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Development of a messaging application for communication and detection of spam on a mobile operator, case study of Airtel, Vodacom and Orange.

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Introduction

0.1 Context and generalities

With the increasing of use of mobile devices in mobile telecommunication, the number of text messages sent every day has grown exponentially. According to *Statista*, a company that provides market and consumer data on a wide range of topics, including digital media and technology; the number of mobile messages sent worldwide in 2020 reached 3.5 trillion [32]. In the same case, with the raise of web pages and social media messaging applications like Whatshap, Teelgra, Snapchat Facebook, Instagram and many others, phone users can now send messages that are only based on text as in former time but also on video, audios which are more chestful comparatively [14].

For sure, for interacting with his partner more professionally, email message is the most mean used, but not in all cases since in some countries a given SIM Card of a telecommunication provider is used as a bank more than being an communication mean, so the importance to secure the communication lines of a mobile users in these countries. Along with the functions and interests that the mobiles messages encompasses in terms of conversing, money sending and receiving, there has been an increase in the number of spam messages that aim to deceive people into providing personal information, sending unwillingly money, menacing to death or taking other actions that benefit the scammer.

To address this problem, the development of a messaging application with advanced spam detection capabilities is crucial to set, filter messages and prevent the users. This dissertation focuses specifically on the development of such application for phone users and in general for mobile networks telecommunications technologies.

0.2 Problematic

In telecommunication domain, we use mobile devices or phones for sharing *SMS*, Email, chats by using some specific apps. Among all we use specifically *SMS* for personal and professional information sharing [23]. The SMS stands for Short Message Service, which is a text messaging service for mobile phones and other mobile devices. It allows users to send and receive short messages of up to 160 characters [24]. It is also possible to send or receive automatic SMS which are not sent by human, whereas by using web interface or API [20].

Time to time, more persons are receiving messages such as : "You won x amount of money send another amount to withdraw it", "Join me at x area to take your money but pay me the transport ...", "I'm *Sirene* Madam I have money for you", "I have a job for you" and many others fake messages. More of them are reported in this spams examples

link.

Furthermore, scammers go the point where they can introduce vulnerabilities in messages which exploit a weakness in the SMS messaging system to remotely install spyware on mobile devices commonly called *Simjacker* [9]. However, in marketing almost similar messages are used to sensitize people to by products and services which confuse users wether it is or not a spam message by leading users to ignore important messages or being more hesitant to engage with mobile marketing campaigns [8],[26].

Considering all above issues caused by spam, what are key technical challenges that could be addressed in messaging system which can effectively facilitate the communication as well as detecting and filtering spam messages ?

0.3 Hypotheses

According to the Oxford dictionary, hypotheses stands for a statement of the expected relationship between things being studied, which is intended to explain certain facts or observations [33]. An idea to be tested. Hence, using the content-based filtering techniques, which involves analyzing the content of messages and determining wether it is a spam or not would be considered as solution.

Firstly this would be done by utilizing the Machine learning algorithms which are : **Naive Bayes, Logistic Regression, and Supper vector Machines**. All these would be combined by the ensemble methods for making a more predictive model [34] including the preparation and classification techniques which avoid biased model [21].

Secondly, during the production steps, we should integrate the model inside of the system able to add technically in a blacklist or whitelist suspect users based on the specific probability of being a potential attack.

Overall, we will jump from Machine Learning as model (*MLaaM*) which is the output of writing ML algorithms run on data and represent what was learned by the algorithm on training data; to ML Model Software Deployment which encompasses all the activities that make a software system worthy to be used [17].

0.4 Delimitation and objectives

0.4.1 Delimitation

The present work aims to develop a messaging application for communication and detection of spam on a mobile network.

Geographically it focuses on all provinces of Democratic Republic Of Congo(DRC) where mobile phones are used and require techniques for implementation.

Besides, it does not function effectively across all languages unless the solution model has been specifically trained on those languages. As a result, it is challenging to claim its effectiveness in languages such as Swahili, Lingala, French, or even English. Moreover, achieving optimal performance often necessitates the involvement of a large population.

Indeed, the current work in terms of planning and execution has spanned a duration of nine months : From January to November 2023.

0.4.2 Objectives

This system present 2 types of objectives such as: functional and non functional.

As functional objectives, this system consist of developing a messaging application that can facilitate efficient communication between users; implementing the machine learning models which has the capacity of classifying the messages and preventing spam messages under a certain probability; designing and integrating a user-friendly interface for messaging application;

For non-functional objectives, it allows the user whose messaging application complies with relevant privacy laws and regulation to protect data information, reducing the attacks and frauds; Increasing the trustfulness of users and mobile services compagne provider, optimizing the power resources of the user against threats posed by scammers.

0.5 Interest

Personally, this paper has allowed the author to gain knowledge and more experience in the field of mobile networks and messaging applications.

Socially, the developed system contributes to facilitating communication and reducing the impact of spam messages, which can be annoying and stressful for citizens.

Economically, this system of detection helps to save business server time and resources by filtering out spam messages allowing for more targeted marketing efforts.

Scientifically, the research achieved contributes to the advancement of the science in the domain of Mobile Networks, SMS messaging, and Machine Learning data processing and classification.

0.6 Research Methodology

Throughout this paper, the research methodology will be used to guide the study towards achieving its objectives. The research will adopt a descriptive research design to describe the development of a messaging application for communication and detection of spam on a mobile network. The study will focus on both qualitative and quantitative research methods [11]. The qualitative method will involve a literature review, interviews and analysis of collected messages. while quantitative method will focus on the development and testing of the messaging application.

The research will be conducted in two phases. The first phase will involve data collection through a survey questionnaire that can be completed on website, or can be directly provided to the web interface (API) by the mobile phone users for collecting their experience with messages and especially spams. Thus, the data collected will be analyzed using descriptive statistics [4] to identify the common types of spam messages and the frequency of occurrence, languages inside, and other attributes.

The second phase will involve the development of the messaging application using the data collected from the survey and the analysis of existing messaging applications. The development of the application will be guided by the principles of agile software development by using Python (Django framework) for *Back-end* and HTML,CSS and JavaScript for *front-end*. Then,the application will integrate the use of machine learning models, including Naive Bayes, Logistic regression, and Support Vector Machine.

The evaluation of the messaging application will be conducted using both quantitative and qualitative methods. The qualitative evaluation will involve the measurement of the

application's accuracy and efficiency in detecting and filtering spam messages, on the other hand the qualitative evaluation will involve a user study to determine the usability and user experience of the application.

0.7 Work Plan (or Work Subdivision)

The work plan of this dissertation is divided into four parts. The first is the introduction, which provides a background information on the research problem. The second part consist of a situation analysis and assessment while the third part focuses on literature review and explanations on the methodology. Then the fourth part presents the practical result of this work. Finally the conclusion part summarizes the key findings and contributions of the study and presents limitations and provide recommendations for future research.

Chapter 1

Situation analysis and assessment on mobile phones

1.1 Introduction

In this chapter, we will focus on various aspects that enhance the comprehensiveness and practicality of this dissertation. It includes explanations of mobile messaging architecture, machine learning models, and spam messages in mobile world. Additionally, it provides an analysis of the architecture used by network operators, highlighting both positive and negative aspects of their approach to message handling.

1.2 Presentation of the working framework and definition of key concepts

1.2.1 Definition of key concepts

- a) SMS(Short Message Service) :
The Short Message Service is a basic service allowing the exchange of short text messages between subscribers [25]. For supporting virtually all mobile devices, SMS is considered as a universal means of communication that enables users to communicate and function even though all users are not active simultaneously (asynchronous communication).
- b) Enhanced Messaging Service (EMS) :
EMS has been created to allow the transmission of richer and more advanced messages. Unlike traditional SMS, EMS accepts not only text messages but also audios, melodies, and animations [24].
- c) MMS (Multimedia Messaging Service):
MMS has been developed to facilitate the transmission of rich multimedia content in mobile messaging. Unlike SMS and EMS, MMS enables users to send not only text messages but also various types of multimedia files such as images, videos, audio recordings and even slideshows [24].

