DE-42 (DC & SE)

NUST COLLEGE OF
ELECTRICAL AND MECHANICAL ENGINEERING

NFT BASED GEMSTONE TRADING AND TRACKING PLATFORM OF PAKSTAN

A PROJECT REPORT

DE-42 (DC & SE)

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BACHELORS

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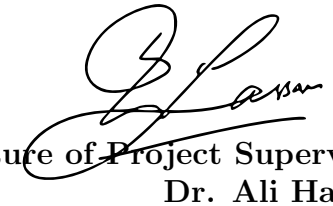
Certification

This is to certify that [**Syed Afraz Shah**], [**354772**], [**Amna Ahmad**], [**345952**], [**Abdul Aleem Abbasi**], [**336150**] and [**Abdul Moeez Hassan**], [**338960**] have completed the final project NFT BASED TRACKING AND TRADING PLATFORM OF PAKISTAN, at the College of Electrical and Mechanical Engineering, NUST to fulfill the partial requirement of the degree B.E. Computer Engineering.



Signature of Project Supervisor
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Sustainable Development Goals (SDGs)

SDG No	Description of SDG
SDG 8	Decent Work and Economic Growth
SDG 9	Industry, Innovation, and Infrastructure
SDG 17	Partnerships for the Goals

Table 1: Sustainable Development Goals

Figure 1: SDG 8

Figure 2: SDG 9

Complex Engineering Problem

Range of Complex Problem Solving

	Attribute	**Complex Problem**	
1	Range of conflicting requirements	Involve wide-ranging or conflicting technical, engineering and other issues.	X
2	Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.	
3	Depth of knowledge required	Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.	X
4	Familiarity of issues	Involve infrequently encountered issues	X
5	Extent of applicable codes	Are outside problems encompassed by standards and codes of practice for professional engineering.	X
6	Extent of stakeholder involvement and level of conflicting requirements	Involve diverse groups of stakeholders with widely varying needs.	
7	Consequences	Have significant consequences in a range of contexts.	
8	Interdependence	Are high-level problems including many component parts or sub-problems	X

Range of Complex Problem Activities

	Attribute	**Complex Activities**	
1	Range of resources	Involve the use of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies).	X
2	Level of interaction	Require resolution of significant problems arising from interactions between wide ranging and conflicting technical, engineering or other issues.	X
3	Innovation	Involve creative use of engineering principles and research-based knowledge in novel ways.	X
4	Consequences to society and the environment	Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation.	
5	Familiarity	Can extend beyond previous experiences by applying principles-based approaches.	X

Dedicated to our advisor, Dr. Shoab Ahmed Khan, whose guidance was the main reason behind successfully completing this humongous task. To all the group members Syed Afraz, Abdul Aleem, Amna Ahmed and Abdul Moeez for their dedication and commitment to the project. To our parents they were the main reason behind our hard work. Thank you, everyone, for making this a reality.

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Also, heartiest appreciation to our FYP group mates, who played key role in uplifting each other's moral and letting us focus on work, without their support we couldn't have reached this point. Their understanding attitude played vital role throughout our journey; we are eternally thankful to them. Their constant support motivated us to do more than we ever realized, and they inspired new hope in us, when we found none in ourselves.

At last, we are thankful to our parents as their patience, support and prayers have a big part in what we have achieved.

Abstract

In Pakistan, the absence of a proper gemstone marketplace and the issues of trust, security, and transparency in existing platforms severely hinder seamless buying and selling of gemstones. To address these challenges, we have made NFT BASED TRACKING AND TRADING PLATFORM OF PAKISTAN known as Gemzon which introduces a unique solution through a comprehensive web and mobile application platform designed to serve as a global gemstone trading hub.

Gemzon's platform incorporates advanced technology, including a custom-built Bluetooth-enabled hardware device that allows users to capture high-quality images of gemstones in a controlled environment while listing gemstones. This setup ensures proper lighting and eliminates noise and shadows, resulting in superior images. The captured images are then sent directly to an AI-driven CNN module trained using DCGAN module via the mobile app. This module authenticates the gemstones, allowing only genuine gemstones to be listed on the platform, thereby ensuring transparency and trust.

Once a gemstone is verified, it is listed on the Gemzon platform, making it available for potential buyers. Simultaneously, the gemstone's credentials, including its history of ownership, are posted on the blockchain. This decentralized ledger ensures that all transactions are transparent and traceable, further enhancing the platform's credibility.

Gemzon also facilitates digital ownership transfers without the need for physical exchanges through sophisticated smart contract technology, streamlining the resale process for gemstone owners. The platform supports both a user-friendly web application and a mobile app, allowing users to browse and trade gemstones effortlessly on the go.

In conclusion, Gemzon emerges as a beacon of trust, innovation, and simplicity within the realm of precious gemstone trading. Gemzon aims to revolutionize the gemstone market and empower individuals worldwide to indulge in a captivating and secure gemstone trading experience by leveraging the power of NFTs, a meticulous verification process, and a secure trading environment.

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Chapter 1

Introduction

The global gemstone market is a thriving and expansive industry, integral to both the economy and culture in many parts of the world. Gemstones, with their natural beauty and rarity, have been coveted throughout history, symbolizing wealth, power, and prestige. Today, the allure of gemstones continues to captivate consumers, from luxury jewelry buyers to collectors and investors. This enduring fascination has translated into a robust and growing market, where the trade of precious stones such as diamonds, rubies, emeralds, and sapphires represents a significant economic activity. Investors around the globe recognize the value and potential of the gemstone market. This industry is not just about the beauty of the stones but also about their financial worth. Gemstones are often viewed as a stable and appreciating asset, making them a popular investment choice. High net worth individuals and institutional investors alike pour substantial amounts of money into the gemstone market, seeking both aesthetic satisfaction and financial returns. The market's attractiveness is further heightened by the stones' use in various sectors, including luxury goods, fashion, and even technology, where certain gemstones are used for their unique physical properties. The economic impact of the gemstone market is substantial. It supports millions of jobs worldwide, from miners and gem cutters to

traders and retailers. Countries rich in gemstone resources, such as India, Brazil, and Myanmar, heavily rely on this sector for economic development. Several factors, including supply and demand, geopolitical stability, and advancements in mining and gemstone processing technologies influence the market's dynamics. As demand for ethically sourced and sustainably mined gemstones increases, the industry is undergoing significant changes, with a growing emphasis on transparency and responsible practices. Despite the market's size and significance, one of the persistent challenges it faces is the lack of a proper channel that ensures complete transparency and trust. The gemstone industry has historically been plagued by issues such as fraud, unethical mining practices, and opaque transactions. Consumers and investors often find it difficult to verify the authenticity and origin of gemstones, leading to mistrust and potential financial losses. The absence of a bonafide platform that guarantees the traceability and genuineness of gemstones hampers the market's full potential and growth. As the industry evolves, the need for a reliable and transparent marketplace becomes increasingly critical to foster trust and promote sustainable investment in gemstones.

1.1 Motivation

The need for a reliable and transparent marketplace for gemstones is not unique to Pakistan. Globally, there is a growing demand for ethical sourcing and transparency in the gemstone and diamond industries. De Beers, a prominent player in the diamond industry, has embarked on a transformative journey with its Tracr Blockchain initiative. This project aims to provide comprehensive origin and impact data for all its diamonds by 2030, utilizing blockchain technology to trace each diamond's journey from mine to market. Such initiatives address consumer concerns regarding ethical sourcing and the environmental impact of the industry. As shown in Figure 1.1, The global gemstones market is projected to grow significantly, with its size

expected to reach USD 53.9 billion by 2032, up from USD 30.8 billion in 2022, at a compound annual growth rate (CAGR) of 5.9% during the forecast period from 2023 to 2032. This growth underscores the increasing demand for gemstones and the economic opportunities they present. In Pakistan, recent data from the Ministry of Commerce shows promising trends. The export value of pearls and precious stones to China reached $4.34 million in 2023, up from $2.95 million in the previous year, indicating a 46.88% increase. Similarly, the export value of semi-precious stones under commodity code (71031000) was above $3.72 million, marking a 27.75% increase in 2023. These figures highlight the untapped potential of Pakistan's gemstone industry and the need for strategic interventions to fully exploit this potential. The motivation behind the Gemzon project stems from these critical issues and opportunities. By providing a comprehensive e-commerce platform for gemstone trading, Gemzon aims to create a secure, transparent, and user-friendly marketplace for buying, selling, and bidding on gemstones. The integration of advanced technology, including AI-driven verification and blockchain for transparency, ensures that only genuine gemstones are traded, restoring trust and encouraging investment in the industry. This initiative not only addresses the core problems of the gemstone industry in Pakistan but also aligns with global trends towards ethical sourcing and transparent trading practices.

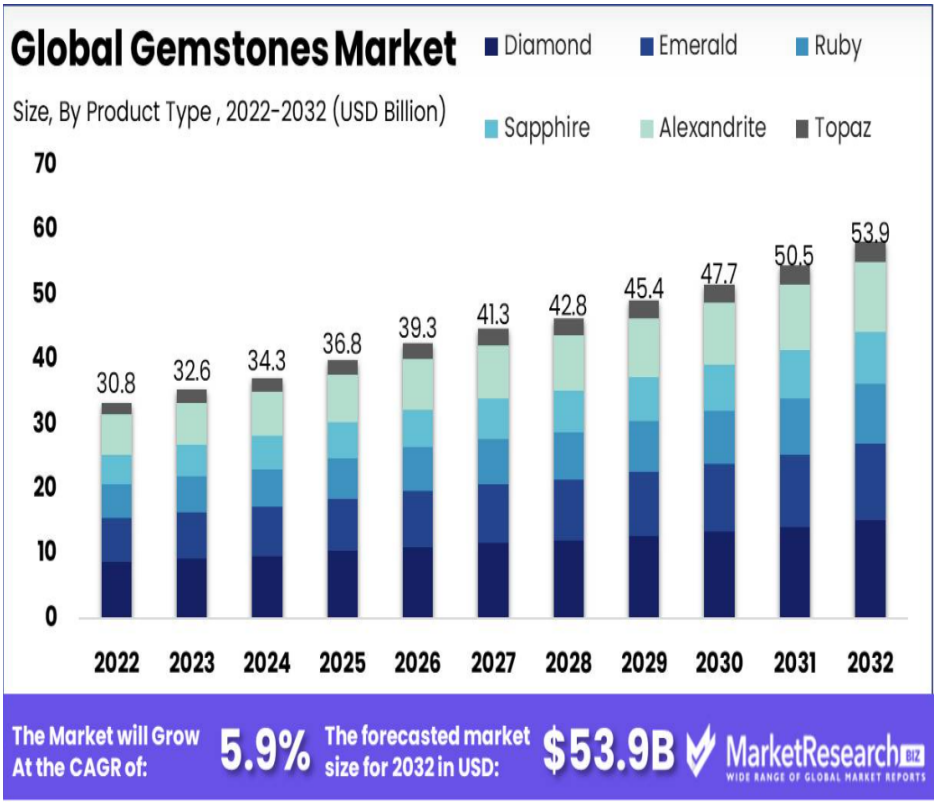

Figure 1.1: Gemstones Future Market Predication [1]

1.2 Problem Statement

Pakistan is home to the fifth largest reservoir of gemstones globally. Despite this significant potential, the gemstone industry in Pakistan faces severe challenges that hinder its growth. The country can export 800,000 carats of Ruby, 87,000 carats of Emerald, and five million carats of Peridot annually. However, outdated mining techniques and the absence of a trustworthy marketplace have led to rampant smuggling of gemstones, depriving Pakistan of substantial economic benefits.

People fond of owning gemstones are deterred by the lack of transparency and prevalent fraud in the market, which discourages them from buying and investing in this industry. This mistrust and inefficiency cause the government to lose significant revenue that could be collected from the gemstone market, further stalling the growth of Pakistan's gemstone industry and its potential contribution to the national econ-

omy. For instance, Matiullah Sheikh, Chairman of the All Pakistan Gems Merchants and Jewellers' Association (APGMJA), highlighted that most gemstones extracted in Pakistan are smuggled out or exported in raw form with undervalued declarations in customs records. These gemstones are then cut and polished in countries like India and Thailand, and often brought back to Pakistan and sold at expensive rates. Moreover, a recent incident in November 2023 at the Torkham border exemplifies the scale of the smuggling problem. Customs authorities intercepted a coal-laden trailer attempting to smuggle 71 kilograms of raw precious stones, including Kunzite, Green Spodumene, and Scapolite, concealed within the consignment. The estimated value of the confiscated stones was Rs405 million.

These issues not only highlight the need for modernization and better regulation of the gemstone industry but also emphasize the urgent requirement for a secure and transparent marketplace to prevent smuggling and ensure that Pakistan can fully capitalize on its vast gemstone resources.

1.3 Scope

The goal of our project, NFT BASED TRACKING AND TRADING PLATFORM OF PAKISTAN, is to develop a comprehensive gemstone marketplace that serves as a revolutionary platform for trading gemstones. This platform will leverage advanced technologies, including AI-driven verification and blockchain, to ensure the authenticity and traceability of gemstones. It will feature robust security measures, a user-friendly interface, and tools for seamless buying, selling, and bidding. Additionally, the project encompasses scalable hardware infrastructure to capture high-quality gemstone images in a controlled environment.

We are creating a proper marketplace for gemstones where people can buy and sell gemstones without any fraud. A key aspect of the platform is the use of Non-Fungible Tokens (NFTs) to digitalize gemstones and their ownership. Each gemstone will be

assigned a unique NFT, which will contain detailed information about the gemstone, including its origin, history, and current ownership. This digital ledger will make it nearly impossible for fraudulent activities to occur and will facilitate seamless tracking of gemstone transactions. This ensures that each transaction is recorded and traceable by government institutions, providing better control over the market and significantly reducing the risk of money laundering.

The deployment of the project is expected to be done at the government level, integrating the gemstone market into a proper tax network. This will enable the government to earn substantial revenue from the gemstone industry and provide a robust framework to combat smuggling and illegal trade. By having a transparent and regulated marketplace, the government can better monitor and control the flow of gemstones, ensuring that all transactions are legitimate and taxable.

Gemzon aims to provide a trustworthy, secure, and transparent marketplace that caters to a global audience, fostering trust and encouraging investment in the gemstone industry.

1.4 Aims and Objectives

The Gemzon project aims to deliver several key functionalities to establish a secure, transparent, and efficient gemstone trading platform. The key aims and objectives we must complete in order to make to the project fully operational are:

1. **User Registration and Authentication:** Gemzon will offer a user-friendly registration process, allowing individuals to create accounts securely. Users will have to go through a verification process to ensure the authenticity of their accounts.

2. **Gemstone Listing and Trading:** Sellers will be able to list their precious gemstones on Gemzon by providing detailed descriptions and images. Buyers will have the opportunity to browse through a diverse range of gemstones and

make purchases securely.

