Text Analytics of the Qur'ān using Statistical and Large Language Models

by

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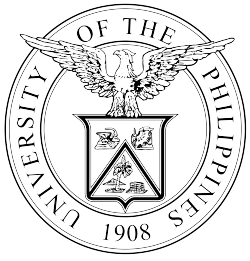

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Dedication

إلى والدي ألراحل، وعلى شعب فلسطين،
وعلى الجيل القادم من هذه الأمة
To my late father, to the people of Palestine,
and to the next generation of this Ummah

أَفَلَا يَتَدَبَّرُونَ ٱلْقُرْآنَ وَلَوْ كَانَ مِنْ عِندِ غَيْرِ ٱللَّهِ لَوَجَدُوا فِيهِ ٱخْتِلَافًا كَثِيرًا
Will they not think about this Qur'an? If it had been from anyone other than God, they would have found much inconsistency in it.
Qur'an 4:82

وَعِبَادُ ٱلرَّحْمَانِ ٱلَّذِينَ يَمْشُونَ عَلَى ٱلْأَرْضِ هَوْنًا وَإِذَا خَاطَبَهُمُ ٱلْجَاهِلُونَ قَالُوا سَلَامًا
The servants of the Lord of Mercy are those who walk humbly on the earth, and who, when aggressive people address them, reply, with words of Peace.
Qur'an 25:63

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Abstract

The interest of the paper is to provide a comprehensive text analytics of the Qur'an. This is by utilizing Statistical and Machine Learning methods to computationally analyze the said scripture. Specifically, the following procedures have been done: descriptive analyses of the structure of the Qur'an, morphological analyses of the Qur'an. Further, the data used for the Qur'anic Arabic corpus is the one in QuranTree.jl by Asaad (2022). The computational software used is Julia programming language.

Chapter 1

Introduction

The use of scientific computing to studying the Qur'ān is still in its early stage in the fields of Islamic Studies and Statistical and Machine Learning applications. This study will indeed benefit not only researchers from Islamic Studies but also Statisticians and Machine Learning researchers who are into text analytics. Having said that, it is therefore necessary to provide context to audiences of these disciplines to provide background on the state of Qur'ānic studies and the increasing adoption of scientific methodology to studying humanities.

1.1 Background

The Qur'ān or *al-qurʾān* اَلقُرآن meaning *the recitation*, the holy book of Islam, is revered by 1.9 billion (according to 2020 projection of Cooperman et al. (2011, p. 13)) Muslims across the globe as the literal words of God. Muslims believed that the Qur'ān was gradually revealed (Qur'ān 25:32) to Prophet Muhammad ﷺ through angel *ǧibrīl* جِبرِيل or Gabriel (Qur'ān 2:97). The Qur'ān contains 77,429 Arabic words in total, which covers only 56 percent of the Greek New Testament which has 138,020 words in total (Sinai, 2017, p. 11).

The Qur'ān is divided into *sūrahs* سُور which are the equivalent of chapters, each containing *ayāt* أَيَات (meaning *signs*), which are the equivalent of verses. The *sūrahs* سُور are not arranged in chronological order as in the Bible's books and chapters, but rather arranged in monotonically decreasing length of number of verses after the first *sūrah* سُورَة (*see* Figure 1.1). The *sūrah* سُورَة of the Qur'ān can be categorized into two types: the *makkiyya* مَكِّيّة (Meccan) and *madaniyya* مَدَنِيّة (Medinan). The categories refer to the geographical location of where the *sūrah* سُورَة was revealed. Figure 1.1 shows the grouping of the *sūrahs* سُور. Note that some of the *sūrahs* سُور have mixed geographical locations[1], that is, a few of the *ayāt* أَيَات in it were revealed in

[1] *see* list of the location in `https://tanzil.net/docs/revelation_order`

other geographical location apart from the geographical location of the rest of the *ayāt* أَيَات. Therefore, the categorization in Figure 1.1 highlights the geographical location of the majority of the *ayāt* أَيَات in the *sūrah* سُورَة.

The Qur'ān (meaning *the recitation*) was revealed *orally* by angel *ǧibrīl* جِبرِيل to Prophet Muhammad ﷺ and passed onto other believers through oral tradition (reciting the Qur'ān to students repeatedly so as to memorize it, instead of writing it down and let the believers read it and memorize it). Memorizing 77,429 Arabic words of the Qur'ān through oral transmission can be a difficult task, but what aids this memorization is the rhythm feature of the Qur'ān. According to one Orientalist, Sinai (2017), "rhyme, however, or rather a periodically recurrent word-final assonance, is a feature of the Qur'ān throughout, and it naturally partitions the