- d) Spam message:
A spam message is understood as an unsolicited or undesired messages received on mobile phones which constitutes veritable nuisance to the mobile subscribers [35]. Clearly, this message can be sent with the intention of gaining financial benefits, collecting personal or organizational information such as security numbers, credit card details, or login credentials, and soliciting money by making false promises of future benefits or rewards that do not materialize.
- e) Networks operators: The networks operators refers to companies or organizations that provide and manage telecommunication networks. These operators own and operate the infrastructure, such as mobile networks, fixed-line networks, or internet service provider (ISP) networks, that enable the transmission of user's information to another user of the network [15]
- f) Artificial Intelligence (AI) : AI refers to the field of computer science that focuses on creating intelligent machines or systems that can perform tasks that would typically require human intelligence. For being practical, it encompasses algorithms, models and technologies that enable computers and machines to simulate human like cognitive processes such as learning, reasoning, problem-solving, perception and language understanding.
- g) ML (Machine Learning) : Machine learning is a subfield of Artificial Intelligence that focus on the development of algorithms and models that enable computers to learn from data and make decisions or predictions without being explicitly programmed[37]. Clearly, when the data is labeled during the training, we refer to it as supervised model. If contrast, when the data is unlabeled and the model must discover patterns and relationships itself, it is an unsupervised model. Additionally, whenever it performs both the labeling and discovering patterns tasks, it refers to a semi-supervised model. Furthermore, there is the last type called reinforcement. This one, is used to teach a computer or an AI agent how to make series of decisions in an environment. Just like, we learn to play the game better by playing it over and over.
- h) NLP (Natural Language Process): NLP is a subfield of Machine Learning that studies the human language and combing techniques from statistics, linguistics, life-hoods for making sentiment analysis, text classification, machine translation, question answering and text generation in a way that it can be understood computationally [7].

1.2.2 Presentation of the working framework

In the eastern party of DRC (South Kivu- and North Kivu) the usage of mobile phones has become more common, transforming communication and connectivity in the region. The DRC itself is large country, covering over 2,345,000 square kilometers with the eastern provinces of North and South Kivu spanning approximately 59,483 and 65,070 square kilometers respectively [46]. According to recent statistics from *GlobalEdge*¹, an Amer-

¹GlobalEdge : Created in 1994 by the International Business Center and the Eli Broad College of Business at Michigan State University (IBC), globalEDGE™ is a knowledge web-portal that connects international business professionals worldwide to a wealth of information, insights, and learning resources on global business activities

ican company, around 95 million people were living in the DRC in 2022 [13], of which approximately 46.9% had active mobile phones based on *GSM*² research.

In this context, it is observed that more people in cities use mobile phones compared to those in villages, primarily due to limited accessibility. A research study conducted by *Target Canibet*³ in 2015 focused on mobile connections in DRC cities including Bukavu, Goma, Kinshasa, Lubumbashi, and Matadi, found that among 1,000 people surveyed in each city, 9 out of 10 individuals were subscribed to a network operator. However, it was noted that approximately half of them subscribed to two operators, while a quarter subscribed to four operators, and 18% used the services of a single operator.

Furthermore, the recent statistics made by *DataReportal*⁴ in DRC shows that the mobiles users continues to increase exponentially merely because of new services provided by internet and Telecoms Operators, at the point that since 2021 to 2022, it has been reported 3.6 million of new users between 2021 to 2022, a report that proves how much mobile phones is inevitable in this last decades.

1.2.3 Network coverage and infrastructure

In fact, two telecoms services exist in DRC such as : Fixed services (26%) and Mobile services (74%). The first one known as landline or wired services, involve the use of physical infrastructure; the second one which is popular is the mobiles services refer to telecommunications services provided through mobile networks. According to the Congolese Regulatory Agency (ARPTC), the DRC has four mobile operators - Vodacom RDC, Airtel Congo, Orange DRC and Africell DRC. Vodacom is the leader in the voice segment, with 35.2% of the market, followed by Orange (30%), Airtel (23.9%) and Africell (10.9%). In the mobile internet market, Vodacom has 37.44%, Airtel 31.25%, Orange 28.14% and Africell 3.17% [3].

Additionally, since the 190s, when the DRC witnessed the first installation of operator systems such as Celtel(now Airtel) and Vodacom, followed by Orange and Africell, the telecommunications sector has shown significant market growth, reaching 1 Billion in 2022\$ and expanding at a rate of 21% per year according to *GlobalData*⁵. However, this growth necessitates the updating of the infrastructure, which includes various generations of technologies, namely the second generation, third, fourth, and fifth(under development).

In fact, the second generation have been deployed in various territories to enable more efficient **voice calls, data networks services, and introduce SMS for text messaging**. The infrastructure required for 2G networks includes the following equipments: 1) BTS(Base Transceiver Station) : Transmit and receives signals between mobile devices. 2) MSC(Mobile Switch Controller) : serves as the switching entity that connects calls

²GSMA (Global System Communications Association) : An industry Organization which represents the interests of mobile network operators worldwide created in 1982 to ease cooperation between countries deploying *GSM* (Global System fo Mobile) technology.

³Target Canibet: Reseach & Consulting Group working in DRC. <https://www.target-sarl.cd/fr/content/etude-sur-la-telephonie-mobile-en-rdc>

⁴DataReportal: A online Company designed to help people and organizations all over the world to find the data, insights, and trends they need to make better informed decisions produced by Simon Kemp, <https://datareportal.com/reports/digital-2023-global-overview-report>

⁵GlobalData: Expert Company of Analysis, innovatove Solutions

between mobile devices. 3) BSC (Base Station Controller) : manages multiples BTSs and controlling radio resources, managing handovers between cells and optimizing network performance, 4) AuC (Authentication Center) responsible for managing subscriber authentication and encryption keys to ensure communication between mobile devices and the network, 5) Home Location Register (HLR) the database that stores subscriber information such as phone numbers, authentication details, and service profiles, 6) Visitor Location Register (VLR) : The VLR is a temporary database that stores information about roaming subscribers within a specific area 7) MS (Mobile Station), including all the technologies used by the users's handset and has two parts : **Firstly, the mobile equipment which contains the radio equipment, the user interface, the processing capability and memory requirements for call signaling, encryption, SMS and the id of the mobile phone(equipment IMEI number). Secondly the Subscriber Identity module (SIM Card)**, used in encryption of codes needed to identify the subscriber, storing subscriber's information, locate the user [12] as (+243 for each congolese number).

Indeed, all the 2G technologies covers a large distance varying between 1880MHz - 2700 MHz.

Besides, the third generation appears as revolution, **allowing multimedia messages, voice calls data, faster data speed**; however it requires a significant upgrade from the previous generation. Thus, the equipment involved in 3G technology includes : 1) BTS (Base station Transceiver) : Which plays the same role as for 2G; 2) Node B: Responsible for handling the radio interface and connecting mobile devices to the core network; 3) Radio Network Controller (RNC) : Controlling the Node B and managing the radio resources 4) Mobile Switching Center (MSC): The MSC is the central switching entity in the network that **connects calls between mobile devices**; 5) Serving GPRS Support Node (SGSN) : Responsible for managing packet-switched data services services and handling mobility for mobile internet access; 6) Gateway GPRS Support Node (GGSN): It serves as interface between the mobile network and external networks like internet; 7) The Home Location Register (HLR) and Authentication Center(AuC): plays the same role as in 2G; 8) Operations Support System (OSS) : It provides and functionalities for monitoring and managing the 3G network. Indeed, the 3G is appreciated for enabling higher- speed services and covers different frequency bands depending on countries, ranging between 850Mhz - 1700 Mhz [29].