3. **Non-Fungible Tokens (NFTs):** For every gemstone listed on Gemzon, a unique NFT will be created. NFTs will act as digital certificates, showcasing the gemstone's history and provenance. Buyers will receive the corresponding NFT address upon purchase, representing their ownership.

4. **Digital Ownership Transfer:** Gemzon will enable buyers to trade gemstones without the need for physical exchange. If a buyer decides to sell their gemstone, they can submit it to the Gemzon bank. Using smart contract technology, the digital ownership will be transferred to the next buyer, ensuring a secure and efficient transaction process.

5. **Gemstone Marketplace Accessibility:** The gemstone marketplace will be accessible through various digital platforms including web applications and mobile applications catering to users' preferences and providing a seamless experience across different devices.

6. **Gemstone Verification and Hardware Integration:** To guarantee the authenticity and quality of gemstones listed on Gemzon, each gemstone will undergo rigorous testing and examination through our AI module. Additionally, Gemzon will integrate a robust hardware infrastructure dedicated to gemstone verification, ensuring superior image quality and enhancing the verification process. Only real gemstones meeting the verification criteria will be listed on the platform, ensuring buyer's trust.

1.5 Outcomes

The Gemzon project will deliver several key outcomes to ensure a comprehensive and seamless experience for users in the gemstone trading industry:

1. **Gemzon Web Application:** A fully functional and user-friendly web ap-

plication enabling users to register, list gemstones, trade, and manage their accounts securely. This platform will provide an intuitive interface and robust features to facilitate all aspects of gemstone trading while ensuring confidentiality of each user's personal information fostering trustworthiness between the user and the platform.

2. **Gemzon Mobile Application:** A mobile application compatible with both Android and iOS devices, offering the functionalities of capturing images of the gemstones from mobile phone making it extremely simple and handy for lay man to get familiar to sell and check gemstones' authenticity. This ensures users can access the platform and perform transactions conveniently from their mobile devices.

3. **NFT Integration:** Integration of Non-Fungible Tokens (NFTs) for each gemstone listed on Gemzon. NFTs will provide buyers with digital ownership and detailed historical information of gemstone ownership, enhancing transparency and trust in the marketplace.

4. **Gemstone Verification Process:**Establishment of a robust gemstone verification process involving rigorous hardware module which will be used to capture high-quality images of gemstones in a controlled environment through the mobile app. This high quality images will then be sent to an AI module, which will verify the authenticity of the gemstones. Only real gemstones will be allowed to be listed on the platform, ensuring transparency and trust in the marketplace.

5. **Hardware Infrastructure for Gemstone Phtography:** Implementation of a robust hardware infrastructure dedicated to gemstone verification. This hardware module will be seamlessly integrated into the Gemzon mobile application, allowing users to capture high-quality images of gemstones in a controlled environment directly from their mobile devices. The hardware module

ensures superior image quality, essential for accurate gemstone verification. These captured images will then undergo scrutiny by an AI-driven module to verify the authenticity of the gemstones. By incorporating hardware module, Gemzon enhances the verification process and ensures that only high quality images' gemstones are listed on the platform.

1.6 Structure of Thesis

The thesis is organised as follows: The structure of the thoracic cavity and various pulmonary diseases, as well as their presentation and symptoms, are briefly covered in Chapter 2. Additionally, various imaging techniques that enable non-invasive imaging of the chest cavity are also discussed.

A thorough review of the literature is provided in Chapter 3 on the most recent methodologies used for the classification of pulmonary diseases, lung segmentation and sub-segmentation of diseased areas, severity scoring and severity quantification, and radiological report generation using CXR. Chapter 4's focus is on the datasets that are utilised in this research work focusing on the different attributes of the said datasets.

Chapter 5 details the multi-head approach for chest disease classification, segmentation, opacity localisation, and severity scoring while Chapter 6 focuses on CXR report generation using a transformer-based network.

This thesis is concluded in Chapter 7, which also summarises the key contributions. The suggested work's future prospects are then discussed.

Chapter 2

Background and Related Work

2.1 Global Advancements in the Gemstone Market

The global gemstone market has been experiencing significant growth, driven by rising consumer interest in jewelry and investment purposes. Key factors contributing to this expansion include increased disposable incomes, the influence of celebrity culture, and the growing popularity of bespoke and designer jewelry. Technological advancements, such as enhanced gemstone identification and treatment processes, as well as online retail platforms, have further propelled the market. According to recent reports, the global gemstone market is projected to grow at a compound annual growth rate (CAGR) of approximately 5.5% over the next few years.

2.2 Market Advancements in the Gemstone Industry: Embracing Technology

According to recent data from Future Market Insights (FMI), the gemstone market is projected to grow from USD 32.38 billion in 2023 to USD 55.96 billion by

2033, achieving a compound annual growth rate (CAGR) of 5.6%. Gemstones account for half of the overall gems and jewelry market. The market for gemstones has seen consistent growth, primarily driven by the increasing consumer demand for luxury goods globally. As more individuals seek high-end products, the appetite for premium gemstones has surged. The market caters to diverse preferences, offering everything from traditional diamond jewelry to vibrant birthstone pieces. The rising interest in colored gemstones and crystals has further fueled market expansion. Stones like emeralds, rubies, and sapphires are particularly in demand as consumers look for unique and striking jewelry. This trend has opened new avenues for gemstone producers and retailers. Diamonds continue to be a significant and sought-after segment of the market. Technological innovations have significantly contributed to the growth of the gemstone market. Advanced technologies have streamlined the production of high-quality gemstones, aligning with consumer expectations. Techniques such as sophisticated imaging and precise cutting and polishing have enhanced supply chain efficiency, allowing manufacturers to market their products more effectively and affordably. The increasing popularity of lab-grown diamonds and synthetic gemstones also presents new opportunities, providing more affordable options to consumers. Environmentally conscious buyers are increasingly seeking ethically sourced gemstones, boosting demand in this sector.

2.2.1 Market Progress and Dynamics in 2022

In the first half of 2022, the gemstone market showed notable growth. The market's dynamics were influenced by factors such as rising consumer incomes and the increasing use of ornaments in various ceremonies. Millennials' growing interest in gemstones and the broader adoption of colored gemstone accessories positively impacted the market. Significant advancements included fashion designers creating innovative jewelry and manufacturers becoming more vertically integrated. For instance, Gemfields introduced a high-quality emerald, Chipembele, in 2021, with

part of the proceeds from its auction supporting conservation efforts in Zambia. However, challenges such as unorganized markets, illegal gemstone activities, and environmental concerns remain.

2.2.2 Comparative Market Analysis and Future Outlook

From 2023 to 2033, the gemstone market is expected to grow at a CAGR of 5.6%, compared to 4.1% from 2018 to 2022. The increasing popularity of lesser-known gemstones, alongside traditional favorites like diamonds, is driving this growth. Rising incomes and the use of ornaments in ceremonies further contribute to market expansion. In regions like Asia Pacific, consumers are shifting from unorganized jewelry markets to branded products to avoid counterfeit items.

2.2.3 Country-Specific Market Insights

2.2.3.1 United States

The U.S. gemstone market is bolstered by trade associations and nonprofit institutions like the American Gem Society, which maintain high standards through member education and accreditation. The growing interest in colored gemstones and the rise of e-commerce platforms have also contributed to market growth.

2.2.3.2 China

China's economic growth and expanding middle class have driven demand for luxury goods, including rare gemstones. Cultural significance and beliefs in the healing properties of gemstones further fuel demand. China is a major global player, producing and exporting a significant portion of the world's processed gemstones.

2.2.3.3 India

Social beliefs regarding the use of specific colored gemstones influence consumer behavior in India. The country's longstanding tradition in gemstone trade, skilled artisans, and significant contributions to the GDP through gold and diamond exports underscore its market importance. Government initiatives promoting "Brand India" are also enhancing the industry.

2.2.3.4 Japan

Japan's gemstone market, renowned for high-quality Akoya pearls and traditional gem-cutting techniques, is evolving with a growing preference for lab-grown gemstones. These changes in consumer preferences are shaping the market's future.

2.2.3.5 France

The rising employment and spending power of women in France are driving demand for gemstones. The shift toward branded products and increasing educational standards also contribute to market growth.

2.2.3.6 Germany

Germany's gemstone industry, with a rich history and a focus on sustainable practices, is centered in places like Idar-Oberstein. German jewelers are prioritizing ethical sourcing and advanced technologies to ensure high-quality gemstone production.

2.2.4 Category-Wise Market Insights

2.2.4.1 Diamonds

Diamonds remain highly valued due to their association with luxury and status. Marketing campaigns and their rarity sustain high demand.

2.2.4.2 Synthetic Gemstones

Synthetic gemstones offer affordability and consistent quality, addressing ethical concerns about natural gemstone mining. This makes them a key revenue source in the gemstone market.

2.2.4.3 Jewelry & Ornaments

Gemstone jewelry, particularly pieces like rings, pendants, and necklaces, dominate the market. The variety and appeal of colored gemstones drive consumer interest.

2.2.5 Competitive Landscape and Innovations

Key players in the gemstone market focus on sustainability, ethical sourcing, and technological advancements. Companies are adopting blockchain for supply chain transparency and leveraging digital marketing to expand their reach. Innovations in gemstone cutting and collaborations with fashion designers are also prevalent. Start-ups like Diamond Foundry and Muzo emphasize sustainable practices, while established companies like Gemfields and Greenland Ruby continue to lead through innovation and ethical sourcing. Collaborative efforts and advanced technologies are shaping the future of the gemstone market.

2.2.6 Market Segmentation and Regional Insights

The gemstone market is segmented by product type, end user, and region, with a significant presence in North America, Latin America, Europe, East Asia, South Asia, Oceania, and the Middle East and Africa (MEA).

By product type, diamonds, emeralds, rubies, sapphires, and other gemstones are key categories. The end-user segment primarily includes jewelry and ornaments, with significant growth opportunities in luxury art. The market also distinguishes between natural and synthetic gemstones.

This comprehensive overview highlights the dynamic growth and technological advancements propelling the gemstone market forward, while also addressing regional trends and competitive strategies.

2.2.7 Gemstone Market in Pakistan

Descending into Pakistan, especially in Peshawar for the first time, a foreign tourist might be surprised to find that amid the historical buildings lies an important gem trading center, as shown in Figure 2.1. Namak Mandi, meaning "salt market" in Urdu, was originally a salt trade and storage center. Today, it attracts buyers and sellers from Afghanistan, Uzbekistan, Tajikistan, and Iran, dealing with gemstones mined in Azad Jammu and Kashmir, Gilgit-Baltistan, and parts of Khyber Pakhtunkhwa in Pakistan. Fifty years ago, no one could have imagined this salt market evolving into Pakistan's primary trading hub for gemstones. This transformation has been significant, and we led an excursion to Namak Mandi to document its evolution and understand the variety of gemstones and commerce.

Figure 2.1: Gemstones Resviour of Pakistan [1]

2.2.8 From Salt to Gemstones: Namak Mandi's Transformation

Namak Mandi is now Pakistan's largest market for trading rough gemstones. Its transformation from a salt market to a gemstone trading hub reportedly began in the 1970s. Initially, the market lacked organization and trade standards. The influx of Afghan refugees during the Soviet invasion of Afghanistan significantly boosted the number of traders, turning Namak Mandi into a bustling gemstone market. Afghan traders, who made up 60–70% of sales until 2007, brought stones such as tourmaline, spodumene, and emerald from Afghanistan. Pakistani traders from regions like Swat and Gilgit-Baltistan added to the variety, bringing in emeralds, aquamarine, and pink topaz.

2.2.9 Establishment of Exporters' Association

The Afghan merchants' dominance in Namak Mandi led local traders to formalize their businesses by registering with the All Pakistan Commercial Exporters Association (APCEA), established in 1984. Official recognition in 1988 by the Ministry of Commerce allowed the APCEA to assist exporters, reducing police harassment and expediting customs processes. The APCEA also organizes an annual international gemstone exhibition in Islamabad, further promoting the trade.

2.2.10 Market Structure and Trade Practices

Namak Mandi's gemstone business can be divided into three main categories: rough and faceted stones, mineral specimens, and ornamental stones. Rough and faceted stones traders often specialize in specific gems, while mineral specimen dealers cater to both local and international markets through online platforms. Ornamental stone traders deal primarily in lapis lazuli and nephrite, with significant exports to China, Hong Kong, and Japan.

Despite its success, Namak Mandi has faced challenges such as unethical pricing tactics and a lack of formal training for lapidaries. The market's reliance on traditional tools like the angoora for cutting and polishing gemstones results in lower-quality cuts compared to international standards. This impacts the market's ability to compete with established gemstone centers in Thailand, China, and Sri Lanka.

2.2.11 Emerging Trends and Online Market

Around 2010, traders in Namak Mandi began leveraging online platforms like eBay to reach global customers. However, challenges such as the absence of PayPal in Pakistan and fraudulent practices by some traders have hindered the growth of the online market. Despite these issues, the entry of women into the gemstone trade, primarily through online platforms, has introduced a more ethical approach,

potentially influencing the market positively.

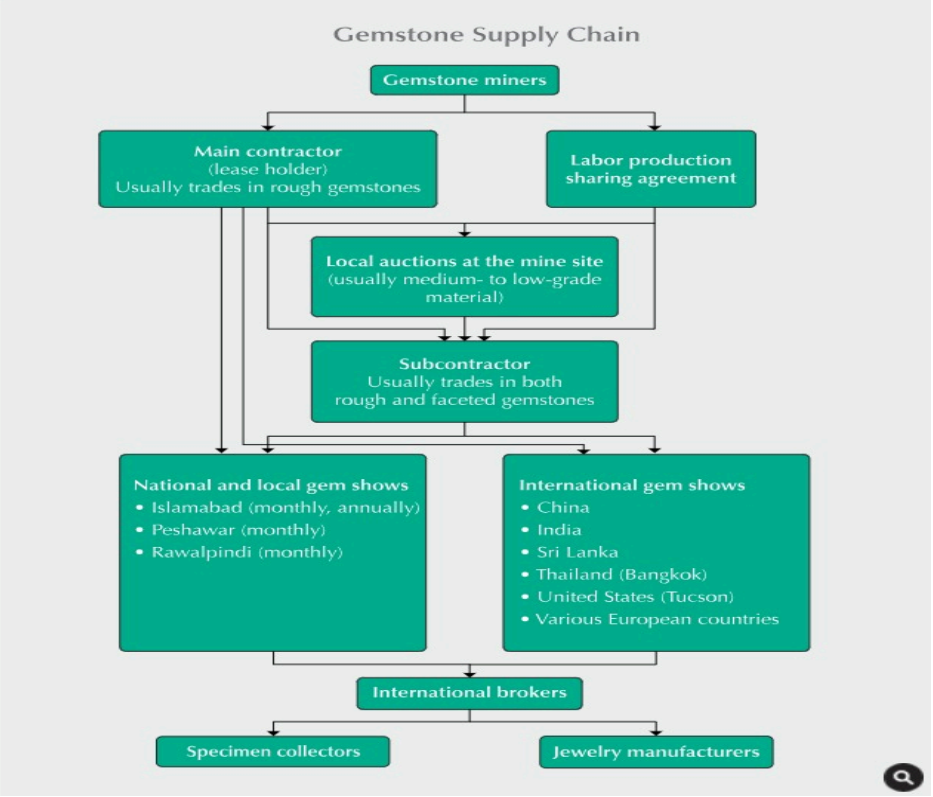

Figure 2.2: Gemstone Supply Chain

2.2.12 Conclusions

Over the past 50 years, Namak Mandi has transformed from a salt market into a vibrant hub for the gemstone trade. This evolution occurred with the support of the APCEA and minimal government intervention. However, issues like unethical trading practices and outdated faceting techniques have hindered its full potential. The recent entry of women into the market, who conduct business ethically, offers hope for a more responsible trading environment in the future.