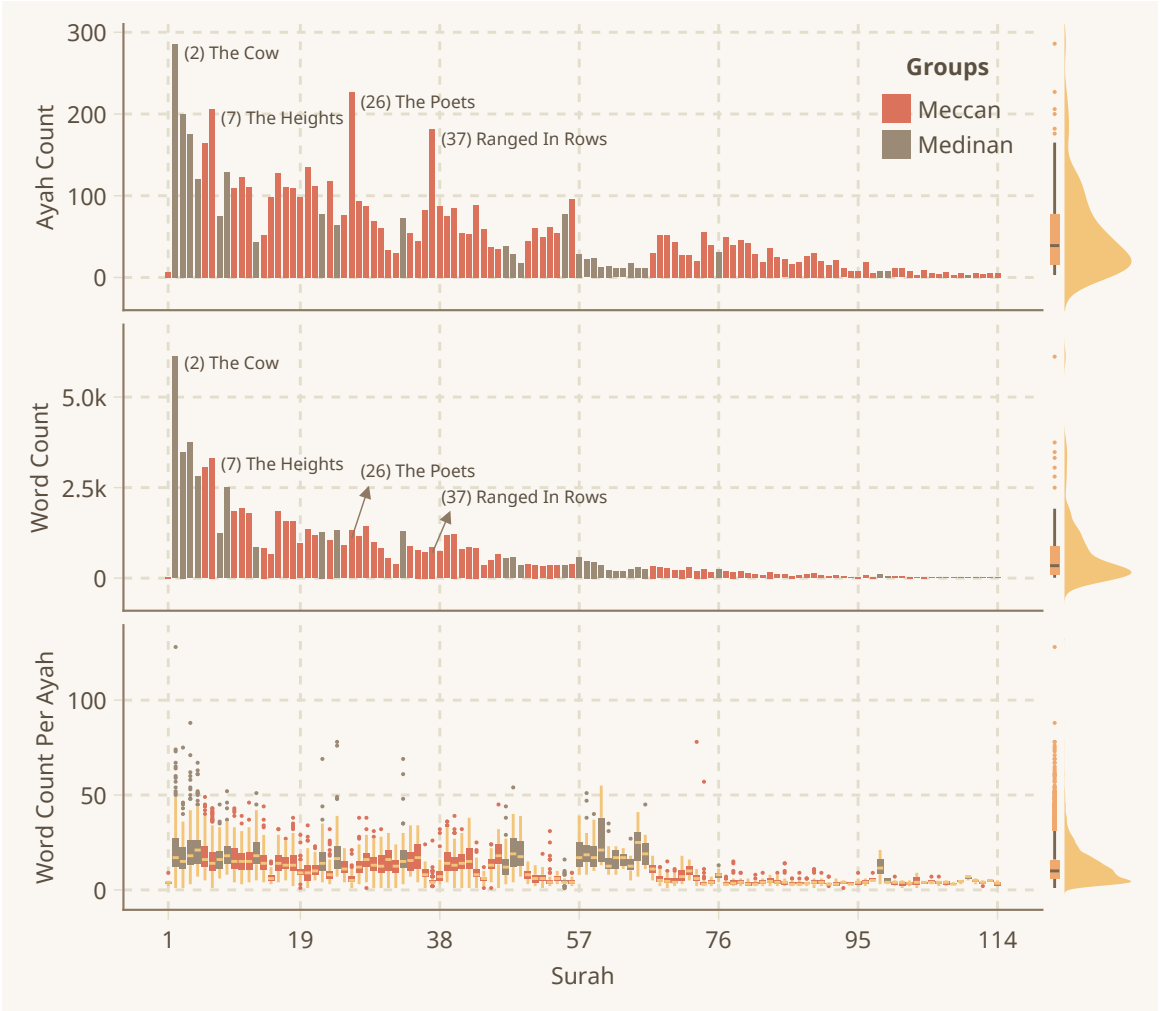

Figure 1.1: Statistics of the words and *ayāt* أَيَات (verses) of the Qur'ān

sūrah سُورَة." Indeed, because of this feature, it makes it easy to memorize the entire Qur'ān, and the one who do so is called *hafiẓ* هَفِظ meaning *one who remembers* or *keeper*. Qur'ān memorization contest is a common event in Muslim countries, the Philippine embassy has hosted one in 2022 in Saudi Arabia (Manila Bulletin, 2022).

According to the Muslim tradition, the oral transmission of passing the Qur'ān from a *hafiẓ* هَفِظ to new believers was gradually put into writings as requested by the believers themselves. The idea was brought up after the battle of Yamama, where many of the Muslims who died were *qurrāʾ* قُرَّآء (*the one who properly recite the Qur'ān*), and so fearing that their numbers will reduce in other battle fields, Umar ibn al-Khattab عُمَرُ بنُ الخَطّاب (who became the second caliph) suggested to the first caliph, Abū Bakr 'Abd Allāh ibn 'Abī ibn 'Abī Quḥāfa, أَبُو بَكرٍ عَبدُ اللّاهِ إِبنِ أَبِي قُحَافَةَ or short for Abū Bakr أَبُو بَكر, to collect the Qur'ān into writing. Abū Bakr then authorized Zaid ibn Thabit زَيدِ بنِ ثَابِتٍ for the task. According to Zaid, he started collecting from the leafless stalks of the date-palm tree and from the pieces of leather and hides and from the stones, and from the chests of men (who had memorized the Qur'ān, i.e. the *hafiẓ* هَفِظ)[2]. Long story short, the effort was finally codified by the third caliph, Uthman ibn Affan عُثمَانُ بنُ عَفّان in the year 645 CE, which was then recopied and distributed to the different regional capitals of the early Islamic empire of that time. The rest of the copies outside this codification were then burned[3] down in order to have one standard Qur'ān. The Qur'ān nowadays is therefore assumed to be based on Uthmanic codex because of the story mentioned. That is, if indeed Uthman has ordered to burn other copies of the Qur'ān outside his codification, then what's left should only be based on his codex or archetype, and that should only be the inherited codex of the Muslims today.

The Qur'ān is believed by the Muslims to have been preserved since it was first recited by angel *ǧibrīl* جِبرِيل or Gabriel to the Prophet ﷺ. Many orientalists had been skeptic about this claim, for example, John Wansbrough theorized that the Qur'ān was collected over a 200-year period (*see* Wansbrough, 2004, p. 101) after the death

[2] *see* `https://sunnah.com/bukhari:7191`
[3] *see* `https://sunnah.com/bukhari:4987`

of the Prophet ﷺ, instead of within a few years after the death of the Prophet ﷺ. However, recent findings through radiocarbon dating brings forward strong evidence of potential preservation of the whole Qur'ān, which the Muslims believed to be so. For example, the Birmingham Qur'ān manuscript discovered in 2015 is dated to be between 568 and 645 CE with 94.5% accuracy, making it among the oldest Qur'ānic manuscript in the world (*see* Birmingham University, 2015). Its predicted range of years intersects with the lifetime (570 to 632 CE) of the Prophet ﷺ. What is interesting is that the Birmingham Qur'ān is consistent with the Qur'ān today, word-by-word and letter-by-letter[4], see Figure 1.2. This is indeed another evidence that the Qur'ān today was codified by Uthman since the discovery of the Birmingham Qur'ān manuscripts have confirm it. In addition to this, the Sana'a Palimphest is also among the oldest Qur'ān radiocarbon dated to be between 578 CE and 669 CE with 95% accuracy (Sadeghi & Bergmann, 2010), which according to Sinai (2017), "neither does the edited portion of the Sana'a palimpsest offer evidence for additional or missing verses or for a divergent verse order within the *sūrahs* سُور." Given these discoveries on the recent Quranic manuscripts, the claim of Wansbrough (2004, p. 101) is now untenable (*see* Sinai, 2014).