Additionally, the fourth generation, commonly referred to as LTE(Long-Term Evolution) represents a significant advancement over previous generations in terms of infrastructure and services. This generation introduces higher data speeds, improved capacity, and better performance for mobile communication and data services. The upgrades in infrastructure include: 1) BTS and MSCs : These components remain unchanged from the previous generation 2) Evolved Packet Core (EPC) The EPC is a critical component of the 4G core network architecture which provides the packet-switched backbone that handles data traffic and ensures efficient data delivery between mobile devices and the internet or other networks; 3) Radio Access Network (RAN): The Ran is responsible for the radio interface between mobile devices and base stations; 4) LTE (Long-Term Evolution) : is the primary air interface enabling the high data speeds, low latency; 5) Back-haul Network : It connects base stations to the core network and internet infrastructure; 6) Spectrum Allocation: Hands over the mobile operator access to specific radio frequency

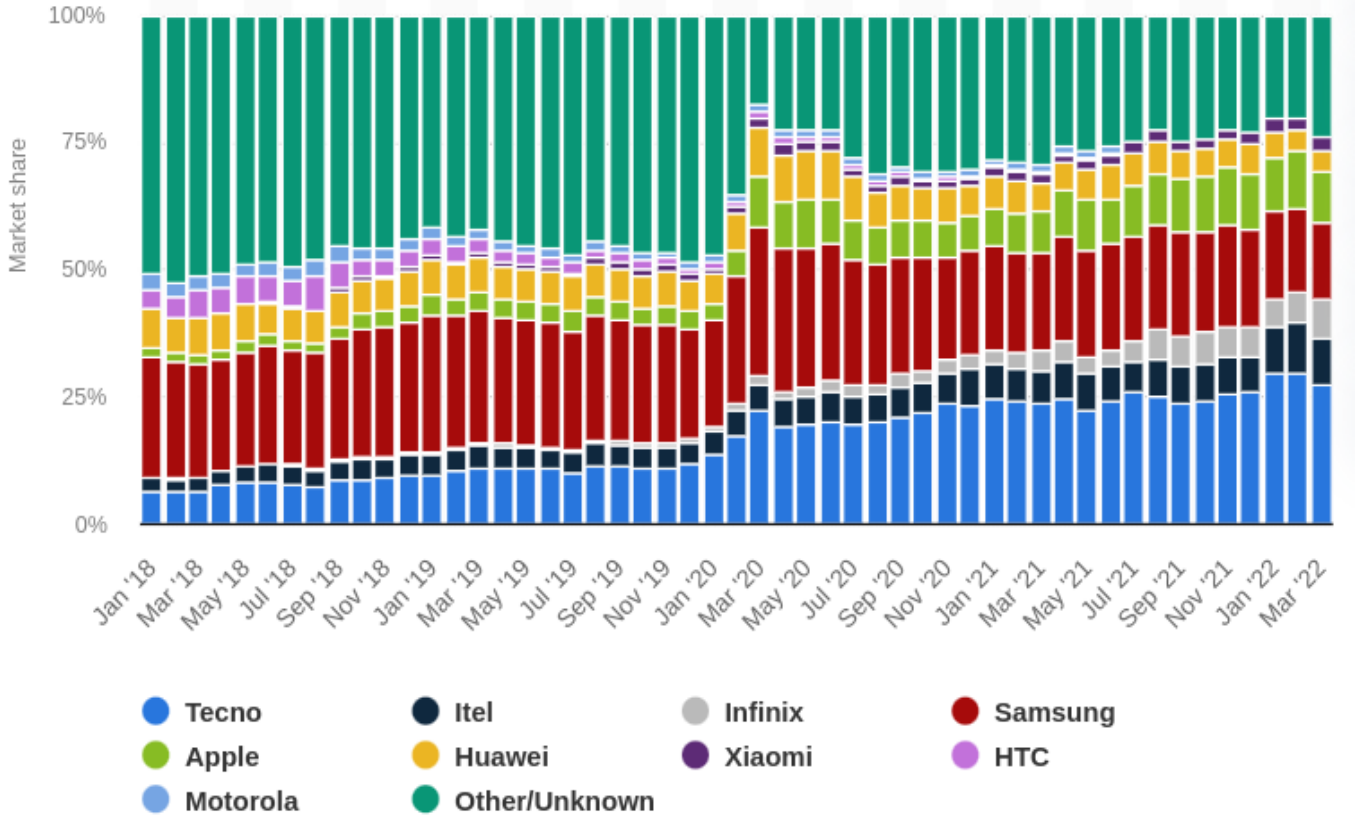


Figure 1.1: Market share of mobile device vendors in the Democratic Republic of the Congo from January 2018 to March 2022

bands; 7) Network Management System: These systems monitor and manage the 4G network, ensuring its smooth operation, performance optimization, and troubleshooting. However, it's spanning or coverage of 4G networks on frequency bands allowed in each country based on their preferences, ranging from 700MHz to 2600 Mhz. The higher frequency bands generally offer faster data speeds but may have a shorter range, while the lower frequency bands can provide broader coverage but with slightly lower data speeds [29].

1.2.4 Mobile Phone Models

Since the mobiles phones are essential tools for communication, there is a wide range of popular mobile widely used by citizens of the DRC. The popular models come from various brands and offer a range of features to cater to different user preferences and needs. Some of the popular mobile phone models in DRC include *Techno*, *Itel*, *Infinix*, *Samsung*, *Apple*, *Huawei*, *Itel*, *HTC*, *Motorola*. As it can be seen on the figure 1.1, according to the recent statistics conducted by *Statistica*, Samsung was the market leader in terms of share from January 2018 to November 2020, but in 2022, Tecno has emerged as the market leader.

Furthermore, all these models provided above sell the telephone following different types which include mobile phones, offering the features such as touchscreen displays, cameras, internet, connectivity, and access to mobile apps; features phones, which are basic mobile phones used for calling and texting; smartphones used by the majority (around 35% in

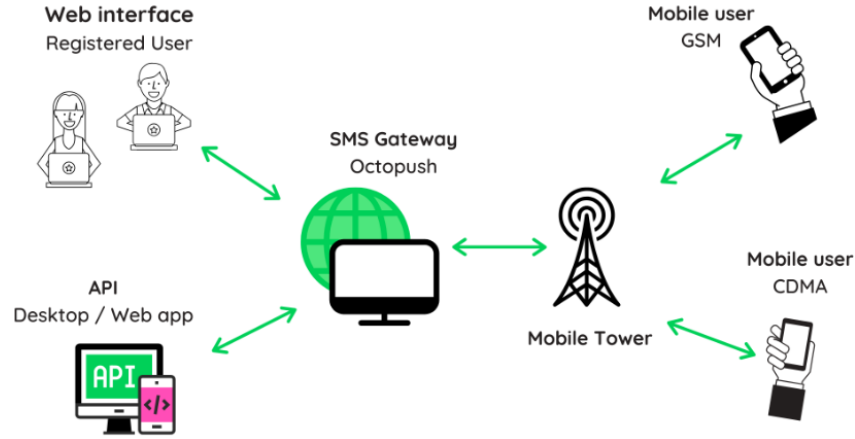


Figure 1.2: SMS Gateway Provider Architecture

DRC), providing access to mobile internet, mobile apps, multimedia messaging, and various productivity tools; Tablets, used for reading and for the same functionalities as smartphones.

1.2.5 Mobile usage and prevalence

In fact, each phone has its own unique set of characteristics that define its capacity and performance compared to others. Some phones come with specific applications that can be used independently, even without being connected to an operator, such as a camera, calculator, games app, and many others. However, other phones may not have such features.

To access the services provided by the operator, the phone's sim-card must be functioning, recognized by the operator, and capable of sending and receiving communication signals. **Of course, all these services work only if the phone's battery has sufficient power.**

Moreover, the services that citizen's subscribers benefit from are as follows :

Firstly, the Internet Access: The Internet services are used to connect people from different nodes. In fact, In accordance with the *WorldBank* ⁶ been used by 23% of the DRC's population in 2020. Nonetheless, it requires payment which proportionally gives mobile data usually expressed in Megabytes.

Secondly, the Text Messaging (SMS): Even though the internet is the most used for texting, the SMS remains a widely used form of communication, especially in regions with **limited internet connectivity or among users who prefer simple text messaging or do not have the internet connection**. Furthermore, with the architecture of GSM(Global System for Mobile Communications) invented in the second generation, sending messages became possible. Nowadays, the web environment has developed application interfaces (API) that connect external systems to operators for sending messages [19]. One of the platforms that offer these services connects its SMS gateway to the GSM operator, as seen in the case of *Octopush* ⁷ architecture shown in Figure 1.2

Thirdly, the Mobile Banking and Payments : With this services subscriber can make

⁶WorldBank : International Telecommunication Union (ITU) World Telecommunication/ICT Indicators Database <https://data.worldbank.org/indicator>

⁷Octopush : SMS platform for businesses connected with their audience

financial transactions; paying bills, transferring money conveniently.