2.3 Key Players and Their Shortcomings

Pakistan is renowned for its abundant gemstone markets, both physical and online. However, each of these marketplaces presents its own unique set of challenges for

consumers.

2.3.1 Shortcomings of Physical Gemstone Markets

1. **Lack of Certification**: In many of these physical markets, gemstones are sold without any certification. This absence of standardized documentation makes it difficult for buyers to assess the true quality and value of their purchases.
2. **Authenticity Concerns**: Without proper certification, the authenticity of the gemstones is questionable. Buyers often face difficulties in distinguishing between natural gemstones and synthetic or treated stones.
3. **Price Manipulation**: Sellers in these markets often set prices arbitrarily. Due to the lack of transparency and standardized pricing mechanisms, customers might end up paying more than the actual worth of the gemstones.
4. **Treatment Disclosure**: It is common for gemstones to undergo various treatments to enhance their appearance. However, sellers frequently fail to disclose this information to buyers, leading to misconceptions about the stone's natural quality and value.
5. **Smuggling Risks**: Gemstones are sometimes smuggled out of Pakistan to other countries, bypassing legal channels. This not only results in significant revenue losses for the country but also impacts the local economy negatively.

2.3.2 Key Online Marketplaces for Gemstones in Pakistan

1. **Gemstone.pk**
    - **Description**: Gemstone.pk is an online platform that offers a variety of gemstones for sale.
    - **Challenges**:

- **Quality Verification**: Customers cannot physically inspect the gemstones before purchase, making it difficult to verify quality.
- **Risk of Fraud**: The absence of face-to-face transactions increases the risk of fraudulent activities, as details provided online may not always be accurate.

2. **Royalgems.pk**
   - **Description**: Similar to Gemstone.pk, Royalgems.pk is an online marketplace specializing in gemstones.
   - **Challenges**:
     - **Quality Assurance**: Like other online platforms, verifying the authenticity and quality of the gemstones is challenging without a physical inspection.
     - **Potential for Fraud**: There is a significant risk of misleading information, making it hard for buyers to trust the product descriptions.
3. **Jewel.pk**
   - **Description**: Jewel.pk focuses on gemstone jewelry and has built a reputation for reliability.
   - **Challenges**:
     - **High Prices**: The jewelry offered is generally more expensive compared to other platforms, which might be a deterrent for budget-conscious buyers.
     - **Limited Options**: The site does not offer individual gemstone specimens, limiting choices for those specifically looking for loose gemstones rather than finished jewelry.

4. **gkjewelers.pk**

   - **Description**: gkjewelers.pk is another trustworthy online retailer of gemstone jewelry.
   - **Challenges**:
     - **Expense**: The items are priced at a premium, potentially making them inaccessible for some buyers.
     - **Specimen Availability**: Similar to Jewel.pk, gkjewelers.pk does not provide loose gemstone specimens, which can be a drawback for collectors and certain buyers.

2.3.3 Conclusion

Both physical and online gemstone markets in Pakistan come with their respective advantages and disadvantages. While physical markets offer the ability to inspect gemstones in person, they suffer from issues like lack of certification and authenticity concerns. On the other hand, online marketplaces provide convenience and a wider range of products but face challenges related to quality verification and potential fraud. Buyers need to carefully consider these factors when purchasing gemstones to ensure they receive genuine, fairly-priced products.

2.4 Initiating Our Project

Our journey with the Gemzon project commenced with a detailed requirement gathering and literature review, in collaboration with CARE Pvt Ltd and AAA Mining Companies. These initial steps were crucial in diving deep into the project's objectives and laying a solid foundation for our platform. By studying the requirements meticulously and examining industry insights, we aimed to understand the intricacies of the gemstone market and the specific needs of consumers and buyers. This

comprehensive analysis was designed to identify gaps in the current market and develop a platform that addresses these issues effectively.

2.4.1 Requirement Gathering and Feasibility Study

The initial phase of the Gemzon project was centered around a thorough requirement gathering and feasibility study, ensuring the platform's success and alignment with market needs. This phase was vital in pinpointing the specific demands of consumers and buyers within the gemstone market, as well as understanding the existing gaps that Gemzon could fill.

2.4.1.1 Consumer and Buyer Requirement Study

To begin, we conducted an extensive study to understand the requirements of consumers and buyers in the gemstone market. This involved:

- **Market Analysis**: Performed thorough market research to analyze current trends, consumer behavior, and the competitive landscape. This included studying existing platforms and identifying their strengths and weaknesses.
- **Research**: Performed research for all the gaps and weaknesses available in the gemstone market that should be addressed in order to make people trust this industry so that they can invest in it without any hesitation.

2.4.1.2 Gap Analysis

Through our research, we identified significant gaps in the current gemstone trading market:

- **Lack of Transparency**: Consumers and buyers expressed a strong need for a transparent and secure marketplace where the authenticity of gemstones is guaranteed.

- **Absence of Digital Ownership**: The market lacked a reliable system for digital ownership and provenance tracking of gemstones.
- **Need for Advanced Verification**: There was a demand for advanced technological solutions to verify gemstone authenticity, reducing the prevalence of counterfeit products.

2.4.1.3 Literature Review

To gain a deeper understanding of how to address these gaps, we reviewed numerous research papers and industry reports. This literature review provided valuable insights into:

- **Blockchain Technology**: The potential of blockchain for ensuring transparency and security in transactions.
- **Artificial Intelligence**: The use of AI and machine learning models for verifying the authenticity of gemstones.
- **E-commerce Trends**: Best practices in developing user-friendly and secure e-commerce platforms.

2.4.1.4 Client Meetings and Expert Consultations

We arranged one-on-one meetings with our clients, facilitated by Sir Shoaib and CARE Pvt Ltd. These sessions were instrumental in:

- **Clarifying Requirements**: Detailed discussions helped us refine the project requirements and understand specific client expectations.
- **Resource Assessment**: Evaluating the resources available, including technological infrastructure, expertise, and budget constraints.

2.4.2 Feasibility Study

With a clear understanding of the market needs and client expectations, we conducted a feasibility study to evaluate the practicality of our project:

- **Technical Feasibility**: Assessed the technical requirements and ensured that the chosen technologies (ReactJS, Flutter, Java Spring Boot, Solidity, etc.) were suitable and accessible for the project's scope.
- **Financial Feasibility**: Developed a detailed cost estimation, including expenses for development, deployment, and maintenance. This included budgeting for hardware, software licenses, and human resources.
- **Operational Feasibility**: Created a development schedule, outlining key milestones, deadlines, and resource allocation to ensure timely project completion.

2.4.3 Outcome of the Feasibility Study

The feasibility study confirmed that with careful planning and resource management, the Gemzon project was viable. As shown in Figure 2.3, We identified the necessary steps to develop a secure, transparent, and user-friendly gemstone trading platform. This stage provided a solid foundation for the subsequent phases of development, ensuring that the project would meet market demands and deliver value to its users.

By addressing the specific needs identified during the requirement-gathering phase and leveraging advanced technologies, Gemzon aims to revolutionize the gemstone trading industry, providing a trustworthy platform for buyers and sellers worldwide.

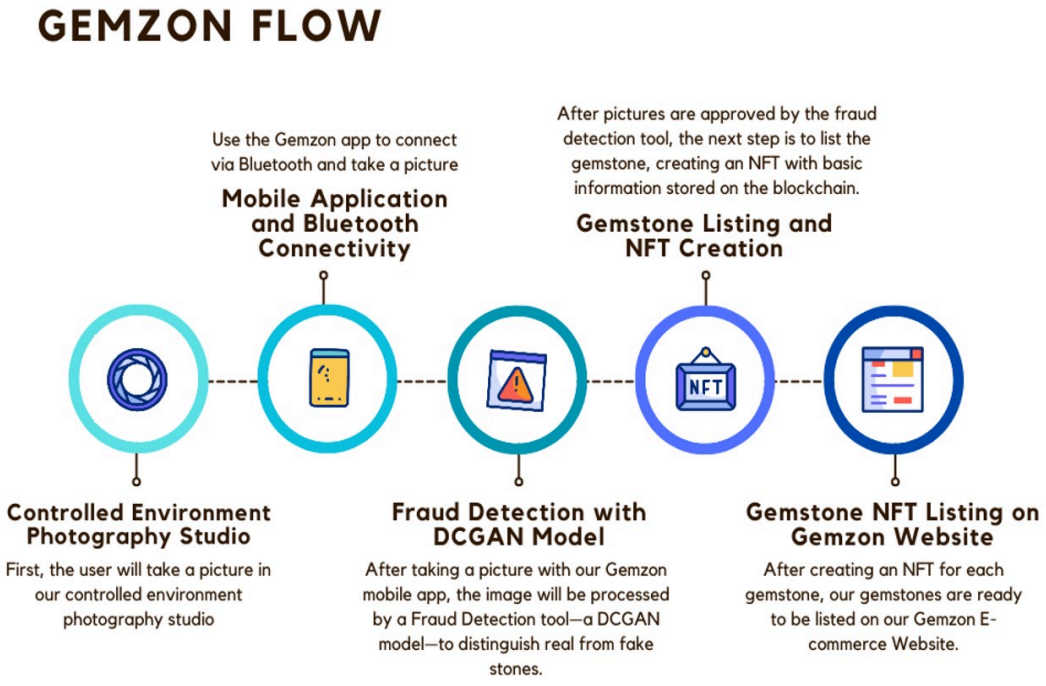

Figure 2.3: Functional flow of Gemzon [1]

Chapter 3

Material and Component

3.1 Tools and Technologies

3.1.1 Programming Languages

- **Python**: Python, 3.1, serves as the primary programming language for various tasks within the Gemzon project. It is utilized for training image generation, segmentation, and classification models, as well as for developing the backend for the AI module. Python's versatility and extensive libraries make it an ideal choice for implementing complex algorithms and handling data-processing tasks efficiently.

Figure 3.1: Python tool [1]

- **Javascript**: Javascript, 3.2, is employed for designing the front end of the Gemzon web application, enabling interactive and dynamic user interfaces. ReactJS is specifically used for front-end development. For backend integration with the blockchain, Web3.js and Node.js are utilized to communicate with both Java backend and the blockchain network, ensuring seamless interaction between different components of the Gemzon platform.

Figure 3.2: JavaScript tool [1]

- **Java**: Java, 3.3, is utilized for backend development in the Gemzon project, particularly with the Java Spring Boot framework. Java's robustness, platform independence, and scalability make it suitable for building enterprise-grade backend systems, ensuring reliability and performance for the Gemzon platform.

Figure 3.3: Java Rest API [1]

- **Solidity**: Solidity, 3.4, is employed for developing smart contracts, which govern the transactions and logic within the Gemzon blockchain network, ensuring

secure and transparent transactions. Solidity's syntax and semantics are tailored for Ethereum blockchain development, allowing developers to define and execute complex business logic securely on the blockchain.

Figure 3.4: Solidity tool [1]

- **Dart (Flutter)**: Dart programming language, along with the Flutter framework, is used for developing the mobile application component of the Gemzon project. Flutter's cross-platform capabilities and expressive UI toolkit enable the creation of visually stunning and performant mobile applications for both Android and iOS platforms.

Figure 3.5: Flutter tool [1]

3.1.2 Design

- **Figma**: Figma, 3.6, is utilized for creating wireframes and designs for both web and mobile applications, ensuring a cohesive and visually appealing user experience. Figma's collaborative features and real-time editing capabilities

streamline the design process, allowing designers and developers to iterate quickly and effectively.

Figure 3.6: Figma tool [1]

3.1.3 Code Editors

- **Visual Studio Code**: Visual Studio Code, 3.7, serves as the code editor for the Gemzon project, facilitating coding tasks in both Python and Javascript, providing an efficient development environment. Its rich ecosystem of extensions and customizable features enhances productivity and workflow efficiency for developers working on the Gemzon platform.

Figure 3.7: Visual Studio Code [1]

- **Eclipse IDE**: Eclipse Integrated Development Environment (IDE), 3.8, is utilized for Java development in the Gemzon project. Eclipse IDE offers a comprehensive set of tools for coding, debugging, and managing Java projects, providing an intuitive and efficient development environment for backend development.

Figure 3.8: ECLIPSE tool [1]

- **Remix IDE**: Remix IDE, 3.9, is used for Solidity development in the Gemzon project. Remix IDE provides a powerful online development environment specifically designed for Solidity, offering features such as integrated compiler and debugging tools, simplifying smart contract development for the Gemzon blockchain network.

Figure 3.9: REMIX tool [1]

- **Arduino IDE**: Arduino Integrated Development Environment (IDE), 3.10, is used for programming NodeMCU, enabling hardware integration in the Gemzon project. Arduino IDE's simplicity and ease of use make it an ideal choice for programming microcontrollers, allowing for seamless integration of hardware components with the Gemzon platform.

Figure 3.10: ARDUNIO tool [1]

3.1.4 Frontend

- **ReactJS**: ReactJS, a Javascript library, is used to develop the frontend user interface components of the Gemzon web application, enabling the creation of interactive and responsive UI elements. React's component-based architecture and virtual DOM rendering optimize performance and maintainability, allowing for seamless updates and enhancements to the frontend interface.

Figure 3.11: REACTJS tool [1]

- **Flutter**: Flutter, powered by the Dart programming language, is utilized for developing the frontend of the Gemzon mobile application. Flutter's rich set of customizable widgets and hot reload feature expedite the development process and ensure a consistent user experience across different mobile platforms.

3.1.5 Database

- **MySQL**: MySQL, a relational database management system, is employed to manage and store data in Gemzon, ensuring efficient data storage and retrieval for the platform's functionalities. With its robust features and scalability, MySQL provides a reliable foundation for storing transactional and user data securely.

3.1.6 Backend

- **Java Spring Boot**: Java Spring Boot framework is utilized for developing the backend of both the web and mobile applications, ensuring robust and scalable backend functionalities. Spring Boot's convention-over-configuration approach and dependency injection mechanism streamline backend development, enabling rapid prototyping and deployment of RESTful APIs for the Gemzon platform.