One likely reason as to why the scribes were able to preserve the Qur'ān in the two folios of the Birmingham Qur'ān manuscripts follows from the fact that the Qur'ān is firstly memorized before it was decided to be written. So that, the Topkapi manuscripts that contain 99% (only 23 verses missing)—dated around 701 to 750 CE (Karatay, 1962)[5], that is, around 69 to 118 years after the death of the Prophet ﷺ—of the Qur'ān today was likely partly written from memory. This is possible since the Qur'ān possesses a rhytmic feature (that aids with memorization) that naturally divides its verses or *ayāt* أَيَات, and that the Qur'ān memorization competition is still held to this day (as in the example of Manila Bulletin, 2022), apart from

[4]The orthography of the Arabic letters in the early days had no diacritics and were written in its basic consonantal skeleton. That is, Arabic orthography and grammar were in their nascent when the Qur'ān was revealed, and therefore has to adjust and catch up, to capture and preserve the proper recitation of the Qur'an.

[5]*see also* `https://corpuscoranicum.de/en/manuscripts/1977/page/1-410?sura=1&verse=1`

the fact that it needs to be recited (any chapter after the first chapter of the Qur'ān according to the choice of the worshipper) every prayer from memory. Bottomline, there are many avenues for Qur'ān recitation from memory, and these have helped in its preservation. Moreover, since there are no significant evidence of insertion or malicious intention on addition or revision in all of the extant Qur'ānic manuscripts so far, some Orientalists came up with other theories of insertions on the basis of the literary style of the Qur'ān, see for example Sinai (2017, p. 92), where verse 102 of *sūra l-ṣāffāt* سُورَة الصّافّات or The Chapter of *Ranged in Rows* is theorized as addition because it is longer compared to other verses in the said chapter, refer to Sinai (2017, p. 92) for his other reasonings. Nonetheless, the Qur'ān is indeed stable based on the extant manuscripts.

Furthermore, the vastness of the early Islamic empire meant that different Mus-

Figure 1.2: 20th Century Qur'ān (left) in its fully featured orthographies vs Birmingham Qur'ān dated between 568 and 645 CE (right) in its basic consonantal skeleton. Image from Wikipedia (2015).

lim regional capitals have covered populations with different Arabic dialects, and so to accommodate these differences, Muslims believed that there were seven variant readings of the Uthmanic codex. Variant readings are defined as different pronunciations of the same word, in this case seven Uthamnic Qur'ān for seven different pronunciations. The *ḥadīṯ* حَدِيث or *narration* comes from Ubayy ibn Ka'b أُبَيّ بِن كَعب who reported[6] that the Prophet ﷺ was near the tank of Banu Ghifar that *ǧibrīl* جِبرِيل or Gabriel came to him and said: "... Allah has commanded you to recite the Qur'ān to your people in *seven dialects*, and in whichever dialect they would recite, they would be right." Recent work of Sidky (2020) shows that the material evidence on the regional variants is in remarkable agreement with well-attested written variants documented in the traditional Muslim literature.

Muslim and non-Muslim scholars alike have been extremely interested in understanding the unique literary characteristics of the Qur'ān. As mentioned earlier, unlike other books like the Bible (arranged in chronological order), the Qur'ān does not follow any obvious organization. In addition to this, a *sūrah* سُورَة does not fit the exact definition of a chapter. Indeed, the name attached to a *sūrah* سُورَة is often decided as the unique entity mentioned in the said *sūrah* سُورَة, its main purpose is to help early Muslims distinguish which *sūrah* سُورَة they are talking about, this is contrary to the chapter name where the associated name is obviously the main topic of the chapter. Further, as described by Sinai (2017), "... the compositional unity of the long surahs located at the beginning of the corpus is anything but obvious: at least at first sight, they can appear a flit back and forth between different topics in a largely haphazard manner. This impression is not limited to Western readers: even pre-modern Muslim scholars have often approached their scripture as a quarry of unconnected verses and groups of verses that bear little intrinsic relation to what precedes and follows." It wasn't until Neuwirth (2007), that the compositional unity of the Qur'ān can be observed in tighter literary unities, as Neuwirth (2007) showed that the many of these texts display a tripartite structure and are often constructive

[6]source: `https://sunnah.com/muslim:821a`

around a narrative middle part (Sinai, 2017). Samples of the organizational style of the Qur'ān was shown in Sinai (2017, p. 88).

1.2 Rationale of the Study

Attempts at understanding the Qur'ān by Qur'ānic scholars were mostly done with the use of manual processes, that is, studying the scriptures by going through its content one-at-a-time manually. However, with the advent of computers, some researchers have started using it to aid in their study. The first known to have used computers for studying the Qur'ān was likely Rashad Khalifa in 1968[7], where he studied the significance of the mysterious initials at the beginning of some *sūrahs* سُور. Rashad uploaded the Qur'ān into his computer by transliterating the Arabic letters and other Qur'ānic orthographies into Roman letters and symbols that the computer can easily parse. This approach of using computers to find new insights is more common in the field of science, and it was new to the field of Qur'ānic studies.

Indeed, to proceed with the use of scientific computing, the Qur'ān will be treated as the data that needs to be analyzed using what is called Natural Language Processing (NLP), a branch of Machine Learning (ML) that aims to understand natural languages, such as Arabic. To instruct the computer to do Statistical analyses, ML, or NLP, one needs to use a *software application* or a formal language called *programming language*. There are several programming languages that the computer can understand. The popular one for researchers in the field of sciences are Python, R, and sometimes Julia (Bezanson et al., 2017). These programming languages will be used to construct instructions for computer. Therefore, if the data is the Qur'ān, then there should be a way to interface with it using any of these programming languages. Or alternatively, there should be a way to upload it into the chosen programming language and encode the Arabic letters into something that can be easily parsed by the computer, like what Rashad Khalifa did. Having said that, there are indeed some programming languages with libraries or packages for

[7] *see* `https://www.masjidtucson.org/quran/miracle/a_profound_miracle_sura68nun133.html`

interfacing with the Qur'ān, and this is true for Python, R, and Julia. For this study, Julia programming language since its library for interfacing the Qur'ān using the QuranTree.jl[8] has more features compared to those available in R and Python (*see* Asaad, 2021). QuranTree.jl is based on Tanzil[9] for the Qur'ānic Arabic texts, and Dukes and Habash (2010) for morphological annotation, which both libraries from R and Python do not have in terms of morphological annotation from Dukes and Habash (2010).