Fourthly, the Mobile Entertainment: Mobile phones offer a range of entertainment options, from streaming videos and music to mobile gaming.

And finally, the others Mobiles apps: This party includes the health services, education, social medias applications.

1.3 Purposes of spammers in mobile messages

Most of the time, spammers prefer to promise recipients prizes and then ask for money to claim the offer. They also attack SMS gateways with DoS (Denial of Service) messages [2] whose goal is to overwhelm the system with unnecessary messages. Spammers send advertising and promotional messages based on company objectives, as well as SMS containing fake links or impersonating organizations to deceive recipients into taking certain actions or providing sensitive information [39]. Additionally, they may send SMS disguised as surveys to gather personal information for various fraudulent purposes.

1.4 Solutions

To address theses problems, it is necessary to involve various stakeholders, including network operators, app developers, regulatory bodies, and users. Firstly, it is recommended to implement mechanisms at the network level [18] to filter messages and block users involved in spamming. Secondly, users (subscribers) should be educated on how to analyze messages and report any one that is causing disturbances. Thirdly, regulatory measures should be enforced to establish stringent regulations and penalties for spammers and those engaged in fraudulent mobile activities. Fourthly, the development of apps that enable filtering, classification, and reporting in the subscriber side would be beneficial. Fifthly, a website can be set to collect messages whether spam or ham reported by users who have doubts about their legitimacy, and then Machine Learning models can be used for detection purposes. For this, supervised or unsupervised methods can be employed to classify and predicting whether a message is spam or ham.

1.5 Summary

Overall, with the growth of mobile technologies, subscribers benefit from diversified services including : text messaging, voice calls, mobile banking, entertainment apps, and many others. However, These advancements also bring new challenges, such as the development of spam messages that aim to disturb network subscribers with unwanted or threatening messages.

In DRC, especially in the eastern party, users face similar issues. This chapter emphasizes methods or techniques that can be used to address this problem and relatively reduce spam. One of the prominent techniques suggested is based on Artificial Intelligence, particularly Machine Learning algorithms.

Chapter 2

Review of the Literature and description of the approach

2.1 Introduction

This chapter delves into theory, methodologies, and machine learning techniques, including relevant algorithms and their deployment in the suggested solution. It also highlights the contributions of previous researchers in the field.

2.2 Revue of the Literature

Numerous researchers have extensively explored the subject of spam detection. Within this domain, some have directed their investigations towards the web environment, while others have delved into realm of mobile technologies.

Furthermore, these researchers have chosen to investigate the detection of spam across various communication channels, including emails and SMS, encompassing Multimedia SMS (MSS) as well. In the following sections, we comprehensively review the body of work that has been accomplished within this context as follows:

[22]. **Dr.V.M Veena K.Katankar** proposed a system that comprises an SMS gateway for transferring SMS messages after they have been stored and encrypted by the web server. This software operates through a web interface. Whenever a client sends a *POST* request, it is received by the web server, which is responsible for encryption or decryption if necessary. Subsequently, the gateway transfers the message as per its designated route. This solution proves to be particularly valuable in mobile banking and organizational marketing systems. Nevertheless, the author encourages other researchers to delve into channel services in communication and advanced encryption techniques.

[6] In their publication titled *Short Message Service*, **Brown, Jeff and Shipman** members of IEEE, delve into several significant aspects. They start by exploring th growth of mobile phones and SMS services. They also examine the system architecture of SMS Centers and technologies used for message communication

Furthermore, they shine the spotlight on aggregators and services providers. These are the entities that enable users to send bulk messages, essentially sending messages with a large amount of text to a group of recipients. This includes the interesting capability of converting email messages into SMS.

Moreover, the article highlights that some of these aggregators may choose to collaborate with cellular networks. In this collaborative role, they act as intermediaries, connecting third-party entities that don't have direct relationships with cellular service providers. To achieve this, they employ a *SMPP (Simple Messaging Peer to Peer)* protocols.

[28] **Researchers A. Medani and A. Gani**, affiliated with the University of Malaysia, have published a comprehensive review focusing on security concerns and techniques related to mobile Short Message Service (SMS).

In their paper, they illuminate the process by which a subscriber sends a message to another party while adhering to specific principles of the Over-The-Air (OTA) structure. This process involves transmitting the message from the sender to the base station and then forwarding it to the intended recipient through the SMS Center (SMSC).

Crucially, they emphasize the importance of securing every SMS using *Public Key Infrastructure (PKI)*, ensuring end-to-end transmission security and safeguarding the message from unauthorized modifications. However, it's worth noting that the use of PKI can potentially impact mobile device performance due to the significant power requirements for the encryption process, and it may not guarantee integrity across all standards.

To address these security concerns within GSM systems, the researchers propose the implementation of *XML Key Management Specification* as a middleware solution. This middleware system serves as an intermediary, facilitating secure communication between mobile devices and enhancing overall system security for the benefit of clients.

[10] **Nikhil Kumar**, a researcher affiliated with the University of New Delhi in India, published an article focusing on the topic of Email Spam Detection Using Machine Learning. In his study, he placed particular emphasis on comparing various machine algorithms, including *Naive Bayes, Support Vector Classifier, AdaBoosting, K-Nearest Neighbour, and Bagging Classifier*. The objective was to predict whether an email was categorized as spam or legitimate (ham). To demonstrate his approach, he utilized an existing dataset available in the Kaggle workspace.

Through experimentation and parameter tuning, Nikhil found that Naive Bayes delivered promising results in terms of accuracy. However, he also pointed out a limitation associated with the Naive Bayes algorithm. This limitation is tied to its assumption of class-conditional independence, which implies that each feature is considered independent of the presence of the other features. In cases where this assumption does not hold, it can lead to misclassification of data points.

To address this limitation and enhance the performance of spam detection, the author recommended the use of **ensemble methods**. These methods involve the use of multiple classifiers for making class predictions, allowing for more robust and accurate results.

[31] In 2018, researchers Pavas Navaney, Gaurav Dubey, and Ajax Rana, who are affiliated with the University of Southern California and Amity presented a conference paper titled "SMS Spam Filtering using Supervised Machine Learning Algorithms".

Their study concentrated on a dataset comprising 5574 records, of which 4827 messages were categorized as "ham" (legitimate messages), while 747 messages were classified as "spam" (unsolicited or unwanted messages).

The researchers applied three different machine learning methods to this dataset. Among these methods, it was observed that the *Support Vector Machine (SVM)* algorithm achieved the highest accuracy compared to the Naive Bayes and Maximum Entropy Classifier al-

gorithms.

[36] **Houshmand Shirani-Mehr**, a researcher in Machine Learning, published an article in 2013 titled : "SMS Spam Detection using Machine Learning Approach". His purpose was to address the spam filtering problem by utilizing ML algorithms. Therefore, He utilized a dataset from the *UCI Machine Learning Repository* repository ¹ , which contained real SMS messages. In development, he employed the algorithms to tackle that problem such as : Naive Bayes with Laplace smoothing, Support Vector Machine, and Ensemble methods (*AdaBoosting and Random Forest*). As an improvement, the author added meaningful features such as the length of messages in terms of the number of characters and certain thresholds.

The results obtained after applying these methods to the dataset indicate that the SVM algorithm achieved the highest accuracy score.

[16] The authors of the article titled "SMS Spam Detection Using Machine Learning", namely **Gupta, Suparna Das and Saha, Soumyabrata and Das, Suman Kumar**. Their focus was on reviewing various techniques employed by other researchers in the realm of machine algorithms for SMS spam detection.

In their research, they adopted a similar approach by incorporating the *TF-IDF (Term Frequency-Inverse Document Frequency)* method. This technique assesses the frequency of a word within a document and evaluates its importance in that document. *TF-IDF* is a well-known method for measuring word relevance in a collection of texts.