3.1.7 Artificial Intelligence

- **DCGAN**: Deep Convolutional Generative Adversarial Networks is utilized within the Gemzon project to generate synthetic gemstone images, enhancing the dataset used for training the AI models. As shown in Figure **??**, DCGAN's sophisticated architecture enables the creation of high-quality fake gemstone images, augmenting the training data and bolstering the performance of AI models for gemstone authenticity verification on the Gemzon platform.

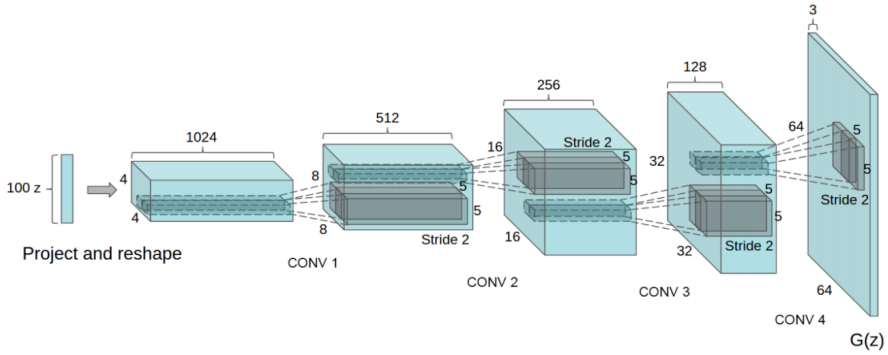

Figure 1: DCGAN generator used for LSUN scene modeling. A 100 dimensional uniform distribution Z is projected to a small spatial extent convolutional representation with many feature maps. A series of four fractionally-strided convolutions (in some recent papers, these are wrongly called deconvolutions) then convert this high level representation into a 64×64 pixel image. Notably, no fully connected or pooling layers are used.

- **Dataset from Kaggle**: The dataset utilized for training the AI models in Gemzon is sourced from Kaggle, 3.12, a platform renowned for providing high-quality datasets and resources for machine learning projects. Kaggle not only offers access to diverse datasets but also provides GPUs and TPUs for training models, facilitating efficient model training and optimization within the Gemzon project.

Figure 3.12: KAGGLE [1]

- **TensorFlow**: TensorFlow, a prominent Python framework for training deep learning neural networks, is leveraged in Gemzon to train the AI models. TensorFlow's comprehensive suite of tools and libraries enables developers to build and train complex neural network architectures effectively, ensuring robust performance and accuracy of the models deployed in the Gemzon platform.
- **CNN Classifier**: Convolutional Neural Network (CNN) classifiers are utilized

to differentiate between real and fake gemstone images, ensuring authenticity verification on the Gemzon platform. As shown in Figure 3.13, CNN's ability to extract features from images and learn complex patterns enables accurate classification of gemstone images, providing users with confidence in the authenticity of listed gemstones on the platform.

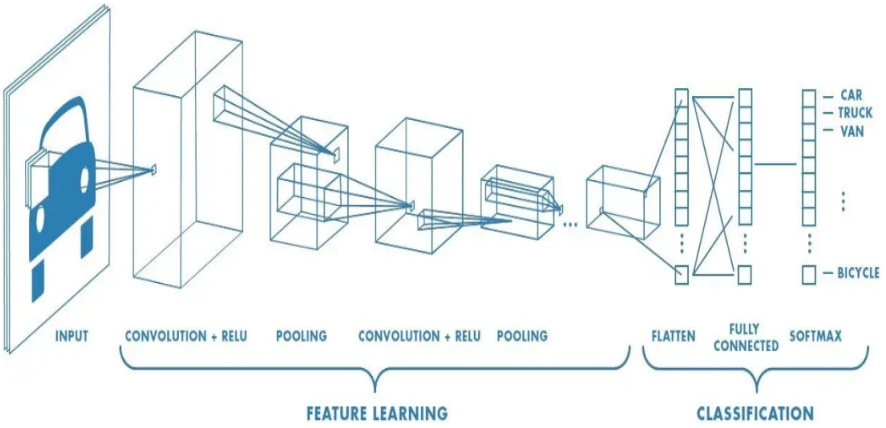

Figure 3.13: Convolutional Neural Network (CNN) classifiers Neural Network [1]

- **Flask**: Flask is used to design the AI module API, enabling communication between the backend and the AI module. Flask's lightweight framework and flexibility make it ideal for creating RESTful APIs, allowing seamless integration and interaction between the AI models and the Gemzon platform.

Figure 3.14: Flask tool [1]

3.1.8 Hardware Integration

- **NodeMCU**: NodeMCU, 3.15, coupled with Bluetooth modules, is utilized for hardware integration, enabling control of hardware components such as LED

lights and rotating motors through the Gemzon mobile application. NodeMCU's compatibility with Arduino IDE and built-in Wi-Fi capabilities make it an ideal choice for IoT applications, allowing for seamless integration of hardware devices with the Gemzon hardware module.

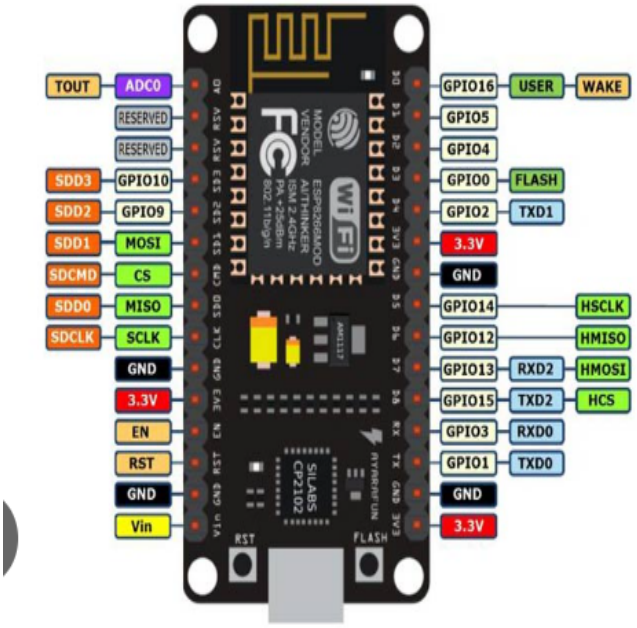

Figure 3.15: ESP 32 Board [1]

- **Darlington Circuit**: Darlington circuits are employed for controlling hardware components efficiently, ensuring seamless integration with the Gemzon platform. Darlington transistors provide high current gain and voltage isolation, enabling reliable and stable control of hardware components such as LED lights and rotating motors, enhancing the functionality of the Gemzon mobile application.

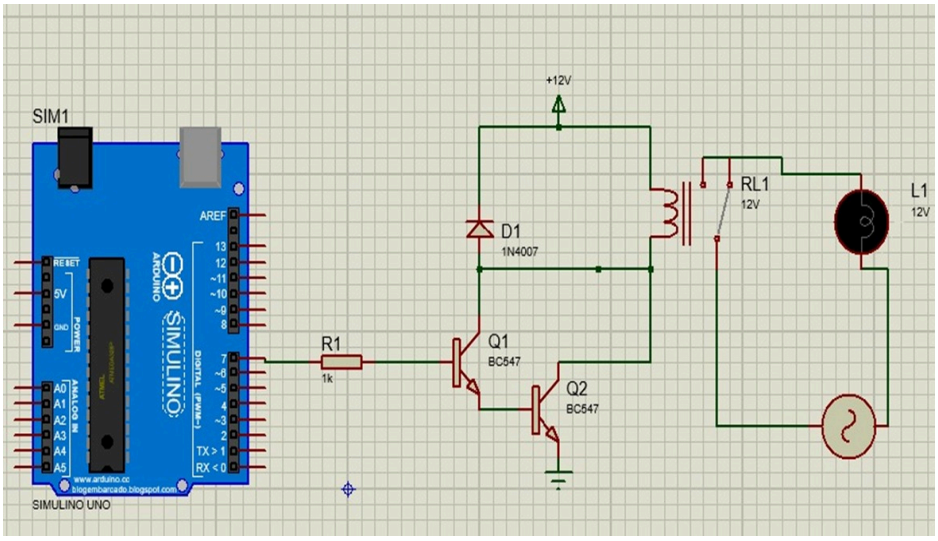

Figure 3.16: Hardware Circuit Diagram [1]

3.1.9 Blockchain Development

- **Node.js**: Node.js is utilized for developing APIs that communicate with the blockchain network, facilitating seamless interaction between the Gemzon platform and the blockchain. Node.js's event-driven architecture and non-blocking I/O operations ensure high performance and scalability for handling blockchain transactions and data retrieval efficiently.

Figure 3.17: Node JS tool [1]

- **Web3.js**: Web3.js libraries interact with the blockchain network, enabling functionalities such as querying blockchain data and executing transactions securely. Web3.js abstracts the complexities of blockchain interaction, providing a simple and intuitive interface for developers to seamlessly integrate

blockchain functionality into the Gemzon platform.

Figure 3.18: Web33 [1]

- **Solidity**: Solidity is employed for developing smart contracts on the Gemzon platform. Solidity ensures secure and transparent transactions by defining the logic and rules of blockchain interactions, which are compiled and deployed using the Solidity compiler (solc).
- **Solc**: Solc, the Solidity compiler, is used to compile Solidity code into bytecode that can be deployed on the Ethereum blockchain. It is a critical component for converting human-readable Solidity code into a format that can be executed by the Ethereum Virtual Machine (EVM).
- **Ganache**: Ganache, 3.19, is utilized for setting up a local Ethereum blockchain environment, allowing developers to test and deploy smart contracts in a controlled and simulated blockchain network. This ensures that smart contracts function correctly before being deployed to the live blockchain network.

Figure 3.19: Ganache tool [1]

Chapter 4

Methodology

4.1 Design

The design stage of the Gemzon project was focused on creating a clear and intuitive user experience through meticulous planning and prototyping. This phase involved developing flowcharts to outline the functionality of each module and designing wireframes to visualize the layout and structure of the web and mobile applications.

4.1.1 Flowchart Development

To ensure a comprehensive understanding of the platform's functionality, we began by creating detailed flowcharts for each module. These flowcharts depicted the sequential flow of actions and interactions within the platform, helping us identify potential bottlenecks or gaps in the user journey, as shown in Figure 4.1. Under the supervision of our supervisors, we refined and optimized these flowcharts to ensure seamless navigation and interaction for users.

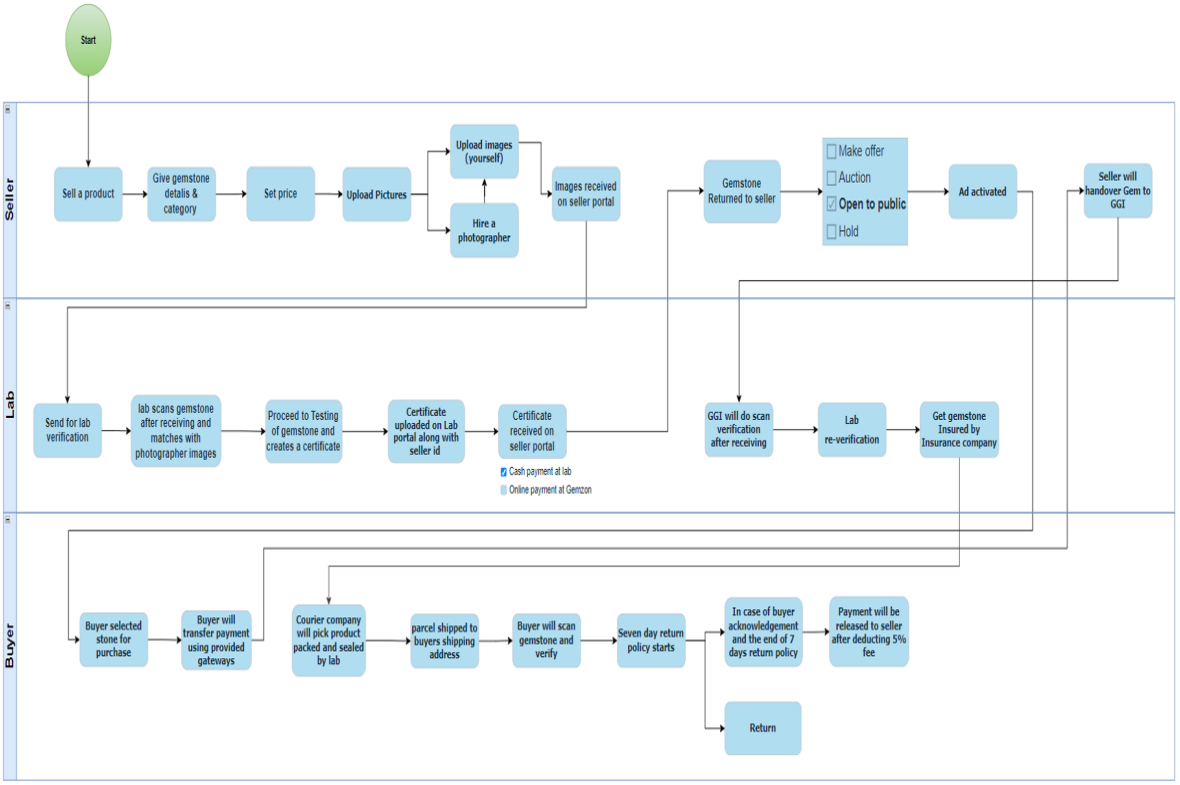

Figure 4.1: Seller Workflow of GemZon

4.1.2 Wireframe Design on Figma

Simultaneously, we commenced the design of wireframes for both the website and mobile applications using Figma. These wireframes served as blueprints for the visual design and layout of the user interface. Our primary focus during this phase was to create designs that were not only aesthetically pleasing but also intuitive and user-friendly. We incorporated all essential modules and functionalities into the wireframes to address market gaps and weaknesses identified during the requirement-gathering phase.

4.1.3 Entity-Relationship Diagram (ERD)

In addition to user interface design, we also developed an Entity-Relationship Diagram (ERD) to guide the database development process.As shown in Figures 4.2 **??**, The ERD provided a visual representation of the database schema, including enti-

ties, attributes, and relationships between them. This helped ensure the integrity and efficiency of the database structure, facilitating data storage and retrieval in line with the platform's requirements.