Now that the programming language for this paper is identified, next is to understand how Statistics and Machine Learning can help in studying the Qur'ān. Statistics is a branch of Science that aims to study features or characteristics of data generated from a random phenomenon. The findings of Statistical analyses can then be used to make conclusions or predictions of the general population of the data or general characteristics of the data. Machine Learning or ML, on the other hand, is a branch of Artificial Intelligence that heavily intersects with Statistics, albeit with distinct differences as well. Both Statistics and ML aims to characterize data by learning its features, but ML research aims on complex models that are often inspired by simpler models from Statistics. Therefore, one can think of Statistics as one of the fundamentals of ML.

One of the goals of Statistics and Machine Learning is to summarize all of the learned features into a hypothesized equation or hypothesized mathematical formula whose parameters or weights are optimized to capture the most characteristics of the data. It is called hypothesized equation since the researcher is the one who decide which family of equation best describe the characteristics of the data. The said equation is called a *model*. Therefore, a model is a generic entity that can be fitted or molded to capture the features of the data. Mathematically and in general, a model can be written as:

$$\hat{y} := h(x|\theta), \tag{1.1}$$

[8] *see* `https://alstat.github.io/QuranTree.jl/stable/`
[9] `https://tanzil.net/download/`

which is a mapping between the sets $\mathcal{X}$ and $\mathcal{Y}$ where $x \in \mathcal{X}$ and $y \in \mathcal{Y}$ through a hypothesized function h. The idea of modeling is to find the optimal value of θ in such a way it will minimize the error between the actual data (represented by y below) and the predicted one $\hat{y}$:

$$\varepsilon := y - \hat{y} = y - h(x|\theta). \tag{1.2}$$

To help understand the concept of modeling, and relate it to the fashion industry, which the author assumes most readers are familiar with, a model in a fashion industry is responsible for representing the characteristics of the target customers (in Eq. 1.1 this is y). Therefore, for a clothing company, they hire Asian models (in Eq. 1.1, this is $\hat{y}$ or $h(x|\theta)$) to target Asian customers (in Eq. 1.1 this is y). So that, when these models wore the clothes sold by the said company, the potential customer will more or less be able to relate to the model, and be able to imagine themselves wearing that same clothes as well, which help them incline to buying the said clothing. The model, therefore, does not necessarily have the looks of every target Asian customers, but at least in terms of height, skin tone, hair, and other common Asian features, the model will likely have it, or at least the difference is more or less minimal (in Eq. 1.1, the difference is represented by $\varepsilon := y - \hat{y}$). The question now is, what are the benefits that this model can bring to the clothing company? Well, the clothing company will be able to create products that are tailored to their Asian customers using the said model, since the company will have the right baseline measurements needed. Relating this analogy to the technical concept discussed earlier, you can think of the target customers as the real or actual data (in Eq. 1.1 this is y), and the model as the same technical term use in Machine Learning and Statistics (in Eq. 1.1 this is $h(x|\theta)$), but this time this technical model is expected to capture the characteristics of the real data analogous to fashion model that is expected to capture the characteristics of the target customer. This Statistical or Machine Learning model brings the following benefit: researchers will be able to study the real data by simply using the model to answer questions that are not

available in the sampled real data.

In this paper, the aim is to make use of the Statistical or Machine Learning modeling to understand the characteristics of the Qur'ān in terms of the morphologies of its canonical text in its modern orthography. More specifically, the following are the general objectives:

1.3 Objectives

The objective of the paper is to answer the following research questions:

1. What are the thematic themes of the surah that can be extracted by a Large Language Model?

2. What other insights that can be extracted by a Statistical and Machine Learning models in terms of the Qur'ānic morphology?

3. How does this combination of Statistical, Machine Learning, and Artificial Intelligence (AI) with the Muslim's traditional literatures help in understanding the Qurān, especially with the advent of Generative AI?

1.4 Significance of the Study

While the Qur'ān has been extensively studied by Muslims and non-Muslims scholars alike, especially in the topic of Meccan and Medinan surahs, there is still a lot to uncover from the perspective of Computational Statistics. Hence, the significance of this study is that it brings forward new ways of extracting insights from the Qur'ān by leveraging Computations, Statistics, Machine Learning, and AI, that is still in its early stage in the field of Qur'ānic Studies. Therefore, this new perspective or process of studying the scripture not only aids the scholars of the Islamic Studies, but may also contribute indirectly to community development and policy makers who use Qur'ān as part of their decision making.

1.5 Scope of the Study

The paper will cover all chapters of the Qur'ān both for the Morphological and Topic Modeling analyses, but it will only present the results of *sūrahs* سُور with at

least 1000 words. The rest of the result will be part of the web application that can be used to query the Qur'ān. It will also not delve into the *tafsir* تَفسِير of each of the verses, but only when necessary for further context.

1.6 Thesis Organization

The paper is organized as follows: Chapter 2 will discuss the related literatures, Chapter 3 will discuss the methodology, Chapter 4 will present the results and discussions, and finally Chapter 5 will contain the conclusion and recommendation. The references and appendices are placed after the Chapter 5.

Chapter 2

Literature Review

As mentioned in the previous chapter, the earliest work in Qur'ānic studies using computer was likely the work of Rashad Khalifa in 1968[1], which led to one of his book entitled 'The Computer Speaks: God's Message to the World' (*see* Khalifa (1981)). While the work of Rashad started at studying the mystery letters in the beginning of some *sūrahs* سُور (for example Qur'ān 2:1, 3:1, 7:1, etc.), it quickly went on to cover what he calls other *mathematical miracles*, all of which are covered in Khalifa (1981). His findings led him to generalize the claim that God revealed His words through this mathematical patterns throughout the Qur'ān, and that those verses that were off and did not conform to this discovered mathematical patterns led him to extensive investigation of the said verses, and concluded that those could be or surely be an insertion that should not have been in the Qur'ān in the first place. There are two verses that were off according to Rashad, and he called these verses as *false verses*[2], these are the last two *ayāt* أَيَات of *sūra l-tāwba* سُورَة التَّاوبَة or The Chapter of *Repentance*. These two verses were removed in Rashad's Qur'ān translation[3]. Rashad believed so much on his findings that he self-proclaimed himself to be a messenger[4] with this new findings and that the Qur'ān nowadays should conform to his found mathematical patterns. This self-proclamation led to his assassination.