To assess the effectiveness of these techniques, the authors applied them to a spam dataset obtained from *Kaggle* ² . After conducting their experiments and evaluations, the authors arrived at a noteworthy conclusion. They found that among all the ML algorithms they employed, the Naive Bayes algorithm consistently achieved the highest level of accuracy in SMS spam detection.

As shown above, many researchers have investigated the same topic using different approaches. Some have focused on security within mobile architecture, including message transfer processes, while others have concentrated on using Machine Learning (ML) models to combat the issue of spam. In general, these approaches are valuable to this project and serve as its inspiration at the point that many techniques related to these approaches have been implemented in this project.

However, what sets this project apart is its practical approach involving specific society. Rather than solely relying on existing datasets from platforms like *Kaggle and UC Machine Learning Repository*, this project has actively engaged with people to collect data. It has also integrated some data from these platform datasets to enhance the quality of information.

Furthermore, this project harnesses the latest advancements in machine learning. It utilizes Ensemble Methods to achieve high levels of accuracy. Additionally, it employs technical parameter tuning, including *GridSearcher and VotingClassifier*. In fact, Grid-

¹**UCI ML** : The UCI Machine Learning Repository is a popular collection of datasets maintained by the University of California, Irvine (UCI). It serves as a valuable resource for researchers and practitioners in the field of machine learning and data mining. <https://archive.ics.uci.edu/>

²**Kaggle** : a platform for data science competitions and datasets. <https://www.kaggle.com/>

Searcher assists in identifying the most suitable parameters required for algorithm models.

Moreover, this project doesn't stop at model development, it extends to the deployment of the models generated through the processes. It provides backend *APIs* for certain platforms interested in learning from these results. Additionally, it outlines the structure of GSM deployment, encompassing the SMSCenter's role in the mobile messaging system.

2.3 Tools and Techniques

In the mission of this project to create a messaging application that not only streamlines mobile communication but also tackles the pervasive issue of spam, this section serves as a technical guide. It will explore the tools and techniques at the core of the approach used.

Building an effective messaging application is like constructing a house- you need the right tools. Thus, this section discusses the software and technologies that form the foundation of our messaging app, including the programming languages, frameworks, and platforms utilized.

To combat spam effectively, this project is enlisting the help of machine learning. It delves into the world of data analysis and machine learning tools and frameworks : *numpy*, *pandas*, *matplotlib*, *scikit-learn*, that empower the authors to analyze, detect and prevent spam messages.

2.3.1 Messaging application development tools

In the realm of modern software development, the choices of development tools can significantly impact the efficiency and effectiveness of the project. When crafting application, the authors carefully considered the tools that will shape the foundation of the *backend* and *frontend* development. Actually, the *backend* references the environment where data of the app are stored, structured and more secured; while the *frontend* involves the space where techniques are developed to show to the user the interface comfortable for his understanding. Among all tools, some serve as programming languages and others as editors.

Hence, The choices made by the authors are *Python (with Django Framework)* as programming language and *SQL* for data structuring language in *backend* development and HTML, CSS and Javascript (with *Vue-Js Framework*) for *frontend* environment.

Back-end Development with *Python (Django)* and *SQL* :



is a powerful language appeared in 1980 firstly implemented by Guido van Rossum at *Stichting Mathematisch Centrum* in the Netherlands as a successor of a language called *ABC* [42]. Its newest version is *Python 3*³ which is available for all most environments, either *Macos* or *Linux* and *Windows*.

³Python : <https://www.python.org/>

```
Python 3.11.4 (main, Jul 5 2023, 14:15:25) [GCC 11.2.0] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> print('hello')
hello
>>> █
```

Figure 2.1: Testing if python is running on the OS (LINUX)

In comparison with *Java*, *C*, *C++*, *MATLAB*, *Python* is more readable, since it requires few lines of code which are clean. Next, it is a good choice for those who want to start with programming [5]. Technically it is versatile, since it used for a wide range of applications, from web development to mobile apps (with Kivy ⁴), data analysis, machine learning, and scientific computing. Actually, the high reason that influenced the use of this programming language is its capacity to deal with data by providing scientists with many libraries.

Since the frameworks help to gain time in terms of development and structuring a project, *Python* provides many frameworks for web development. Notable these are Django, Flask, and more. Authors's choice, Django, is a high-level, open-source web framework for building robust and dynamic web applications. It's written in *Python*, which is one of the reasons for its popularity. It follows the **batteries-included** philosophy, providing a wealth of built-in features like authentication, URL routing, a powerful admin interface, and an ORM (Object-Relational Mapping) system, which simplifies database operations [1].

Actually, Django's ORM abstracts many *SQL* complexities, enabling developers to interact with the database using *Python* code, without needing to write raw *SQL* queries. This higher-level interaction simplifies database access and makes the development process more efficient. So, while *SQL* is at core of database interaction, Django's *ORM* provides a user-interface for developers, streamlining the development of data-driven web applications.

Suppose we want to retrieve all the employees in a database with salaries greater than \$4000 using raw *SQL*. Here's what the *SQL* query would look like :

```
1 SELECT * FROM employees WHERE salary > 4000
```

While Django accomplishes the same task using the following code:

```
1 from myapp.models import Employee
2 employees = Employee.objects.filters(salary__gt = 4000)
```

How did we get there ?

In fact, the project must be running for doing that. For installing *Python*, just go to the official website for the download, no matter the OS version, either *MACOS*, *Windows* or *Linux/UNIX* since *Python* is portable. Indeed, the last version at the writing of this project was Python 3.12.0. To test if the it is working, just enter the command `python` as in figure 2.1.

⁴Kivy: <https://realpython.com/mobile-app-kivy-python/>

```
(base) christianresearcher@christianresearcher-HP-EliteBook-8470p:/$ sudo python3 -m venv SpamAppEnv
(base) christianresearcher@christianresearcher-HP-EliteBook-8470p:/$ source SpamAppEnv/bin/activate
(SpamAppEnv) (base) christianresearcher@christianresearcher-HP-EliteBook-8470p:/$ pip install django
```

Figure 2.2: How to install django ? Here, the name of *VE* is SpamAppEnv

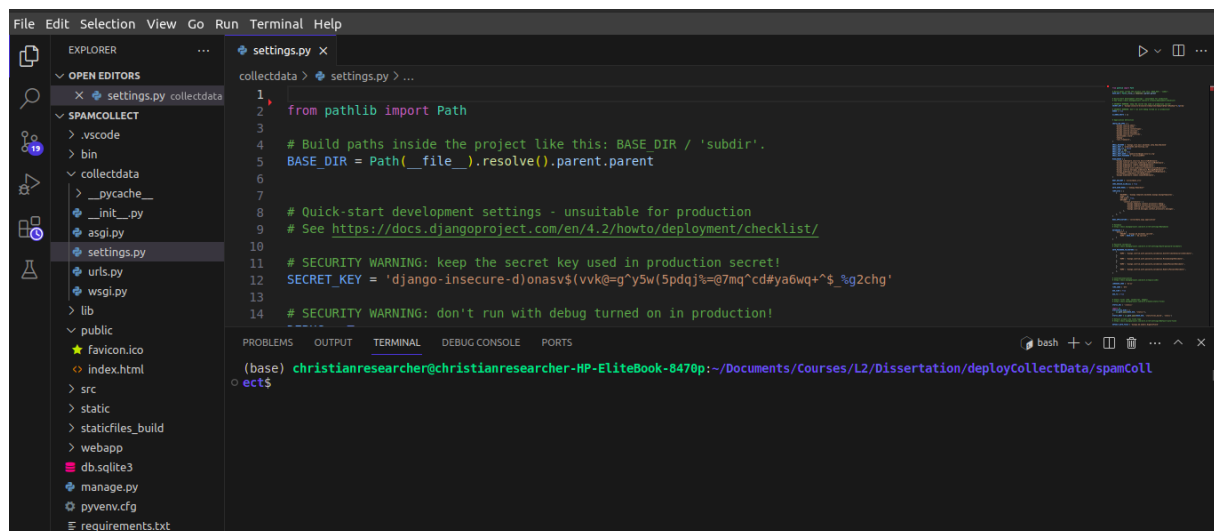


Figure 2.3: After the project and app are already created

Next, for installing Django, the steps remain pretty the same, going on the official page and following the guides as resumed in the as follows: For the step 1, Installing the virtual environment (*VM*) ⁵ :

In Windows : `python -m venv myenv`; then active it by : `myenv\Scripts\activate`
The word *myenv* is just the name of virtual environment. But Why do we create it ? In fact, it is a best practice in Python development to manage dependencies, isolate projects, and maintain a clean and organized development environment.