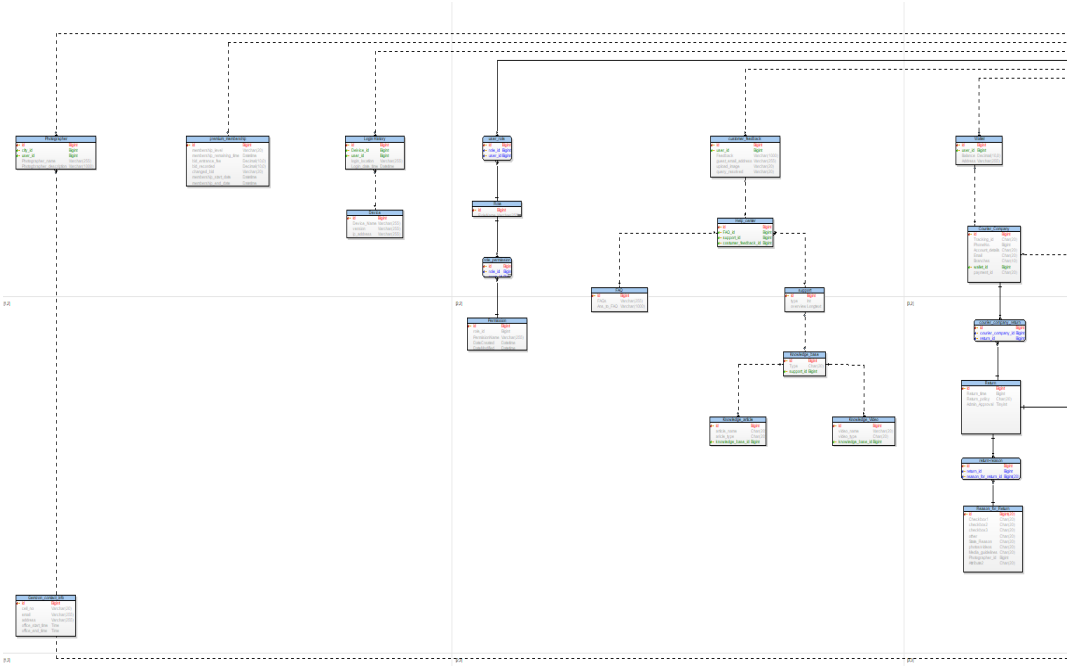

Figure 4.2: ERD of GemZon

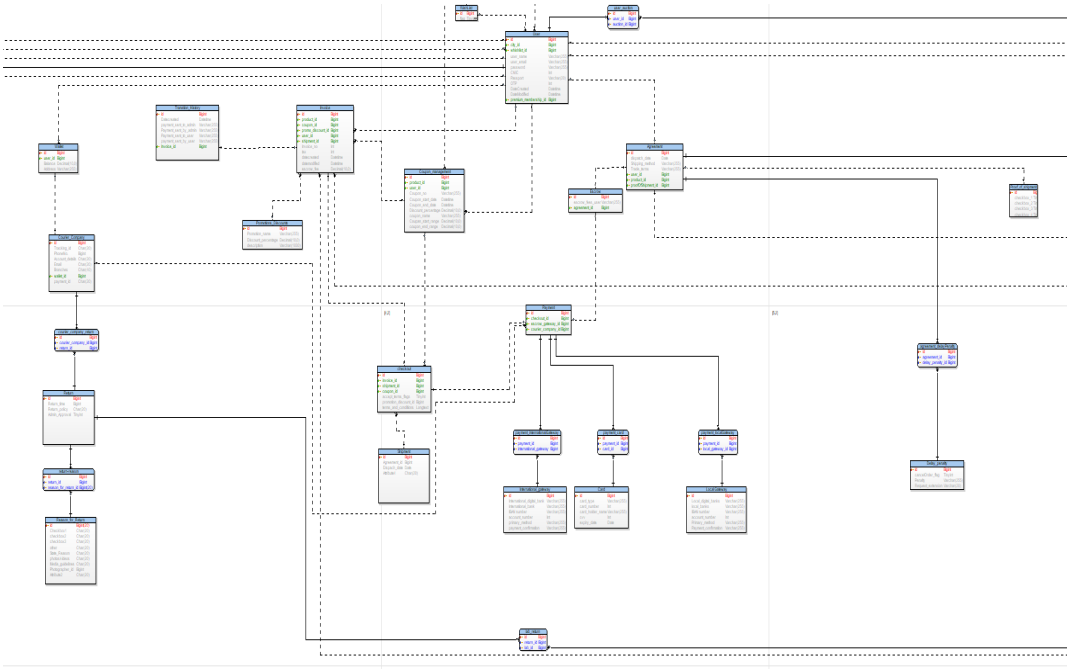

Figure 4.3: ERD of GemZon [1]

4.1.4 Supervisor Feedback and Iteration

Throughout the design process, we regularly sought feedback from our supervisors to ensure that the designs aligned with project goals and user expectations. By incorporating their insights and suggestions, we iteratively refined the wireframes to achieve optimal usability and accessibility. Supervisors played a crucial role in guiding the design decisions, emphasizing simplicity and clarity in the user interface while maintaining the platform's functionality.

4.1.5 UI/UX Principles

Our design approach emphasized adherence to UI/UX principles to create a compelling and engaging user experience. We focused on:

- **Simplicity**: Streamlining the user interface to eliminate unnecessary complexity and cognitive load.
- **Consistency**: Maintaining consistency in design elements and interactions

across different screens and modules.

- **Visual Appeal**: Employing visually appealing aesthetics and graphics to enhance user engagement.
- **Accessibility**: Ensuring that the platform was accessible to users of all abilities, including those with disabilities.

4.1.6 Outcome

The design stage culminated in the creation of comprehensive wireframes that served as the foundation for frontend development. By meticulously planning the user experience and interface design, we aimed to create a platform that not only addressed market gaps and weaknesses but also provided a delightful and intuitive experience for users. The iterative design process, guided by supervisor feedback and UI/UX principles, ensured that Gemzon would be a visually appealing and user-friendly platform poised to revolutionize the gemstone trading industry.

4.2 Frontend Development

4.2.1 Web Application

In the dynamic realm of e-commerce, Gemzon emerges as a trailblazing platform, revolutionizing the gemstone trading landscape through a meticulously crafted web-based portal. This section elucidates the methodology meticulously employed in architecting Gemzon's frontend, a convergence of leading-edge technologies engineered to elevate the gemstone trading experience. Anchored by React.js, Gemzon's frontend development journey embodies a commitment to authenticity, innovation, and user-centric design. With a steadfast focus on user-friendliness and aesthetics, Gemzon endeavors to create the most attractive and engaging platform for gemstone enthusiasts worldwide.

4.2.1.1 Why React.js?

React.js, the cornerstone of Gemzon's frontend, epitomizes a paradigm shift in web development, renowned for its agility, scalability, and performance. Its component-based architecture empowers developers to create modular, reusable UI components, fostering agility and maintainability. Leveraging React.js' declarative syntax, virtual DOM rendering, and thriving ecosystem, Gemzon ensures a fluid, responsive, and immersive user experience across all devices.

4.2.1.2 Development Environment and Technologies

Gemzon's frontend development is fortified by a robust suite of technologies meticulously curated to deliver an unparalleled user experience. The following technologies and tools constitute the bedrock of Gemzon's frontend architecture:

- **Styling:** @emotion/react, @emotion/styled, and @mui/material
- **Form Handling:** react-hook-form
- **Routing:** react-router-dom
- **State Management:** useState and useContext
- **Animations:** react-spring
- **Charts and Graphs:** recharts
- **HTTP Requests:** axios
- **Date Handling:** dayjs

4.2.1.3 System Architecture and Key Functionalities

Gemzon's web-based portal is intricately structured to cater to the distinct needs of buyers, sellers, and customs officers. The platform is delineated into the following user roles and portals, each facilitating specific interactions and transactions:

1. Buyer Portal: Enables browsing, searching, and purchasing gemstones.
2. Seller Portal: Empowers sellers with product management tools and analytics.
3. Customs Portal: Facilitates blockchain-based verification of gemstone authenticity.

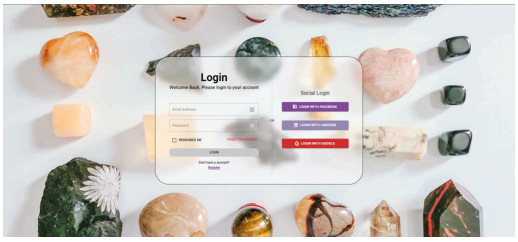

Figure 4.4: Login Page

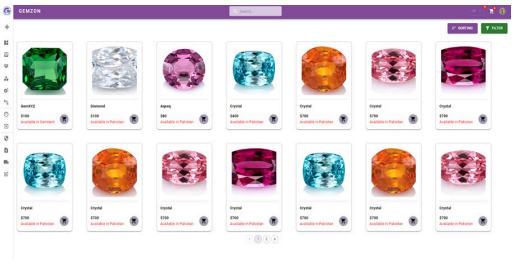

Figure 4.5: Explore Page

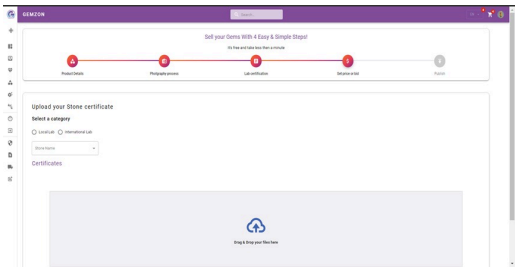

Figure 4.6: Listing Page

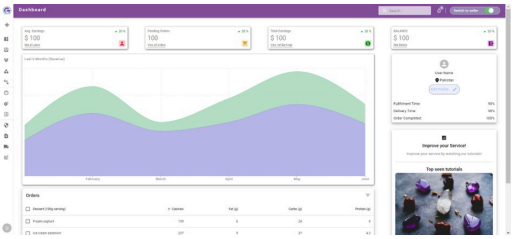

Figure 4.7: User Profile

4.2.1.4 Testing and Validation

Ensuring the reliability, functionality, and performance of Gemzon's frontend is paramount to delivering a seamless user experience. The following testing methodologies and validation techniques are employed to validate the robustness of the frontend architecture:

- **Unit Testing**

  Unit testing forms the bedrock of Gemzon's testing strategy, facilitating the validation of individual components and functions. Leveraging industry-standard tools such as Jest and React Testing Library, developers meticulously scrutinize each component and function to ensure compliance with predefined specifications. By isolating and testing discrete units of code, Gemzon endeavors to

identify and rectify potential defects or inconsistencies, thereby fortifying the overall integrity of the frontend architecture.

- **Integration Testing**

  Integration testing serves as a critical validation mechanism, ensuring the harmonious interaction and interoperability of different modules within Gemzon's frontend ecosystem. With a focus on verifying the seamless integration of various components, modules, and subsystems, Gemzon meticulously orchestrates integration testing scenarios. Through comprehensive test suites, developers ascertain that disparate elements coalesce seamlessly, fostering a cohesive and interconnected frontend architecture. By validating the integrity of integration points, Gemzon bolsters the robustness and reliability of its web-based gemstone trading platform.

In essence, Gemzon's frontend development journey embodies a harmonious fusion of innovation, functionality, and user-centric design. By embracing React.js and a rich array of frontend technologies, Gemzon sets the stage for a transformative gemstone trading experience, poised to redefine industry standards and revolutionize online commerce.

4.2.2 Mobile Application

The mobile application for Gemzon, as shown in Figure 4.8, is a crucial component of the platform, providing users with a seamless and user-friendly interface for capturing gemstone images and interacting with the Gemzon ecosystem. Built using Flutter, the application offers cross-platform compatibility and a rich set of features designed to enhance the user experience.

- **User-Friendly Interface:** The Flutter-based mobile application boasts an intuitive and user-friendly interface, making it easy for users to navigate through different functionalities and access key features with minimal effort. The ap-

plication's design prioritizes simplicity and clarity, ensuring that users can capture gemstone images and perform other tasks efficiently.

- **Integration with Java Spring Boot Backend:** The mobile application seamlessly integrates with the Java Spring Boot backend of the Gemzon platform, enabling secure communication and data exchange between the frontend application and the backend server. JWT tokens are used to authenticate users and ensure the confidentiality of user information during data transmission.

- **Camera Functionality with camera.dart:** One of the primary features of the Gemzon mobile application is its ability to capture high-quality images of gemstones using the device's camera. This functionality is implemented using the `camera.dart` library, which provides access to the device's camera hardware and allows users to capture images with ease.

- **Bluetooth Connectivity with bluetooth.dart:** To enhance the user experience and enable advanced functionalities, the Gemzon mobile application leverages Bluetooth connectivity to interact with hardware modules. The `bluetooth.dart` library facilitates seamless communication between the mobile application and external hardware components, enabling features such as remote gemstone rotation.

- **Automatic Gemstone Rotation:** When users initiate the process of capturing gemstone images using the mobile application, the hardware module automatically rotates the gemstone to ensure optimal image capture from different angles. This automation is achieved through synchronization between the mobile application's backend and the hardware module, which receives signals from the NodeMCU controller.

- **Image Capture and Processing:** Upon capturing gemstone images using the mobile application, the images are sent to the backend server for processing

and storage in the database. Additionally, the images are passed through an AI module integrated into the Gemzon platform to verify the authenticity of the gemstones. This seamless process ensures that users can capture images confidently, knowing that their authenticity will be verified accurately.

- **Enhanced User Experience:** Throughout the image capture process, the Gemzon mobile application prioritizes user convenience and relaxation. By automating gemstone rotation and seamlessly integrating with backend services and hardware modules, the application ensures a stress-free and enjoyable experience for users, allowing them to focus on capturing high-quality gemstone images effortlessly.