Fast forward to 20th century, among the pioneers to creating a stemmer systen for the Qur'ān is the work of Thabet (2004). A stemmer system is a system for trimming inflected words into its basic form, which grammatically mean its the root form. For example, in English language the root word for *computational*, *computer*, *computation*, and *computerize* is *compute*. Therefore, from the root of the word forms different stems representing the different words. Hence, the idea of stemming is to

[1] https://www.masjidtucson.org/quran/miracle/a_profound_miracle_sura68nun133.html
[2] https://submission.org/App24.html
[3] https://www.masjidtucson.org/quran/frames/
[4] https://www.masjidtucson.org/submission/faq/rashad_khalifa_summary.html

trim these words into its basic form, so that it would be easy to do word clustering or grouping through word similarity. According to Thabet (2004), the rich morphology of the Qur'ānic language or the Classical Arabic makes it even more difficult to do word stemming. Moving on, Thabet (2005) builds on this stemming system, and used it for tokenization of the Qur'ānic words. Tokenization is the process of listing all of the words in a sentence, and Thabet (2005) makes use of Thabet (2004) to further cleanse the noise from these tokens brought by the morphological variants of the Classical Arabic words. After cleansing the data, Thabet (2005) makes use of a statistical methodology for clustering or grouping the chapters of the Qur'ān, in particular the statistical methodology used is the Agglomerative Hierarchical Clustering based on the Euclidean distance of the adjusted word frequency of the *sūrah* سُورَة.

The work of Thabet (2004) and Thabet (2005) makes use of the Qur'ān corpus transliterated to Roman letters and symbols. Indeed, with interest growing on studying the Qur'ān from the lense of Data Analysis and Natural Language Processing, more work have been put in place into creating digital corpi of the Qur'ān that captures the different aspects of its linguistic styles. Hence, a series of work by Sharaf and Atwell led to the following publications: Sharaf and Atwell (2009) studied knowledge representation of the Qur'ānic verb valences using FrameNet frames, the output of which is a lexical database of the corpus of Qur'ān verbs. Further, the work of Sharaf and Atwell (2012a) came up with corpus for the annotations of the Qur'ānic pronouns, the authors named it as QurAna. Building on this work, Sharaf and Atwell (2012b) came up with a corpus for studying Qur'ānic relatedness based on the commentary of Ibn Kathir اِبن كَثِر, the authors named this corpus as QurSim.

Moving on, an unpublished work by Nassourou (2011) used a Support Vector Machine (SVM) to predict the classification of the place of revelation of the Qur'ānic *sūrahs* سُور. The idea was to use *sūrahs* سُور with well attested place of revalation as the training set, and then train an SVM to predict the remainings of the chapters.

Furthermore, the work of Shahzadi, ur Rahman, and Sawar (2012) developed a simple classifier based on the frequency distribution of words in *ayāt* أَيَات and the corresponding words in *sūrahs* سُور.

Moving on, the work of

Chapter 3

Methodology

This chapter will discuss the methodologies that will be used to address the objectives of the paper. In particular, the chapter is organized as follows: Section 3.1 will discuss the Descriptive Statistics, Section 3.2 will discuss Probability distributions, Section 3.3 will discuss the concept of Histogram, Section 3.4 will discuss the concept of Topic Modeling, Section 3.5 will discuss the concept of Large Language Models, and finally Section 3.6 will discuss how to implement this in Julia programming language.

Further, the topics discussed here may be self-explanatory for Statisticians, ML researchers or those with Mathematical background. However, for the benefit of readers coming from humanities background, the paper will present the methodology as follows: mathematical formulas are formalized through Definition, Proposition, and Corollary for the sake of brevity, but immediate to these will be an explanation or examples hoping to be simple enough for non-Statistician readers. As a guide, Statisticians or ML researchers can simply read the Definition, Proposition, and Corollary. Whereas for humanities readers, don't stress too much in the said sections, instead use the example or discussions immediate to the said sections to aid with the understanding.

3.1 Descriptive Statistics

Among the basic statistical methodologies for summarizing information or data is what is known as Descriptive Statistics. From its name, these statistics are meant to convey simple description of the data. For example, *mean*, and *variance* are common statistics used for describing data. The formulas for these statistics are given in the following definitions:

Definition 3.1.1 (Mean)**.** Let $x_i, i \in \{1, \cdots, n\}$ where $n \in \mathbb{N}$, then the *mean* of x_is is

defined as follows:

$$\bar{x} = \sum_{i=1}^{n} x_i, \qquad \text{where } x_i \in \mathbb{R}. \tag{3.1}$$

Definition 3.1.2 (Variance)**.** Let $x_i, i \in \{1, \cdots, n\}$ where $n \in \mathbb{N}$ and let $\bar{x}$ be the mean defined in Defn. 3.1.1 then the *variance* of x_is is defined as follows:

$$\mathbb{V}\text{ar}(x) = \frac{1}{n-1} \sum_{i=1}^{n} (x_i - \bar{x})^2, \qquad \text{where } x_i \in \mathbb{R}. \tag{3.2}$$

The mean is simply the average of the data points, while the variance is a single number that measures or summarizes the distances of the data points from the mean. The variance therefore gives us an idea of how spread or varied is the data points.

3.2 Probability Theory

Another statistical tool to understanding patterns in the data is through the use of Probability distribution. Probability distribution is a model (*see* discussion in Chapter 1 for understanding the model). Therefore, Probability distribution is a mathematical formula design to characterize or describe the patterns of a data point—mathematically represented as a variable (think of this like a placeholder of the data point of the said data). Modeling one variable makes it a univariate model or specifically a univariate probability distribution. Further, modeling more than one variable makes it a multivariate model or a multivariate probability distribution. Formally, the following are necessary definitions to build up on the concept of probability.