In MACOS/Linux : Only the way of activating the *VM* changes. Then just by entering the following command:

`source myenv/bin/activate`; the virtual will be functioning.

Finally, as the *VM* is working Django, can be installed, by the command : `pip install Django`. At the writing of this project, the last version 4.2.6. The bit steps to follow for installing are demonstrated in the figure 2.2

Now, the project can be created, followed by the app inside, depending on interests. For that the commands : `django-admin startproject projectname` and : `django-admin startproject appname` can be utilized. The result is demonstrated in figure 2.3.

However, the configuration about the app created, ought to be made lest it should raise the error. Thus, in settings file, present in the project folder the properties called *INSTALLED_APPS*, as in the figure 2.4.

After, this we can just enter the commands :

```
1 python manage.py makemigrations
2 python manage.py migrate}
```

For sure, the first command line says to Django the new changes, and the second applies or assesses them.

⁵How to create the VM ?<https://realpython.com/python-virtual-environments-a-primer/>

```

22 INSTALLED_APPS = [
23     'django.contrib.admin',
24     'django.contrib.auth',
25     'django.contrib.contenttypes',
26     'django.contrib.sessions',
27     'django.contrib.messages',
28     'django.contrib.staticfiles',
29     'appname',
30 ]

```

Figure 2.4: Adding the appname in *INSTALLED_APPS* dependencies

How does Django deal with the database ?

Django deals with databases through *ORM* as mentioned above. Its management involves to follow different steps such as:

Database Configuration : in the Django project's settings (usually in the *settings.py*, we have to specify the database we want to use. Django supports various databases types, including *PostgreSQL*, *Mysql*, *SQLite* and *Oracle* ⁶ . We have only define the database backend, connection details, and other options in the *DATABASES* setting. For instance the configuration of *MYSQL* will be like this :

```

1 DATABASES = {
2     'default': {
3         'ENGINE': 'django.db.backends.mysql',
4         'NAME': 'the_db_name',
5         'USER': 'the_db_user',
6         'PASSWORD': 'the_db_password',
7         'HOST': 'localhost', # or the IP address of the MySQL
                             server
8         'PORT': '3306', # MySQL default port
9     }
10 }

```

Model Definitions : *Django* models are Python classes that define the structure of the database. Models are defined in the the *models.py* file. Each model class represents a database table, and each model field represents a table column. The syntax used for creating a database is as follows:

```

1 from django.db import models
2 class Employee(models.Model):
3     name = models.CharField(max_length=100)
4     salary = models.DecimalField(max_digits=10,
                                   decimal_places=2)

```

The corresponding *SQL* code is this:

```

1 CREATE TABLE Employee (

```

⁶Setting Databases in Django : <https://docs.djangoproject.com/fr/4.2/ref/databases/#mysql-notes>

```

2         id INTEGER PRIMARY KEY,
3         name VARCHAR(100),
4         salary NUMERIC(10, 2)
5     );

```

Migrations : Every time a model (database table) is created or modified, *Django* need to notified for assessing these changes. As mentioned earlier, the command '**python manage.py makemigrations**' is executed in the terminal for managing the changes, '**manage.py migrate**' command is entered to apply all of these changes.

Database abstraction : With this technique, we do'nt no longer need to write *SQL* code, since by *Python* it is possible to interact with the database, and making a *queryset* request(*crud* ⁷).Let's see how it works once again:

```

1 new_employee = Employee(name ="Eistein", salary=450000)
2 new_employee.save()

```

instead of doing this in *SQL* :

```

1 INSERT INTO employees (name, salary) VALUES ('Einstein',
        45000);

```

Indeed, we can see that even a non-professional in *SQL* can now deal with the databse without any *SQL* code.

Furhermore, the use of abstraction techniques to interact with database, enhances its security of by guarding against *SQL injection*.

What does *Django* do for interacting with APIs ?

Django presents a useful package for interactiong with the *API* called *DRF* ⁸ It allows : authentication policies including optional packages for *OAuth1a* and *OAuth2* ⁹, web browsable API and serialization ¹⁰ and deserialization that supports both *ORM* And *NO-ORM* data sources [30].

Front-end Development with *HTML*, *CSS* and *Js* :

The Front-end development is a crucial aspect of web development that focuses on creating the user interface and user experience of a website or web application. It involves using a combination of *HTML*,*CSS*, and Javascript to build the visible and interactive elements of a website.

The *HTML* (Hypertext Markup Language) is used as a maker of web pages by providing its structure and content. It uses a markup language with various tags to define headings, paragraphs, links, images, forms, and more [38]. For example a page with a heading and a paragraph should look like this in the content :

⁷CRUD: Create Read Update Detele item

⁸DRF (Django Rest Framework) : a powerful tools serving to interact with Apis. <https://www.django-rest-framework.org/>

⁹OAuth2 : (Open Authorization 2.0) : is a framework that allows third-party applications to access a user's data without exposing their credentials, such as passwords.OAuth 1.Oa is the old version of OAuth2

¹⁰Serialization : converting data into formats like *JSON*, *XML*, etc. The deserialization involves the recontruction of the same operation

```

1 <div>
2     <h1>Page Dev</h1>
3     <p>this is our page</p>
4 </div>

```

Furthermore, the *CSS (Cascading Style Sheets)* is used for styling and layout. Thus, it controls the visual presentation of HTML elements. For example for our above code :

```

1 h1{
2     color : blue; /* set the color to the element*/
3     font-size: 24px; /* sets the font size */
4     text-align: center; /* centers the element*/
5 }

```

Apart from that, the other powerful tool used in web development is *JS(JavaScript)*. It adds interactivity and dynamic behavior to web pages. It also leveraged for creating features like images sliders, form validation, animations and real-time updates without having to **reload the page**. The common frameworks used to extend its productivity are : React, Angular and Vue-js [44]. By updating the above *HTML* code, we can see the interactivity created by JS:

```

1 <!DOCTYPE html>
2 <html>
3 <head>
4     <title>JavaScript Example</title>
5 </head>
6 <body>
7     <div>
8         <h1 id="pageTitle">Page Dev</h1>
9         <p>this is our page</p>
10    </div>
11
12    <button id="changeTitleButton" onclick="changeTitle()">
13        Change Title</button>
14
15    <script>
16        // JavaScript function to change the title
17        function changeTitle() {
18            // Get the h1 element by its ID
19            var titleElement = document.getElementById("
20                pageTitle");
21
22            // Check if the element exists
23            if (titleElement) {
24                // Change the text of the h1 element
25                titleElement.innerText = "New Page Title";
26            }
27        }
28    </script>

```

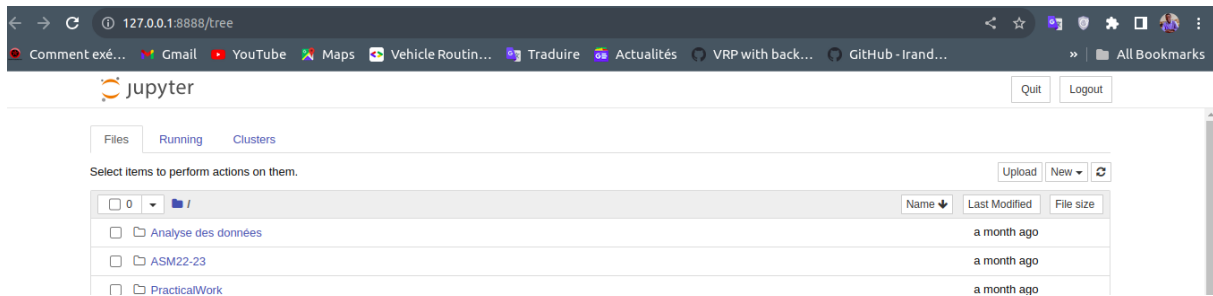



Figure 2.5: Start jupyter in conda kernel

```
27 </body>
28 </html>
```

In this example, the button with the ID 'ChangeTitleButton' and the function called 'ChangeTitle()' are added. The click on the 'Change Title' button executes the changeTitle function. Then, the function retrieves the `<h1>` element by its ID ("pageTitle") and changes its text to "New page Title". Thus, by this bit snippet code, *JavaScript* really appears interactive.

