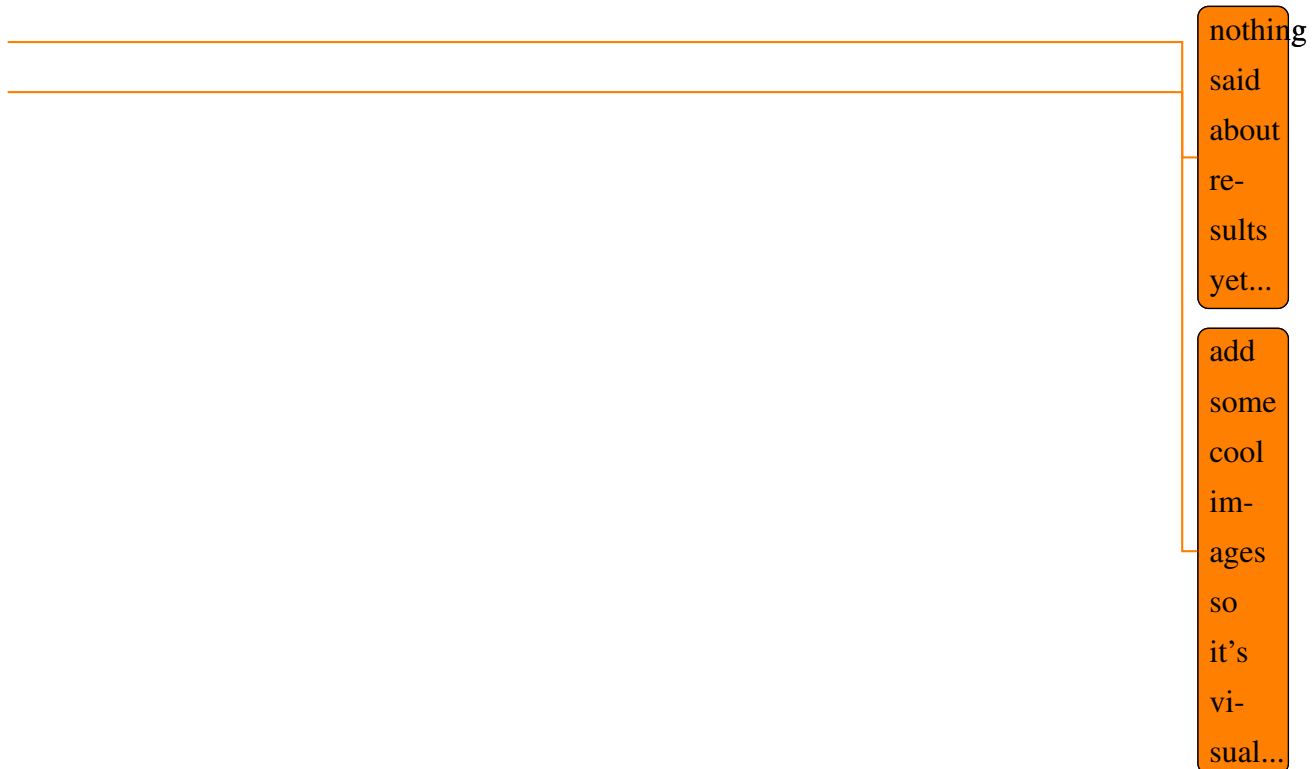
The task used to measure will be the longest pipeline available in the oculus system - comparing a movie, percentage wise with all other movies in the database. This process touches a tremendous amount of data, and is also very parallelizable.

At first I measured the time to process the input movie

4.2. Scaling the Loader (actor system)

scale
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nodes..

5. Results and processing times



6. Conclusions

The applied technologies have indeed been very helpful, and proved to be very elastic for different kinds of jobs related to processing large amounts of data. I was also positively surprised with the ease of Scaling Hadoop infrastructure.

conclude
stuff...

A. Preparing the cluster

Hadoop's filesystem must be formatted before put into use. This is achieved by issuing the `-format` command to the namenode:

```
kmalawski@oculus-master > hadoop namenode -format
```

It is worth pointing out that a "format" takes place only on the namenode, it does not actually touch the data stored on the datanodes, but instead it deleted the data stored on the namenode. The Namenode, as explained previously, stores all metadata about where a file is located, thus, cleaning it's data makes the files stores in HDFS un-usable, since we don't know "where a file's chunks are stored".

Bibliography