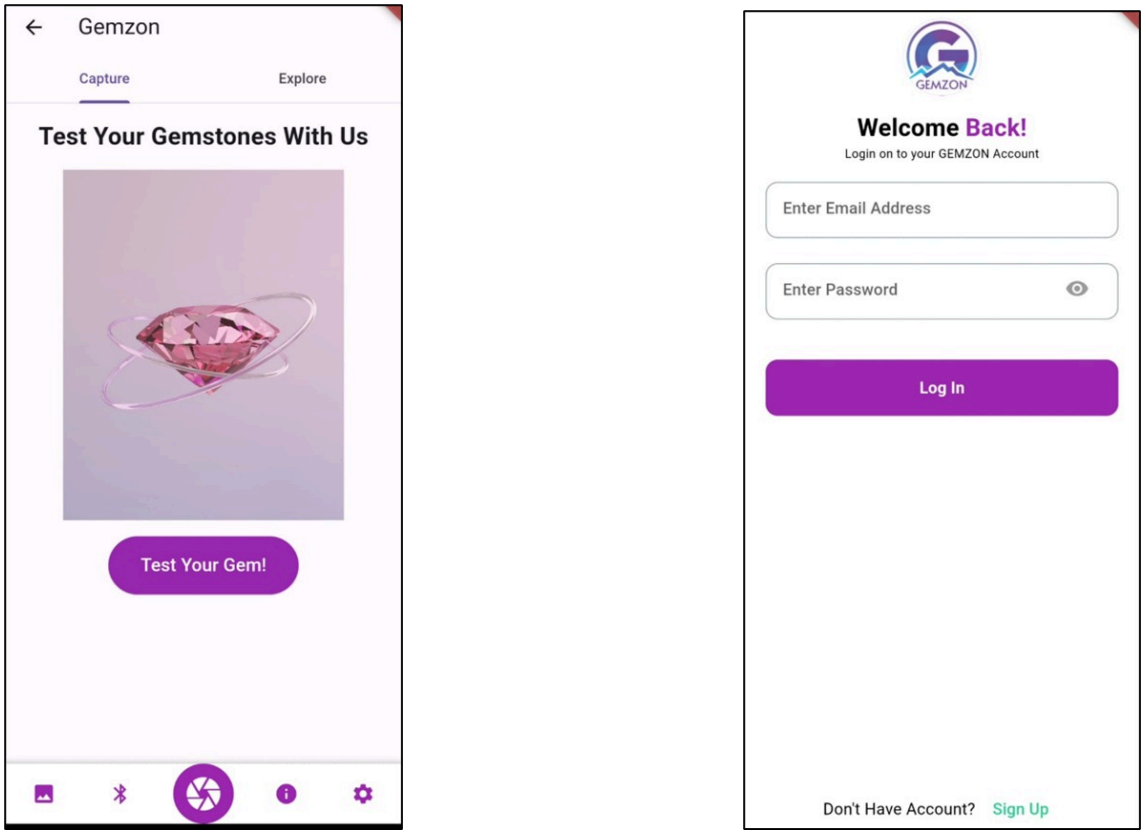

Figure 4.8: Mobile APP Pages

4.3 Backend Development

The backend development phase of the Gemzon project was a pivotal stage where we meticulously crafted the underlying architecture and implemented core functionalities to support the platform's operations. This phase involved a comprehensive selection of technologies, rigorous development methodologies, and stringent security measures to ensure the reliability, scalability, and security of the backend infrastructure.

4.3.1 Requirement Analysis and Technology Selection

Before commencing the development process, we conducted an in-depth analysis of project requirements, identifying key functional and non-functional aspects essential for the success of Gemzon. Collaborative discussions with stakeholders, including gemstone enthusiasts, traders, and industry experts, provided valuable insights into user preferences, market trends, and pain points within the gemstone trading domain. Through surveys, questionnaires, and one-on-one consultations, we gained a deep understanding of user expectations, market dynamics, and existing challenges in the gemstone industry.

Based on our extensive research and requirements gathering efforts, we carefully selected the technology stack best suited to meet Gemzon's objectives. The decision to utilize Java Spring Boot framework for backend development was driven by its robustness, versatility, and extensive ecosystem support. Spring Boot's convention-over-configuration approach and built-in features, such as auto-configuration and starter templates, streamlined the development process and expedited time-to-market.

4.3.2 Benefits of Java Spring Boot and Hibernate Integration

Java Spring Boot, coupled with Hibernate for ORM, offered numerous advantages for Gemzon's backend development:

- **Rapid Prototyping:** Spring Boot's inherent simplicity and productivity features allowed us to rapidly prototype backend components, enabling quick iterations and feedback cycles. This facilitated agile development practices and accelerated feature implementation.
- **Scalability and Performance:** The lightweight nature of Spring Boot, coupled with its support for microservices architecture, ensured scalability and performance optimization. By leveraging Spring Boot's built-in support for embedded servers and asynchronous processing, we enhanced the platform's responsiveness and scalability under varying workloads.
- **Simplified Database Interaction:** Hibernate's ORM capabilities abstracted the complexities of database interaction, enabling seamless communication between Java objects and the underlying MySQL database. This abstraction eliminated the need for manual SQL queries, reducing development overhead and enhancing code maintainability.

4.3.3 Development of RESTful APIs with Java Spring Boot

In the backend development phase of the Gemzon project, Java Spring Boot played a pivotal role in the creation of RESTful APIs to handle business logic and facilitate seamless data transactions. Leveraging the power and flexibility of Spring Boot, we meticulously crafted a suite of APIs to cater to various functional requirements and ensure smooth interaction between the frontend, backend, and external systems.

4.3.4 Benefits of Java Spring Boot for API Development

Java Spring Boot offered several advantages for API development:

- **Simplified Configuration:** Spring Boot's opinionated approach to configuration minimized boilerplate code and simplified the setup of RESTful endpoints, enabling rapid development without sacrificing flexibility or customization options.
- **Annotation-based Development:** With Spring Boot's support for annotations, defining RESTful endpoints, request mappings, and request/response handling became intuitive and concise. This annotation-driven approach reduced development effort and improved code readability.
- **Automatic Endpoint Documentation:** Spring Boot's integration with Swagger and OpenAPI standards facilitated automatic generation of API documentation, providing developers with comprehensive and up-to-date documentation for all API endpoints. This documentation enhanced API discoverability and facilitated seamless integration with frontend and external systems.

4.3.5 Key API Endpoints Developed

During the backend development phase, we designed and implemented a range of API endpoints to support essential platform functionalities:

1. **User Authentication Endpoints:** APIs were developed to handle user registration, login, and authentication processes. These endpoints facilitated secure user authentication using JWT tokens and runtime OTP generation, ensuring robust security measures to safeguard user accounts.
2. **Gemstone Listing and Trading Endpoints:** APIs were created to enable users to list, browse, and trade gemstones on the platform. These endpoints facilitated the creation of gemstone listings, retrieval of gemstone data, and

execution of trade transactions, providing users with a seamless and intuitive trading experience.

3. **Gemstone Verification Endpoints:** APIs were implemented to support the gemstone verification process, enabling users to verify the authenticity and quality of gemstones listed on the platform. These endpoints integrated with external verification services, certified labs, and AI modules to ensure comprehensive gemstone verification and validation.

4. **Add to Cart API:** APIs were developed to handle adding gemstones to the user's cart, facilitating smooth shopping experiences and order management.

Blockchain Integration and User Account Assignment: Each user was assigned a blockchain account after registering to carry out transactions of gemstones in the future. This integration ensured transparent and secure transactions, leveraging blockchain technology to enhance trust and authenticity within the platform.

Handling Images and Certificates Securely: Images and certificates of gems were handled securely to maintain the integrity and authenticity of gemstone listings. By employing encryption techniques and secure data storage practices, we ensured that the platform served as a bona fide marketplace for gemstone trading, fostering trust and confidence among users.

4.3.6 Backend Dependencies and Libraries

The Gemzon project utilized a curated set of dependencies and libraries within the Maven configuration to support various backend functionalities:

- **Spring Boot Starters:** We leveraged Spring Boot starters for web development, data validation, data JPA, email functionality, WebSocket communication, and testing, ensuring comprehensive coverage of essential features and components.

- **Web3j Core:** Integration of Web3j Core facilitated interaction with the Ethereum blockchain network, enabling blockchain-related functionalities within the platform, such as smart contract interaction and transaction processing.
- **JWT Libraries:** JSON Web Tokens (JWT) libraries, including jjwt-jackson, jjwt-api, and jjwt-impl, were utilized for implementing secure authentication mechanisms. JWT tokens were employed to authenticate and authorize user access to API endpoints, ensuring data confidentiality and integrity.
- **ModelMapper and Lombok:** ModelMapper was employed for entity-to-DTO mapping, simplifying data transformation between layers of the application. Lombok reduced boilerplate code by automatically generating getter, setter, and constructor methods, improving code readability and maintainability.
- **Apache Commons IO and Java Servlet API:** Apache Commons IO facilitated efficient file input/output operations, while Java Servlet API enabled the handling of HTTP requests and responses, facilitating communication between frontend and backend components.

4.3.7 Security Measures and Best Practices

Ensuring the security and integrity of user data was paramount throughout the backend development process. To mitigate potential security risks and vulnerabilities, we implemented several security measures and best practices:

- **JWT-Based Authentication:** User authentication was implemented using JSON Web Tokens (JWT), which provided a stateless and secure mechanism for verifying the identity of users accessing the platform. JWT tokens were securely generated, validated, and managed to prevent unauthorized access to sensitive resources.

- **Runtime OTP Generation:** To enhance user authentication security, runtime One-Time Password (OTP) generation was implemented using Spring Boot's email functionality. New users were required to verify their email addresses by entering a unique OTP sent to their registered email address, thereby preventing unauthorized account access.
- **Data Encryption and Confidentiality:** Sensitive user data, such as photos and certificates, were securely transmitted using Base64 encoding to prevent data interception and tampering during transmission over the network. This encryption ensured the confidentiality and integrity of user information, safeguarding it from unauthorized access or manipulation.

4.3.8 Outcome and Impact

The backend development phase of the Gemzon project culminated in the creation of a robust, scalable, and secure backend infrastructure that laid the foundation for the platform's core functionalities. As shown in Figure 4.9, By leveraging Java Spring Boot, Hibernate, and a carefully curated set of dependencies and libraries, we established a backend architecture that prioritized performance, reliability, and security.

The resulting backend system seamlessly integrated with frontend, blockchain, and AI modules, providing a cohesive and feature-rich platform for gemstone trading. Moving forward, this meticulously crafted backend architecture would serve as the backbone of Gemzon, enabling future enhancements, expansions, and optimizations to meet the evolving needs of users and adapt to changing market trends.

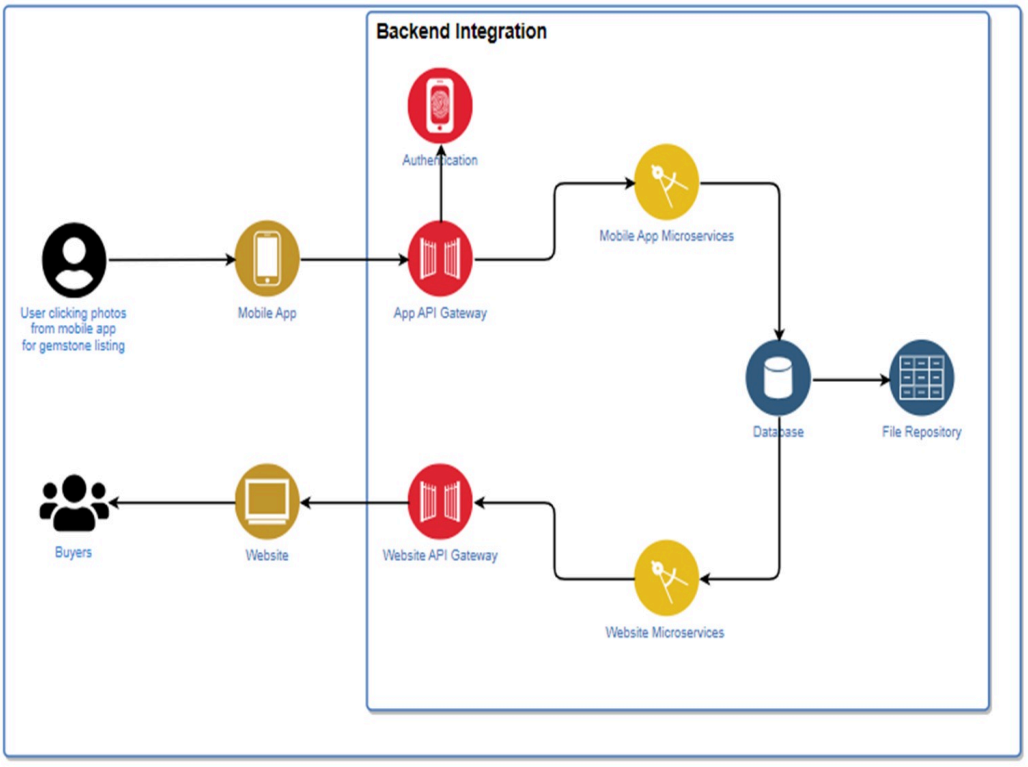

Figure 4.9: Back-end integration with buyer and seller

4.3.9 Database Management

The database management aspect of the Gemzon project plays a crucial role in ensuring the efficient storage, retrieval, and management of data related to users, gemstones, transactions, and more. Our database architecture was meticulously designed to meet the scalability, reliability, and security requirements of the platform. Here's an overview of our approach to database management:

Selection of MySQL: For the Gemzon project, we chose MySQL as the relational database management system (RDBMS) due to its reliability, performance, and widespread adoption in the industry. MySQL's robust features, including ACID compliance, support for transactions, and scalability, made it an ideal choice for handling the diverse data requirements of Gemzon.

Schema Design and Table Structure: The database schema was carefully de-

signed to reflect the logical structure of the Gemzon platform and accommodate the various entities and relationships within the system. We defined tables to store user profiles, gemstone listings, transaction records, authentication tokens, and other essential data elements. Each table was structured with appropriate columns and data types to accurately represent the attributes of its corresponding entity. Foreign key constraints were employed to enforce referential integrity and maintain data consistency across related tables.

Data Integrity and Security Measures: Ensuring data integrity and security was a top priority throughout the database management process. We implemented several measures to protect sensitive user information and maintain the confidentiality of data:

1. **Indexing:** Proper indexing of database tables was performed to optimize query performance and facilitate faster data retrieval. Indexes were created on columns frequently used in search and filter operations to improve query efficiency.

2. **Foreign Key Constraints:** Foreign key constraints were utilized to establish relationships between tables and enforce data integrity. By defining foreign key constraints, we ensured that only valid and existing data could be referenced in related tables, preventing orphaned records and maintaining referential integrity.

3. **Encryption Techniques:** Sensitive data such as user passwords, authentication tokens, and financial transactions were encrypted using industry-standard encryption algorithms to protect against unauthorized access and data breaches. Encryption ensured that even if the database were compromised, the encrypted data would remain secure and unreadable to attackers

4. **Password Protection:** The MySQL database was configured with strong

password protection mechanisms to prevent unauthorized access. Password policies were enforced to ensure that database passwords met minimum complexity requirements, and access to the database was restricted to authorized users with appropriate credentials.

Handling Images and Certificates: Images and certificates associated with gemstones were securely stored in the local file system of the server hosting the Gemzon application. Only the file paths to these images and certificates were stored in the database, minimizing database storage requirements and optimizing performance.

Backup and Recovery: Regular database backups were performed to safeguard against data loss due to system failures, human errors, or unforeseen events. Backups were stored in secure off-site locations to ensure data availability and integrity in the event of a disaster or data corruption.

4.3.10 Outcome and Impact

Database management in the Gemzon project involved meticulous schema design, robust data integrity measures, and stringent security practices to ensure the reliability, security, and performance of the database infrastructure. By leveraging MySQL and implementing best practices in database management, As shown in Figure 4.10, Gemzon was able to establish a solid foundation for its data storage and management needs, ensuring a seamless and secure experience for users interacting with the platform.