2.3.2 Data Science tools and frameworks

Data science involves learning from data, visualizing, analyzing it, and making predictions. To do this, we need the right tools. *Python* is one of best and powerful tools used for these tasks. It has a large and active community that continuously contributes to its growth. *Python* offers a variety of packages that assist data scientists in their work.

In Python, common packages used for working with data include **numpy**, **pandas**, **matplotlib**, **seaborn**, **scikit-learn**, **tensorflow**, and more.

The *IDE* (*Integrated Development Environment*) used for working in Python, even for all backend-development is : Visual studio which is portable and downloadable from the official page : <https://code.visualstudio.com/>. On the other hand, we have a famous *IDE* called *Anaconda* including *Jupyter notebook* is used for machine learning and data science projects. It's designed to simplify package management and deployment by using a package manager called *Conda* which helps users to install, update, and manage packages, libraries and dependencies [40].

To start a new project we just execute in the terminal, the command : `jupyter notebook`, then a default browser configured just open directly the link. The page look like in the fig 2.5.

Data manipulation with Numpy, Pandas

Numpy Library :

Numpy is a fundamental library for scientific computing with Python. It provides support for large, mutli-dimensional arrays and matrices, along with an assortment of high-level mathematical functions to operate on these arrays.

Actually, the reason of thinking about a new tool of computing in Python is because, all data structures it provides: lists for enumerating a collection of objects, dictionaries to build hast tables, are not ideally suited to high-performance numerical computation [43]. Basically, the usage of Numpy asks for importing its modules like this :

```

1 import numpy as np #np is a common alias used
2 In [4]: np.__version__
3 Out [4] : '1.24.3'

```

The structure and creation of a *NumPy* array. The fundamental data structure provided by the Numpy library for representing arrays is **ndarray** it refers to the array which is n-dimensional or multi-dimensional [45]. Thus, several means can be used to create an array as follows :

- With 1D(dimension):

```

1 In[8] : np.array([1, 2, 3, 4, 5])
2 #Creates a NumPy array from a given list or iterable.
3 Out[8] : array([1, 2, 3, 4, 5])
4
5 #2D array
6 In[12] : np.array([[1, 2, 3], [4, 5, 6]])
7
8 In[12]: array([[1, 2, 3],
9               [4, 5, 6]])

```

```

1 In[10] : np.arange(1, 10, 2)
2 # Creates a 1D array from 1 to 9 with a step of 2
3 Out[10] : array([1, 3, 5, 7, 9])
4 #2D array for arange function, requires manipulation

```

Many other functions can be used for creating arrays, like : empty, zeros, ones, eye, etc.

Manipulation of arrays. The manipulation operation includes : The splitting, slicing, indexing, reshaping, arithmetical operations, concatenations, comparisons and many others. Let's dive into some of that operations as follows:

```

1 #We generate the integers from zero to twelve and
2 # re pack them into a 4x3 array
3 In [21] : np.arange(12).reshape((4,3))
4 Out [21] : array([[ 0,  1,  2],
5                  [ 3,  4,  5],
6                  [ 6,  7,  8],
7                  [ 9, 10, 11]])
8 #Suppose we want to multiply each vector element by 3
9 In [24] : a = [3,7,4]
10           [4*x for x in a]
11 Out[25] : [12, 28, 16]
12 #Concatenate arrays vertically
13 In [29] : np.vstack(([1, 2, 3],[1, 2, 3]))
14 Out [29] : array([[1, 2, 3],
15                  [1, 2, 3]])
16 #Concatenate arrays horizontally
17 In [31] : np.hstack(([1, 2, 3],[1, 2, 3]))
18 Out [31] : array([1, 2, 3, 1, 2, 3])

```

Let's mention that ndarray object is homogeneous since all elements within must have the same data type. The types allowed are : Float, int, bytes, str, number and complex (for decimal complex numbers). To define, the type on the array on creation is made by **dtype** property like this:

```
1 In [55] : np.array([1, 2, 3, 4, 5], dtype='float')
2 Out [55] : array([1., 2., 3., 4., 5.])
```

Besides, dealing with slicing and splitting still depends on the dimension. Lets break in the code to see that :

```
1 In [56] : arr = np.array([[1, 2, 3],
2 [4, 5, 6],
3 [7, 8, 9]])
4
5 #split along rows (axis=0)
6 In [59] : split_rows = np.vsplit(arr, 3) # Split into threee
       1-row arrays
7 Out[59] : [array([[1, 2, 3]]), array([[4, 5, 6]]), array([[7,
       8, 9]])]
8
9 #slicing
10 In [60] : arr[1:3, 1:3] # Get a 2x2 subarray
11 Out [60] : array([[5, 6],
12              [8, 9]])
```

Some others functions are used as follows : all, any, cov-corrcoef, dot, where, random(), randint() and many others. The details of usage are given on the official of Numpy package ¹¹.

Pandas library :

Pandas ¹² is an essential open-source Python library used for data manipulation and analysis. It provides functions for reading and writing data structures in various formats, including CSV and text files, Microsoft Excel, SQL databases, and the fast *HDF5* ¹³ format. Additionally, Pandas can **align data, handle missing data, allow reshaping and pivoting, perform data aggregation and transformation, and merge and join data sets** [27].

It offers many other capabilities for efficient data processing. To start with *pandas*, we have to create the pandas object like this:

```
1 import pandas as pd # pd is an alias name
```

Data Structures. Pandas has two main structures: Series and DataFrame. The first is one-dimensional array, while the second is a two-dimensional table that is similar to a spreadsheet or SQL. Let's break in example: - Series:

¹¹Numpy, official page : <https://numpy.org/>

¹²<https://pandas.pydata.org/>

¹³HDFR (Hierchical Data Format version 5) : It is a versatile and high-performance data storage format commonly used in scientific and data analysis fields.

```

1 # Creating a Series from a list
2 In [46] : data = [1, 2, 3, 4, 5]
3 Out [46] : pd.Series(data)
4 0      1
5 1      2
6 2      3
7 3      4
8 4      5
9 dtype: int64

```

- DataFrame:

```

In [48]: data = {'Name': ['Chris', 'Alice', 'Jojo'],
                'Age': [25, 30, 22],
                'City': ['Bukavu', 'Goma', 'Matadi']}
pd.DataFrame(data)

```

```

Out[48]:
   Name  Age  City
0  Chris   25  Bukavu
1  Alice   30   Goma
2   Jojo   22  Matadi

```

Reading and Writing data. Pandas offers versatile functionality which deal with various sources and formats. The common sources include :

- **CSV files:** They are read and written like this :

```

1 #Reading from CSV
2 data = pd.read_csv('datafile.csv')
3 #Writing to CSV
4 data.to_csv('new_data_file_name.csv', index=False)

```

- **Excel files :**

```

1 # Reading from Excel
2 data = pd.read_excel('datafile.xlsx', sheet_name='Sheet1')
3
4 # Writing to Excel
5 data.to_excel('new_data_file_name.xlsx', sheet_name='Sheet1',
6               , index=False)

```

- **SQL Databases :**

```

1 # Reading from SQL database sqlite
2 connection = sqlite3.connect('my_database.db')
3 query = 'SELECT * FROM my_table'
4 data = pd.read_sql(query, connection)
5
6 # Writing to SQL database
7 data.to_sql('new_table', connection, if_exists='replace',
8             index=False)

```

In the same way, functions **read_json**, **read_html** are also respectively used for dealing with the JSON and HTML data.