Definition 3.2.1 (Sample Space)**.** Let $\omega_1, \cdots, \omega_n, \forall n \in \mathbb{N}$ be the list of all possible outcomes of a random event or a phenomena, then the sample space, denoted by Ω, is defined as the collection of all these possible outcomes including the empty set denoted by $\emptyset$. □

Example 3.2.1. Consider the random phenomenon or event where someone randomly picks a verse from the Qur'ān, what is the probability that it will be a Meccan

مَكِّيَّة or a Medinan مَدَنِيَّة verse?

The possible output for such random event is either Meccan or Medinan. Suppose, we let Meccan be denoted by ω_1 and Medinan be ω_2, then the sample space, which is the collection of all possible output is denoted as follows:

$$\Omega := \{\text{مَدَنِيَّة}, \text{مَكِّيَّة}\} = \{\text{Meccan}, \text{Medinan}, \} = \{\omega_1, \omega_2, \} \tag{3.3}$$

It should be understood that $\emptyset$ is also included in Ω, but is not written for brevity.

□

Definition 3.2.2 (Event)**.** Let $\Omega = \{\omega_1, \cdots, \omega_n\}, \forall n \in \mathbb{N}$, be the sample space, then an event, denoted here as $\mathscr{A}$, is defined as the subset of the sample space, i.e., $\mathscr{A} \subseteq \Omega$. □

Example 3.2.2. From Ex. 3.2.1, the event of getting a random verse can be as follows: suppose the first two draws were Meccan and Meccan verses, then mathematically this event can be written as $\mathscr{A} = \{\text{Meccan}\}$. Therefore, $\mathscr{A}$ is a subset of all possible outcomes which is the sample space given in Eq. 3.3, and thus $\mathscr{A} \subseteq \Omega$. □

Definition 3.2.3 (σ-algebra)**.** Let $\Omega := \{\omega_1, \cdots, \omega_n\}, \forall n \in \mathbb{N}$, then the collections of all disjoint partitions, which are the events, are defined as the σ-algebra or σ-field, denoted here as $\mathfrak{F}$, and should satisfy the following conditions:

1. The empty set $\emptyset \in \mathfrak{F}$
2. If $\mathscr{A} \in \mathfrak{F}$, then the complement $\Omega \backslash \mathscr{A}$ is also an element of $\mathfrak{F}$
3. If $\mathscr{A}_1, \mathscr{A}_2, \cdots$ is a countable sequence of sets in $\mathscr{A}$, then the $\bigcup_{i=1}^{\infty} \mathscr{A}_i$ is also an element of $\mathfrak{F}$

□

Example 3.2.3. Given the sample space $\Omega := \{\text{Meccan}, \text{Medinan}\}$, the σ-algebra is $\mathfrak{F} = \{\{\text{Meccan}\}, \{\text{Medinan}\}, \Omega, \emptyset\}$. □

Definition 3.2.4 (Probability Measure)**.** Let Ω be the *sample space*, $\mathfrak{F}$ be the σ-algebra, $\mathbb{P}$ be the probability measure, then the probability of a set $\mathscr{A}$, $\mathscr{A} \in \mathfrak{F}$, on the probability space $(\Omega, \mathfrak{F}, \mathbb{P})$, denoted by $\mathbb{P}(\mathscr{A})$, satisfies the following properties:

1. Non-negativity: For any set $\mathscr{A}$, $\mathbb{P}(\mathscr{A}) \geq 0$
2. Normalization: $\mathbb{P}(\Omega) = 1$
3. Countable additivity: For any sequence of disjoint sets $\mathscr{A}_1, \mathscr{A}_2, \cdots$ in $\mathfrak{F}$, such that the union $\bigcup_{\forall i \in \mathbb{N}} \mathscr{A}_i$ is also in $\mathfrak{F}$, we have: $\mathbb{P}\left(\bigcup_{\forall i \in \mathbb{N}} \mathscr{A}_i\right) = \sum_{\forall \in \mathbb{N}} \mathbb{P}(\mathscr{A}_i)$

□

Basically, the idea of Defn. 3.2.4 is to define the concept of "measure" in general sense, although above is a special measure called probability measure. One can think of this probability measure like a tape measure in simple sense. This tape measure has some properties that should be expected for a measurement tool. The first property or condition is that the probability measure has to be positive. Indeed, if we use any tape measure for measuring length, never will someone get a negative measure like -2cm length. It always has to be positive. Further, the second condition to expect is that for this type of tape measure called probability measure, the total measure of all objects available in the given space should be equal to 1. That is, the total is normalized to 1. Think of this like 100% coverage if we measure all of the objects. Lastly, for any object, this tape measure should be able to measure the object through partitions, such that the measure of the union of these partitions is equal to the sum of the measure of each partition. All of these conditions are logical criteria for a general idea of "measure," although the normalization part above is unique for probability measure. Note that, the concept of proability measure here is should not be confined to measuring length as in the analogy, it should generalize to measuring volume and complex objects in general.

Definition 3.2.5 (Random Variable)**.** Let Ω be the sample space, and $\mathbb{R}$ be the set of all real numbers, then a random variable X is a function defined as $X : \Omega \rightarrow \mathbb{R}$. □

Example 3.2.4. Consider the example of drawing a random verse or *ayāt* أَيَات again, what is the probability that it will be an *ayāt* أَيَات from *sūrah l-baqara*'s *ayāt* آيَةُ سُورَة البَقَرَة or the Chapter of Cow?

The answer to this is 4.59% probability, this is because there are 286 *ayāt* أَيَات and there are 6236 verses in the Qur'ān, so that the probability is $\frac{286}{6236} = 0.04586$. □

Example 3.2.5. To apply the concept so far, consider again Ex. 3.2.4, what is the probability of getting 5 *sūrah l-baqara*'s *ayāt* آيَةُ سُورَة البَقَرَة if we randomly pick 20 *ayāt* أَيَات in total from the Qur'ān?

Solution. The following are given:

- $n = 20$ independent trials of drawing $x = 5$ أَيَات from the Qur'ān
- Each trial has two possible outcomes: *naᶜam* نَعَم meaning Yes or *lā* لَا meaning No. That is, if the *ayāt* أَيَات is from the *sūrah l-baqara* سُورَة البَقَرَة then its نَعَم, otherwise لَا.