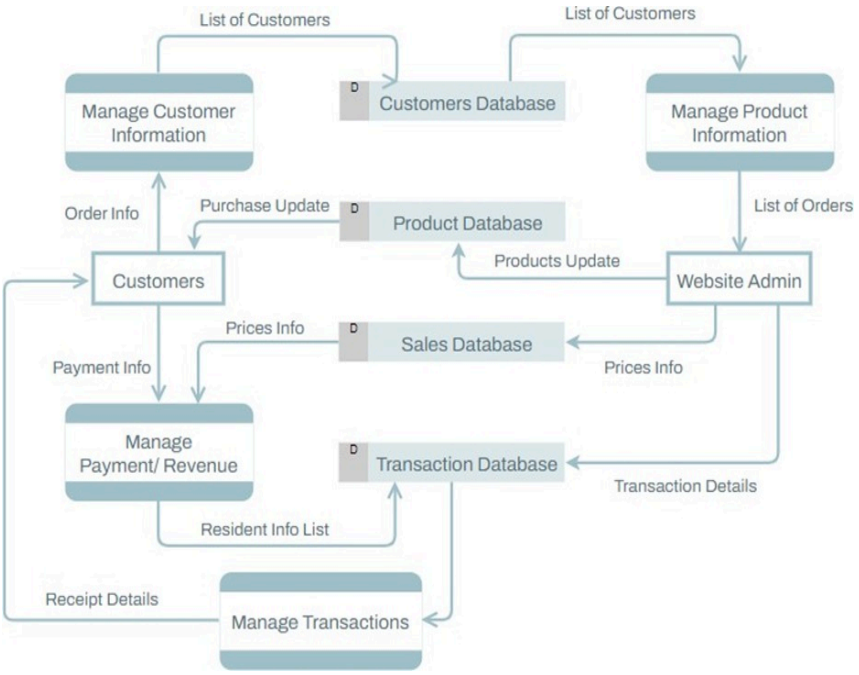

Figure 4.10: GemZon DataBase Logic Flow

4.4 Blockchain Integration

Gemzon emerges as a beacon of innovation, offering a transformative platform that leverages cutting-edge technologies to revolutionize gemstone trading. With a seamless blend of blockchain, artificial intelligence, and hardware integration, Gemzon sets a new standard for authenticity, security, and user experience in the gemstone industry.

4.4.1 Why Solidity?

Solidity, a programming language specifically designed for writing smart contracts on blockchain platforms like Ethereum, plays a pivotal role in Gemzon's architecture. The decision to use Solidity stems from its unique capabilities in facilitating trustless, decentralized transactions and enforcing transparent business logic. By deploying smart contracts written in Solidity, Gemzon ensures immutable records of gemstone ownership, transparent transaction histories, and automated execution of trading

agreements. Solidity's robustness and security features make it the ideal choice for implementing the backbone of Gemzon's blockchain-based platform, fostering trust and confidence among users in the authenticity and integrity of gemstone transactions.

4.4.2 Wireframe Design on Figma

4.4.3 Smart Contract Functions

1. **NFT Creation:**

- **Listing Process:** When a seller lists a gemstone on the E-commerce platform, an automated process triggers the creation of an NFT representing that gemstone. The NFT contains specific and sensitive information about the gemstone listed on Gemzone Website, including:
  - Gemstone Name: The unique name assigned to the gemstone e.g., Diamond.
  - Gemstone Weight: The weight of the gemstone, measured in carats e.g., 0.1 carats.
  - Gemstone Price: The price of the gemstone, in Eth e.g., 2 Eth.
  - Color: The color grade or description of the gemstone e.g., Faint Yellow.
  - Origin: The geographical source of the gemstone e.g., New South Wales, Australia.

  Whenever a seller lists a gemstone, the seller is assigned with a unique blockchain address, linking them to the NFT of the gemstone.

4.4.4 Smart Contract Functions:

- **Manage Ownership:** A smart contract manages the ownership details and records every movement involving the gemstone. It updates the owner's address upon the selling gemstone or transfer of the gemstone ownership.
- **Transferability of Ownership:** The contract includes transferability functions that allow the transfer of ownership from one user's address to another. This ensures that the process ownership can be transferred with transparency.
- **Traceability of Gemstone:** The traceability of gemstone keeps a comprehensive log of the gemstone's history, including past owners, first owner, and transaction details. This log is immutable and difficult to modify the details and can be queried at any moment to verify the gemstone's provenance and authenticity.
- **Payment Integration:** The smart contract also integrates with payment gateways to conduct transactions. Payments are recorded and saved on the blockchain, so that each transaction is secure, traceable, and verifiable.
- **Retrieval of First Owner:** A specific function 'Retrieval of First Owner' allows for the retrieval of the first owner's details, ensuring traceability from the point of origin to the end.
- **Retrieve Current Owner Details:** The smart contract provides functions to fetch the current owner's information like owner's unique address, maintaining transparency.

4.4.5 Tools Used and Environment:

- **Solidity Compiler (solc):** Smart contracts are coded in Solidity programming language. Solidity programming language is specifically designed for the Ethereum blockchain. The solc compiler converts Solidity scripts into

Ethereum Virtual Machine (EVM) bytecode. The compiler checks for errors and ensures that it is ready for deployment on the blockchain.

- **Ganache:** It provides a personal Ethereum blockchain used for developing and testing smart contracts. It simulates the Ethereum network, allowing us to deploy smart contracts, run test cases, and perform debugging.
- **Remix:** For testing smart contract scripts, Remix demo accounts have been used to see whether our transaction is working fine or not and transactions are taking place or not.

4.4.6 Blockchain Communication:

- **Node.js and Web3.js:**
  - **Backend Framework (Node.js):** Node.js is used to build the server-side logic of the Gemzone E-commerce platform. It handles API requests, processes data, and makes a bridge to the frontend.
  - **Web3.js:** Web3.js is a JavaScript library that facilitates communication between the Gemzone platform and the Ethereum blockchain. It enables the execution of smart contract functions like traceability of gemstones, transferability of gemstones.
- **API Functionalities:**
  - **Querying Blockchain Data:** APIs are developed to query data from the blockchain, such as ownership records saved on NFT, transactions history, traceability of gemstone. These queries provide real-time data on Gemzone E-commerce website, ensuring transparency and authenticity.
  - **Executing Transactions:** APIs manage the main functionalities like transferring ownership. They ensure that transactions are securely processed and recorded every transaction on the blockchain.

4.4.7 Security and Transparency:

- **Blockchain-Based Verification:** Every transaction on the Gemzone E-commerce platform is verified. This process of verification ensures the authenticity and integrity of the data, preventing fraud and ensuring that all transactions are legitimate and authorized.
- **Logging:**
  - **Immutable Records:** All actions, for example, listing a gemstone, buying a gemstone, selling a gemstone, and transferring ownership of gemstone, traceability of gemstones, retrieval of gemstone information are logged on the blockchain. These records are immutable, meaning they cannot be altered or deleted, providing a transparent audit trail, making it difficult to change original records.
  - **Transparency:** Users can access these logs to verify the history and provenance of any gemstone, ensuring confidence in their transactions as we all know Blockchains are decentralized databases.

4.4.8 Outcome:

Implementing blockchain technology in Gemzone E-commerce Website ensures that each gemstone listed on our platform is authorized, traceable, and securely transacted. The use of NFTs and smart contracts, powerful development tools like solc and Ganache, and blockchain communication facilitated by Node.js and Web3.js, creates a secure, transparent, and efficient marketplace for buying, selling, and bidding on gemstones. This integration makes our Gemzone E-commerce platform a very secure and powerful E-commerce marketplace for users and also enhances user trust and ensures the authenticity and integrity of every gemstone listed on our website.

4.5 AI Module

The development of an AI module for gemstone image verification stemmed from the pressing need to address the challenges prevalent in the gemstone trading industry, particularly concerning the authentication and verification of gemstones. With instances of fraudulent practices on the rise and the absence of a reliable verification mechanism, there was a critical need for technological intervention to accurately distinguish between real and fake gemstones. Thus, the project aimed to leverage AI technology to develop a robust verification system capable of effectively addressing these challenges.

4.5.1 Identification of Gemstone Image Sources

4.5.1.1 Real Gemstone Images

The project commenced by sourcing a collection of real gemstone images from Care Pvt Ltd, understanding the pivotal role of authentic data for training and testing the AI module.

4.5.1.2 Fake Gemstone Images

However, the absence of corresponding fake gemstone images presented a significant challenge, necessitating the generation of synthetic gemstone images through AI-driven methods.

4.5.2 Literature Review and Supervisor Consultations

4.5.2.1 Literature Review

Extensive literature review and consultations with project supervisors were conducted to gain insights into existing methodologies and best practices for gemstone image verification.

4.5.2.2 Consultations with Supervisors

This phase involved studying relevant research papers, exploring various AI techniques, and seeking expert guidance to formulate an effective approach tailored to the project's objectives.

4.5.3 Challenges Faced in Obtaining Fake Gemstone Images

4.5.3.1 Unavailability of Fake Images

One of the primary challenges encountered during the project was the unavailability of synthetic or fake gemstone images for training purposes.

4.5.3.2 Innovative Solutions

This limitation posed a significant obstacle, compelling the team to devise innovative solutions to generate synthetic gemstone images artificially.

4.5.4 Selection and Evaluation of Generative Adversarial Networks (GANs)

4.5.4.1 Vanilla GAN

The Vanilla GAN was the initial consideration due to its simplicity and ease of implementation. However, it lacked the sophistication needed to generate high-quality gemstone images and a high FID matrix score of 78 made us reject this model.

4.5.4.2 DCGAN (Deep Convolutional GAN)

DCGAN was selected for its ability to generate clear and realistic gemstone images. It demonstrated superior performance with a relatively low FID score of 55, making it suitable for the project's objectives.

4.5.4.3 Conditional GAN

Although Conditional GAN offered the advantage of conditional image generation, it did not provide significant improvements in gemstone image quality compared to DCGAN.

4.5.4.4 Style GAN

Style GAN showcased impressive capabilities in generating diverse and high-resolution images. However, its complexity and computational requirements made it less practical for the project's scope.

4.5.5 GAN Training Process

4.5.5.1 Dataset Preparation

- We provided a dataset of 3000 real gemstone photos, each with dimensions of 128x128 pixels. This dataset was crucial for training the GAN to generate high-quality synthetic images.
- To efficiently process this data, we used a batch size of 64, which balances memory usage and training speed.

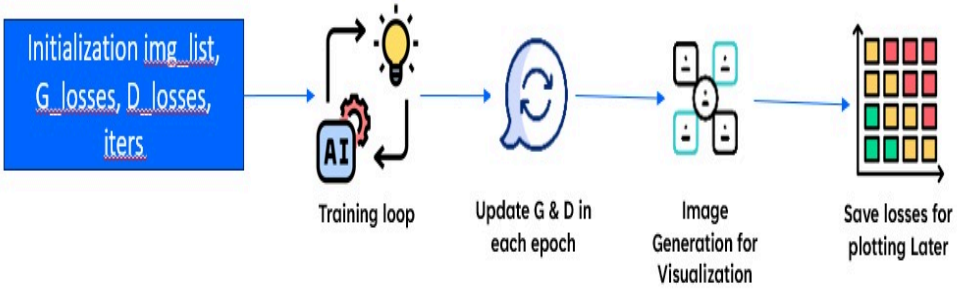

Figure 4.11: DCGAN architecture metrix

4.5.5.2 Model Architecture and Training

- The GAN architecture comprised two primary components: the generator and the discriminator. The generator's role was to create images, while the discriminator's function was to classify these images as real or fake.
- The generator began with random noise and progressively upsampled this noise through a series of layers, each adding complexity and detail to the images. The discriminator, conversely, took input images and downsampled them through convolutional layers to make a classification decision.
- Both networks were trained in tandem, with the generator trying to fool the discriminator and the discriminator learning to better distinguish real images from the fakes. This adversarial process helped both networks improve iteratively.
- Training was carried out for 1350 epochs, as shown in Figure 4.12,. During this process, the losses for both the generator and the discriminator were calculated and used to update their respective parameters, striving for a balance where the generator produced realistic images that the discriminator could no longer easily classify as fake.

Figure 4.12: GAN images result

4.5.6 Training and Testing Convolutional Neural Network (CNN) Model

The dataset containing both real and synthetic gemstone images was utilized to train and test a Convolutional Neural Network (CNN) model.

4.5.6.1 Dataset Utilization

- For the CNN model, we used the 1000 generated fake images from the GAN alongside approximately 1000 real gemstone images from our original dataset. This balanced dataset ensured that the model had sufficient examples of both real and fake gemstones to learn from.

4.5.6.2 Model Architecture

- We implemented a simple yet effective 6-layer convolutional network, As shown in Figure 4.13. This architecture was chosen for its ability to capture essential

features while being computationally efficient. The layers included convolutional layers with ReLU activations, pooling layers to reduce dimensionality, and fully connected layers to make the final classification.

- The convolutional layers applied filters to the input images to extract features such as edges, textures, and shapes. Pooling layers then reduced the spatial dimensions, which helped reduce the computational load and control overfitting.

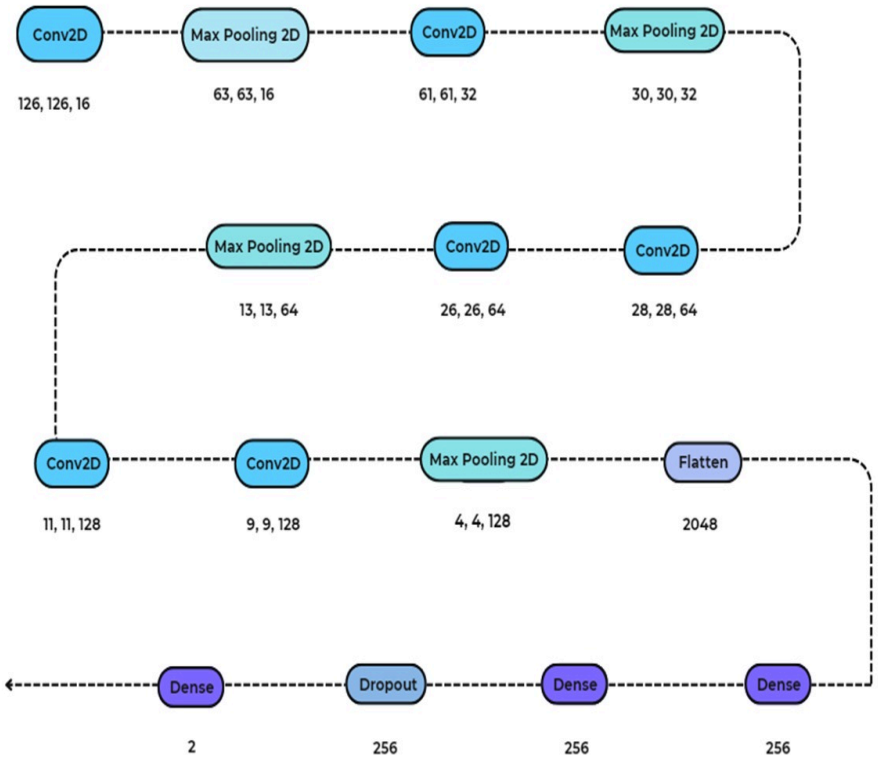

Figure 4.13: 6-layerS of convolutional networt

4.5.6.3 Training Process

- The CNN was trained over 70 epochs, a period long enough to allow the model to learn the intricate features distinguishing real and fake gemstones without overfitting.