- **Data Cleaning.** Pandas uses several functions, among them we have **drop_duplicates()**, **fillna()**. Which are used like this:

```
1 # Removing duplicates
2 df = df.drop_duplicates()
3
4 # Handling missing values
5 df = df.fillna(0)
```

- **Data Exploration.** Pandas provides methods for exploring the dataset, such as **head()**, **tail()**, **describe()**, and **info()**. Thus, the application will look like :

```
1 data = {'A': [1, 2, 3, 4, 5],
2         'B': ['X', 'Y', 'Z', 'X', 'Y']}
3 df = pd.DataFrame(data)
4 # Display the summary statistics of numeric columns
5 print(df.describe())
6
7          A
8 count  5.000000
9 mean   3.000000
10 std    1.581139
11 min    1.000000
12 25%    2.000000
13 50%    3.000000
14 75%    4.000000
15 max    5.000000
```

Data Manipulation. Pandas performs the manipulation of tables as Excel using the **pivot_table()** and **merge()** function perform combination operation for analysis. Additionally it allows indexing, slicing, filtering, modifying data. Let's break into the demonstration:

- **Pivot table :**

```
1 In [72] : df.pivot_table(index='B', values='A', aggfunc='mean')
2 print(pivot)
3          A
4 B
5 X    2.5
6 Y    3.5
7 Z    3.0
8
9 #The operation computed is the average measurement
```

- **Merging :**

```
1 #Create two DataFrames
2 data1 = {'Key': [1, 2, 3, 4, 5],
```

```

3 'Value1': ['A', 'B', 'C', 'D', 'E']}
4 data2 = {'Key': [3, 4, 5, 6, 7],
5 'Value2': ['X', 'Y', 'Z', 'U', 'V']}
6 df1 = pd.DataFrame(data1)
7 df2 = pd.DataFrame(data2)
8
9 # Perform combination-like operation
10 result = pd.merge(df1, df2, on='Key', how='left')
11 print(result)
12
13 Key Value1 Value2
14 0      1      A    NaN
15 1      2      B    NaN
16 2      3      C      X
17 3      4      D      Y
18 4      5      E      Z

```

- Slicing:

```

1 #Consider the example on the top about
2 #name, age, city
3 # Slice specific rows and columns
4 df.loc[1:3, 'Name':'Age']
5 #From the second column till the threeth line
6 #From the Name till the Age column
7 #The result gives this:
8
9 Name  Age
10 1      Bob    30
11 2  Charlie    35

```

Assume we want to apply some characteristic on a column :

```

1 # Create a new column based on an existing column
2 df['days'] = df['Age'].apply(lambda x: x * 360)
3 print(df)
4 # The result is like this:
5      Name  Age  City  days
6 0  Alice   25  New York  9000
7 1    Bob   30  Los Angeles 10800
8 2  Charlie  35   Chicago 12600

```

- Modifying Data :

```

1 df.loc[2, 'Name'] = "Jonathan"
2 print(df)
3 #The df becomes like this :
4 Name  Age  City  days
5 0  Alice   25  New York  9000
6 1    Bob   30  Los Angeles 10800
7 2 Jonathan  35   Chicago 12600

```

Data Visualization With *Matplotlib*

Matplotlib is a open-source, flexible and customizable Python package used for generating 2D plotting that generates production-quality graphs. In addition to this, it includes the capacity of saving images in different output formats (JPG, PNG, PS and others) [41].

To get started with it, we just go to the official page and download the version ¹⁴. However, for those using some *IDE* like *Anaconda*, packages like : *numpy*, *pandas*, and *matplotlib* are incorporated inside. When working with data visualization, the type of plot to choose should depend on the nature the data. In the table , the overview of types of plots and when to use them is given. However, some plots can be combined even though they are primarily made for whether categorical or numerical visualization.

The usage of *matplotlib* properties require a good manipulation of data, often done by the *numpy* and *pandas*. Let's break into examples of it usage: First all, the import of *matplotlib* is required for the manipulation like this :

```
1 import matplotlib.pyplot as plt #plt is also an alias

1 import matplotlib.pyplot as plt
2 import numpy as np
3
4 # Data
5 x = np.arange(1, 11)
6 y1 = x
7 y2 = x**2
8 y3 = np.sqrt(x)
9
10 # Create a figure with subplots (1row and 3 columns)
11 fig, axs = plt.subplots(1, 3, figsize=(15, 5))
12
13 # First Subplot: Line Plot
14 axs[0].plot(x, y1, color='b', marker='o') # 'o' is a clue
15
16 #define legends
17 axs[0].set_title('Line Plot')
18 axs[0].set_xlabel('X-axis')
19 axs[0].set_ylabel('Y-axis')
20
21 # Second Subplot: Bar Plot
22 axs[1].bar(x, y2, color='g', alpha=0.6)
23 axs[1].set_title('Bar Plot')
24 axs[1].set_xlabel('X-axis')
25 axs[1].set_ylabel('Y-axis')
26
27 # Third Subplot: Scatter Plot
28 axs[2].scatter(x, y3, color='r', marker='x')
29 axs[2].set_title('Scatter Plot')
30 axs[2].set_xlabel('X-axis')
31 axs[2].set_ylabel('Y-axis')
```

¹⁴Matplotlib: <https://matplotlib.org/>

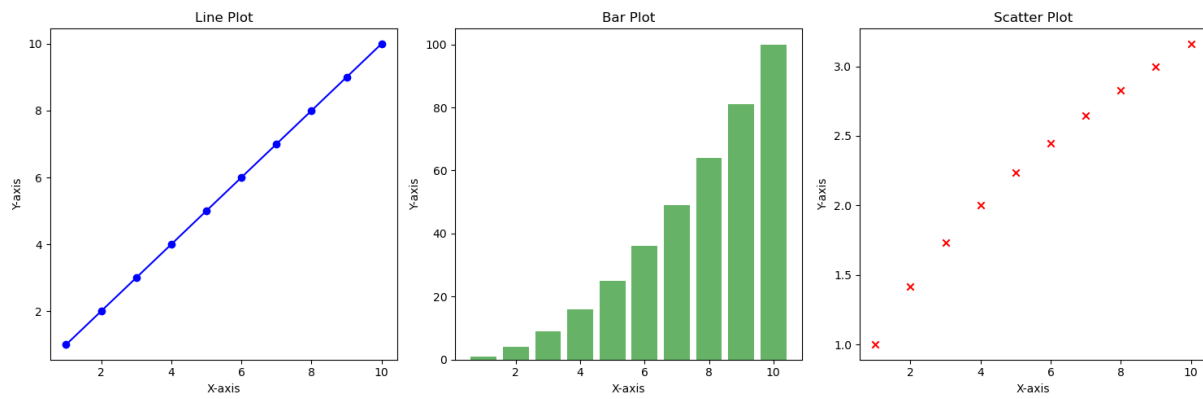


Figure 2.6: How to use matplotlib for visualization

```
32  
33 # Adjust subplot layout to prevent overlapping  
34 plt.tight_layout()  
35  
36 # Display the figure  
37 plt.show()
```


Type of data	Plot name	Utilities
Categorical Data	Bar Plot	It is deal for showing the frequency or count of categorical data. Example: Comparing the number of apples, bananas, and oranges sold at a fruit stand
	Pie Chart	Suitable for displaying parts of a whole. Example: Showing the composition of monthly expenses (eg. rent, groceries, utilities).
	Stacked Bar Chart	Useful for comparing categories while also showing their composition
Numerical Data	Histogram	Visualizes the distribution of a single variable or continuous data. Example : Analyzing the distribution of ages in a population
	Box Plot	Displays the distribution and spread of numerical data
	Scatter Plot	Depicts relationships between two numerical variables Example : Showing the correlation between the number of study hours and exam scores for multiple students.
	Line Plot	Shows changes in variable over a continuous range, often over time. Example : Plotting stock prices over several months to visualize trends.
Mixed Data	Violion Plot	Combines a box plot with a kernel density estimation to visualize the distribution. Example: Comparing the distribution of test scores across different schools.
	Heatmap	Useful for displaying relationship between multiple variables in matrix. Example : Analyzing the correlation between various factors (eg., age, income, and education level) in a survey.

Table 2.1: Choose the plot depending on data's nature

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