Now, the sample space consists of all possible sequences of 20 نَعَم and لَا. That is,

$$\Omega = \{(\text{لَا}, \text{نَعَم}, \text{لَا}, \cdots, \text{نَعَم}), \tag{3.4}$$

$$(\text{لَا}, \text{نَعَم}, \text{لَا}, \cdots, \text{لَا}), \tag{3.5}$$

$$\vdots \tag{3.6}$$

$$(\text{لَا}, \text{لَا}, \text{لَا}, \cdots, \text{لَا})\}. \tag{3.7}$$

In total, there are $20^2 = 400$ possible samples in the sample space Ω. Further, from Ex. 3.2.4, the probability of getting a *sūrah l-baqara*'s *ayāt* آيَةُ سُورَة البَقَرَة is 0.0459 or 4.59%. Therefore, if we assign لَا and نَعَم as either 0 or 1, respectively, then mathematically $\mathbb{P}(X = 1) = 0.0459$. In addition, the probability of getting an *ayāt* أَيَات from other *sūrah* سُورَة would be $\mathbb{P}(X = 0) = 1 - \mathbb{P}(X = 1) = 1 - 0.0459 = 0.9541$.

Further, let Z be the random variable for the event of getting n نَعَم from 20 trials, then the problem is equivalent to finding the number of ways to choose 5 positions out of 20 in the collection or set. This can be solved using *combination* formula as

shown below:

$$\binom{n}{x} = \frac{n!}{r!(n-r)!} \Rightarrow \binom{20}{5} = \frac{20!}{5!(20-5)!} = 15,504. \tag{3.8}$$

That is, there are 15,504 possible cases with 5 positions for نَعَم in a 20 trial. Moreover, in each of these samples 5 has a probability of $\mathbb{P}(X = 1) = 0.0459$, while the remaining 15 has a probability of $\mathbb{P}(X = 0) = 0.9541$. So that,

$$\begin{aligned}\mathbb{P}(Z = 5) &= 184,756 \times \mathbb{P}(X = 1)^5 \times \mathbb{P}(X = 1)^{20-5} \\ &= 15,504 \times 0.0459^5 \times 0.9541^{20-5} \\ &= 0.0016. \end{aligned} \tag{3.9}$$

Hence, there is a 0.16% probability of getting 5 *sūrah l-baqara*'s *ayāt* آيَةُ سُورَة البَقَرَة when randomly drawing 20 أَيَات from the Qur'ān. □

Note that Ex. 3.2.5 can be solved using a known formula in probability called *Binomial* mass function. The general concept of probability distribution is defined in the following definitions.

Definition 3.2.6 (Normal Density Function)**.** Let Y be a random variable and let $\mu \in \mathbb{R}$ and $\sigma \in \mathbb{R}$ be the mean and variance parameters, if y is the random value, then the *Gaussian* or *Normal* density function is given below:

$$\mathbb{P}(Y = y) := \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left\{-\frac{(y-\mu)^2}{\sigma^2}\right\}, \quad \text{where } -\infty < y < \infty \tag{3.10}$$

Definition 3.2.7 (Dirichlet Density Function)**.** Let $\mathbf{Y}$ be a vector random variable with a random value $\mathbf{y} := [y_1, \cdots, y_k]^{\mathrm{T}}$ and let $\boldsymbol{\alpha} := [\alpha_1, \cdots, \alpha_k]^{\mathrm{T}}$ be the parameters, then the *Dirichlet* density function is defined as

$$\mathbb{P}(\mathbf{X} = \mathbf{x}; \boldsymbol{\alpha}) := \frac{1}{B(\boldsymbol{\alpha})} \prod_{i=1}^{k} x_i^{\alpha_i - 1}, \tag{3.11}$$

where,

$$B(\boldsymbol{\alpha}) := \frac{\prod_{i=1}^{k} \Gamma(\alpha_i)}{\Gamma\left(\sum_{i=1}^{k} \alpha_i\right)} \tag{3.12}$$

□

Definition 3.2.8 (Multinomial Mass Function)**.** Let $\mathbf{X}$ be a vector random variable with a random value $\mathbf{x} := [x_1, \cdots, x_k]^{\mathrm{T}}$ such that $x_i \geq 0, \forall i \in [1, k]$, let $\boldsymbol{p} := [p_1, \cdots, p_k]^{\mathrm{T}}$ and n be the parameters, the probability mass function of a Multinomial distribution is

$$\begin{aligned} f(x_1, \cdots, x_k; n, p_1, \cdots, p_k) :=& \mathbb{P}(X_1 = x_1 \text{ and } \cdots \text{ and } X_k = x_k) \\ =& \begin{cases} \dfrac{n!}{x_1! \cdots x_k!} p_1^{x_1} \times \cdots \times p_k^{x_k}, & \text{when } \sum_{i=1}^{k} x_i = n \\ 0 & \text{otherwise,} \end{cases} \end{aligned} \tag{3.13}$$

3.3 Statistical Graphs

Graphs or plots are data visualization tools that are useful for exploratory data analysis apart from the Descriptive Statistics discussed above. It supplements the Descriptive Statistics findings through shapes visualized in the graphs. Among the popular statistical graphs is the bar graph. An example of this is given in Figure 1.1. Other graphs used are the box plots and the density plots which is also in Figure 1.1

3.3.1 Box, Density, and Histogram Plots

While most statistical plots are easy to understand like bar graphs and scatter plots, others like Box, Density, and Histogram plots may not be easy to comprehend for someone with no Statistical background. This section will discuss how it is interpreted. Let's use Figure 1.1, Figure 3.1 for easy reference in this section.

As shown in Figure 3.1, both the Box and Density plots are tied to each other.

This is indeed the case because both are describing the same information but presented in different style of visualization. In fact, Histogram is also used to describe the same information as the Box and Density, and the three are therefore related. So much so, that the three can be put into one graph. As to how to interpret these, readers are referred to for further details [to add reference].

3.4 Topic Modeling

As presented in Chapter 1, the first objective is to extract the thematic themes of *sūrahs* سُور with at least 1000 words. In Statistics and Machine Learning, this task is called Topic Modeling. There are several ways to do this, but the popular methodology is to use the Latent Dirichlet Allocation (LDA) discussed in the next section.

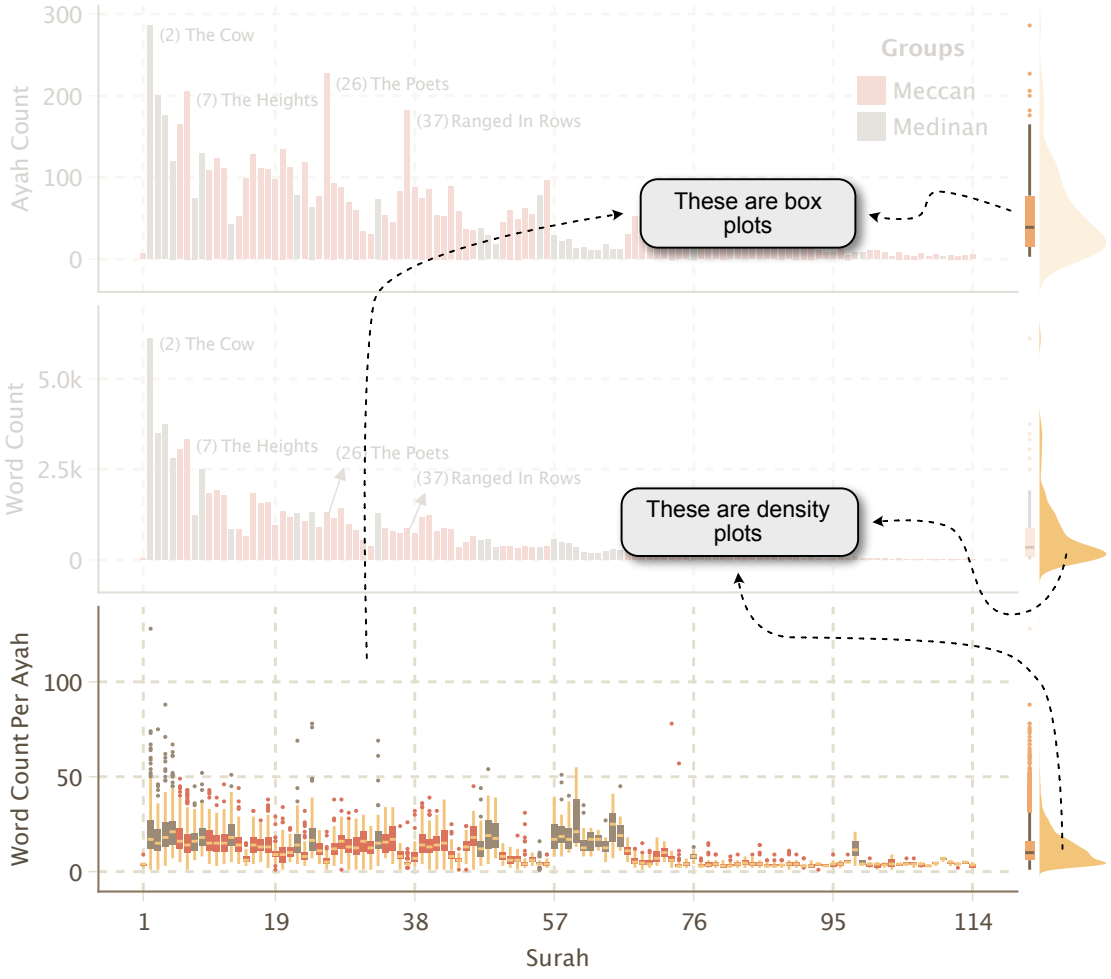

Figure 3.1: Statistics of the words and *ayāt* اَيَات (verses) of the Qur'ān

3.4.1 Latent Dirichlet Allocation

Latent Dirichlet Allocation (LDA) is a Statistical methodology that is based on Bayesian inference (Bayes, 1763; Laplace, 1986). It is a generative probabilisitic model for collection of discrete data such as text corpora (Blei, Ng, & Jordan, 2003). The main formula is defined below:

Definition 3.4.1 (Latent Dirichlet Allocation)**.** Let $\mathbf{W}, \mathbf{Z}, \boldsymbol{\theta}, \boldsymbol{\varphi}$ be the random variables, and let α and β be the hyper-parameters, then the probability of generating a document is

$$\mathbb{P}(\mathbf{W}, \mathbf{Z}, \boldsymbol{\theta}, \boldsymbol{\varphi}) = \prod_{j=1}^{m} \mathbb{P}(\boldsymbol{\theta}_j; \alpha) \prod_{i=1}^{k} \mathbb{P}(\boldsymbol{\varphi}; \beta) \prod_{t=1}^{n} \mathbb{P}(\mathbf{Z}_{j,t}|\boldsymbol{\theta}_j)\mathbb{P}(\mathbf{W}_{j,t}|\boldsymbol{\varphi}_{\mathbf{Z}_{j,t}}) \tag{3.14}$$

3.5 Large Language Models

Generative Artificial Intelligence or GenAI for short has been making waves on its effectiveness to generate texts, images, audio, video, etc. It has elevated humanity to a new level of capability. However, behind this amazing capabilities is that GenAI is by design a mathematical formula that are called *model*. There are several types of *models*, and one of those is the Large Language Model (LLM). The following section will discuss what LLM is and its mathematical formulation.

3.5.1 Retrieval-Augmented Generation

The problem with LLM is that it was only trained on huge but limited data, and is therefore not able to infer what should be the context when asked.

3.6 Julia Code Setup

This section will discuss the coding setup. As mentioned in Chapter 1, the main programming language to use is Julia. As such, it is necessary to present where the codes will be stored so that readers are able to reproduce it.

3.7 Desktop Application using SvelteKit and Rust

Chapter 4

Results and Discussions

The chapter is organized as follows: Section 4.4 will discuss the results for thematic analysis using Large Language Model with a comparison to one Statistical model that to emphasize the power of the LLM. Further, Section 4.5 will discuss the Information Retrieval result.

4.1 Descriptive Statistics

In this section, the count statistics for the verses and words of the Qur'an. Figure 1.1 shows the count of *ayāt* اَيَات (verses) and word of the Qur'an.

4.1.1 Verses

4.2 Morphological Analysis

4.3 Structural Analysis

4.3.1 Concentric Structure

4.3.2 Mathematical Structure

4.4 Topic Modeling

4.4.1 Latent Dirichlet Allocation

4.4.2 OpenAI LLM

4.5 Information Retrieval using RAG

Chapter 5

Conclusion and Recommendation

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