- Throughout the training, we used techniques such as dropout and data aug-

mentation to enhance the model's generalizability. Dropout randomly deactivated certain neurons during training, preventing the network from becoming too reliant on specific paths. Data augmentation involved randomly modifying the training images (e.g., rotations, flips) to increase the dataset's diversity.

4.5.7 Model Performance Evaluation

4.5.7.1 Accuracy and Confusion Matrix

- Upon testing, the CNN model achieved an accuracy of 86%. This metric indicates the overall percentage of correct predictions made by the model out of all predictions.
- The confusion matrix, as shown in Figure 4.15, providing deeper insights into the model's performance. It showed that out of 176 real gemstone images, the model correctly identified 173 as real, and out of 150 fake images, 146 were correctly identified as fake. This high level of correct classification underscores the model's robustness and reliability.

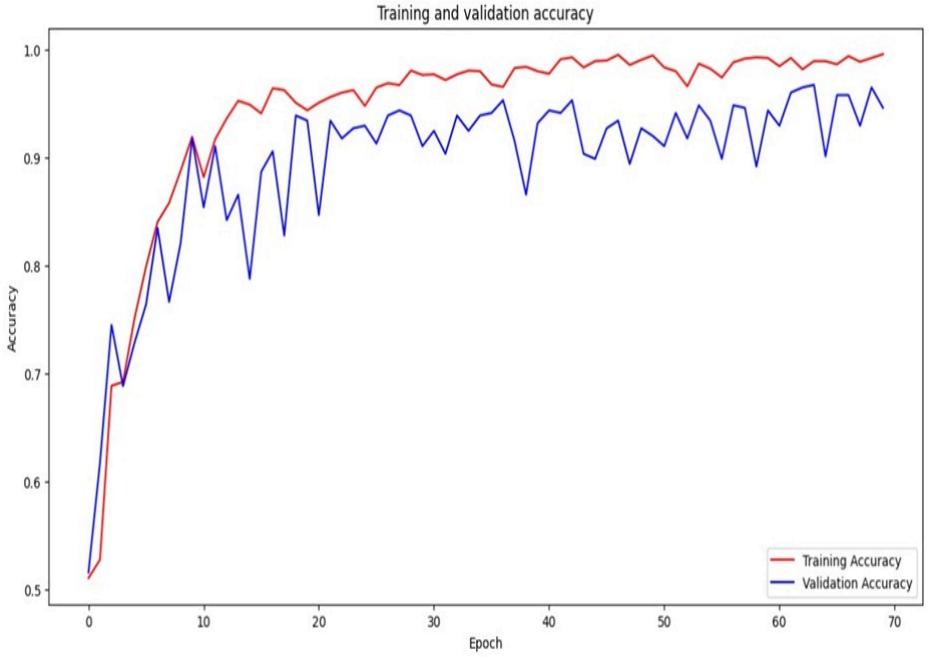

Figure 4.14: CNN TRAINING AND VALIDATION ACCURACY

4.5.7.2 Confusion Matrix

- Additional evaluation metrics such as precision, recall, and Confusion Matrix score were analyzed. Precision measures the accuracy of the positive predictions (real gemstones), recall measures the model's ability to identify all relevant instances, and the Confusion Matrix score provides a balance between precision and recall.

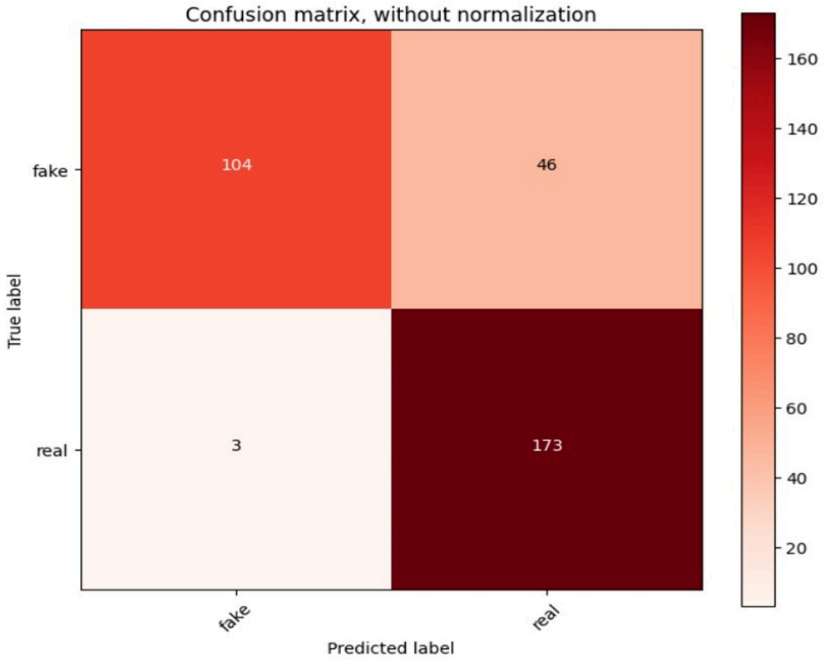

Figure 4.15: CNN result through confusion metrix

4.5.8 Conclusion

Through this detailed methodology, the AI module for gemstone image verification was developed, overcoming challenges posed by the absence of fake gemstone images and demonstrating its potential to revolutionize the gemstone trading industry by providing a reliable and efficient mechanism for authentication and verification.

Chapter 5

Deployment and Validation

5.1 Validation:

Validation and quality assurance are integral parts of the Gemzon project, ensuring that the platform meets high standards of functionality, reliability, and security. Testing is conducted rigorously at various stages of development to identify and rectify any defects or issues. Here's an overview of our quality assurance processes and testing methodologies:

5.1.1 Black Box Testing:

Boundary Analysis: Boundary analysis is a type of black-box testing that focuses on testing the boundaries between valid and invalid input conditions. In the context of Gemzon, boundary analysis is applied to various input fields to ensure that the system behaves correctly at the edges of acceptable input ranges.

Email and Password Validation:

- **Invalid Test Case:** Testing for an empty email field or password field to ensure that appropriate error messages are displayed to the user.

- **Valid Test Case:** Verifying the system's response when a registered email or valid password is provided.
- **Invalid Test Case:** Checking the system's behavior when an unregistered email or incorrect password is entered.

Image and Certificate Handling:

- **Invalid Test Case:** Verifying the system's response when attempting to upload an image or certificate in an invalid format.
- **Valid Test Case:** Testing the successful upload of images and certificates in acceptable formats.
- **Invalid Test Case:** Checking the system's response when attempting to upload documents or text files instead of images.

Class Partition Testing: Class partition testing involves dividing input classes into valid and invalid partitions and testing each partition separately. This approach ensures thorough coverage of all possible input scenarios and helps identify potential issues or inconsistencies in the system.

User Profile Data Validation:

- **Invalid Cases:** Testing for null values or invalid characters in user profile fields such as height, weight, length, address, country, city, etc.
- **Valid Cases:** Verifying the system's response when providing valid data for user profile attributes.
- **Invalid Cases:** Checking the system's behavior when providing excessively long or inappropriate data for user profile fields.

5.1.2 White Box Testing:

Statement Coverage: Statement coverage involves testing every statement in the source code to ensure that all code paths are executed during testing. In Gemzon, statement coverage testing is applied to critical functions such as listing new gems, user sign-up, login, and image uploads.

Branch Coverage: Branch coverage testing verifies that all decision branches in the code are executed during testing. It ensures that both true and false conditions are tested thoroughly. For example, in the listing new gem function, branch coverage testing ensures that all possible outcomes of the token authentication process are tested.

Path Coverage: Path coverage testing examines all possible execution paths through a function or program. In Gemzon, path coverage testing is applied to image upload functionality to ensure that different scenarios, such as uploading multiple images, uploading a single image, or attempting to upload an image with an incorrect ID, are tested comprehensively.

Outcome: Quality assurance in the Gemzon project involves a comprehensive approach to testing, encompassing black-box testing techniques such as boundary analysis and class partition testing, as well as white-box testing methodologies including statement coverage, branch coverage, and path coverage. By conducting thorough testing at various stages of development, we ensure that Gemzon meets high standards of quality, reliability, and security, providing users with a seamless and error-free experience on the platform.

5.2 Integration and Deployment

Following the completion of the development and validation stage for each module in the Gemzon project, the integration phase was initiated to combine all the individual

components into a cohesive and functional system. Integration was primarily focused on linking the blockchain, AI, and frontend modules with the backend, which serves as the backbone of the entire project. Additionally, deployment processes were implemented to make the system accessible for testing and eventual launch.

5.2.1 Integration of Blockchain Module

The blockchain module, crucial for gemstone ownership tracking and verification, was integrated with the backend by deploying it locally using Ganache, a personal Ethereum blockchain for development purposes. Solidity code, responsible for smart contract functionality, was compiled using the Solidity compiler (solc). A Node.js backend was specifically designed to communicate with the deployed smart contracts using the web3.js library. Node.js APIs were developed to interact with the blockchain, including functionalities such as gemstone listing, ownership transfer, and verification. These APIs were then called through Java Spring Boot when executing tasks related to gemstone trading and ownership management.

5.2.2 Integration of AI Module

The AI module, tasked with verifying the authenticity of gemstones through image analysis, was deployed locally, and a Flask server was set up to expose APIs for interaction. These APIs accept image paths as input and use a trained machine learning model to determine whether a gemstone is real or fake. Upon verification, the Flask server notifies the Java backend, which regulates gemstone listing based on the AI's assessment.

5.2.3 Integration of Frontend

The frontend modules for both the mobile application and web platform were integrated by invoking APIs exposed by the Java Spring Boot backend. This integration

simplified the communication between the frontend and backend, allowing seamless data exchange and interaction. The frontend components simply make HTTP requests to the backend APIs and receive responses, enabling functionalities such as user authentication, gemstone listing, and trading.

5.2.4 Integration with Hardware Module

The Gemzon application integrates with the hardware module via Bluetooth communication. When specific APIs are called from the Java Spring Boot backend, signals are sent to the NodeMCU microcontroller, instructing it to generate signals for controlling the hardware components. For instance, when a user initiates gemstone image capture in the app, the backend sends a signal to the NodeMCU to activate the motor for rotating the gemstone. This integration ensures synchronized operation between the software and hardware components of the Gemzon system.

5.2.5 Integration Testing

Throughout the integration process, thorough integration testing was conducted to ensure the seamless operation and interoperability of all integrated modules. Integration test cases were designed to validate the communication between different modules, verify data consistency and accuracy, and identify and resolve any integration-related issues or bugs. By running these test cases, the system was made bug-free and efficient, ready for further testing and eventual deployment.

5.3 Deployment:

Upon successful integration and testing Currently, the Gemzon project is deployed on localhost for testing and development purposes, as shown in Figure 5.1. Deployment on localhost provides several benefits, including ease of setup and configuration, fast iteration cycles during development, and enhanced control over the

environment. With localhost deployment, developers can quickly test new features, troubleshoot issues, and experiment with different configurations in a controlled environment. Additionally, deploying locally allows for efficient collaboration among team members, as everyone can access the system from their own development environment. Overall, localhost deployment streamlines the development process and facilitates rapid iteration and testing. However, the project aims to transition to cloud deployment in the future.

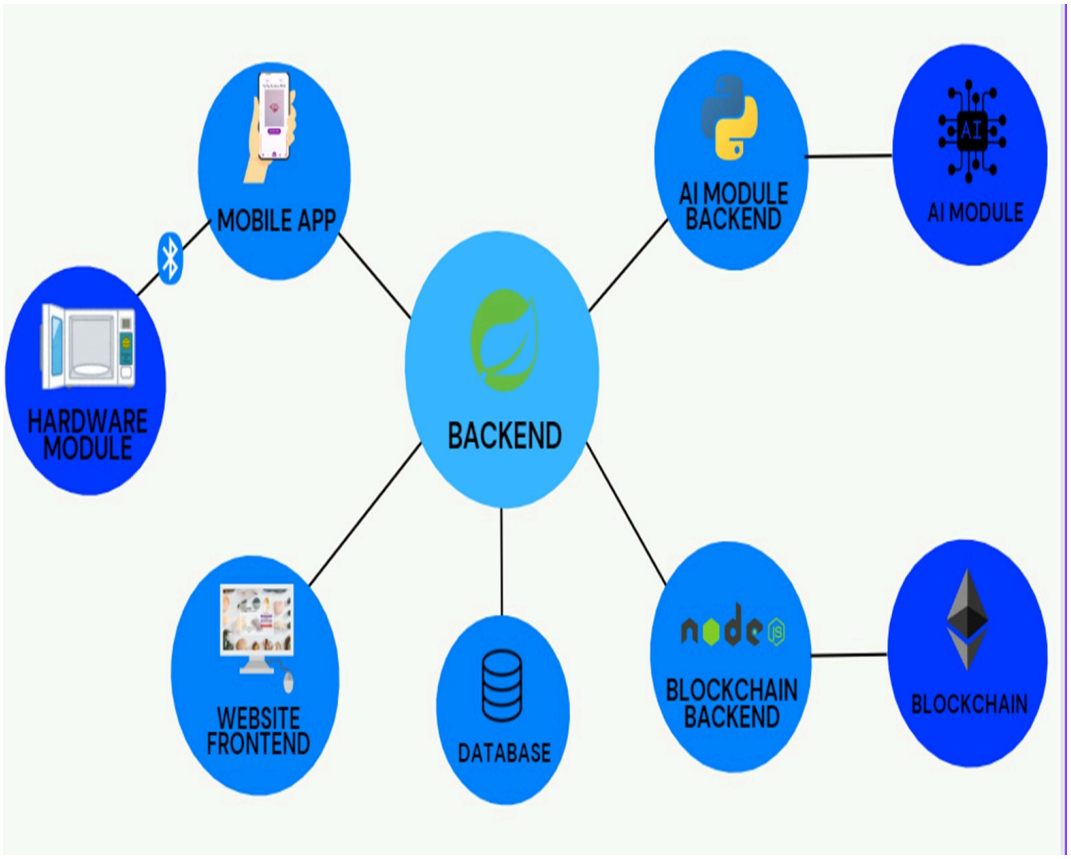

Figure 5.1: Integration Flow of GemZon

Chapter 6

Conclusion and Future Work

6.1 Conclusion

The Gemzon project has achieved significant milestones in revolutionizing the gemstone trading industry through the implementation of cutting-edge technology and innovative solutions. By seamlessly integrating blockchain technology, artificial intelligence, and hardware components with a robust backend and user-friendly frontend, Gemzon offers a comprehensive platform for gemstone enthusiasts, traders, and investors. The successful completion of development, integration, and deployment stages underscores our commitment to delivering a reliable, scalable, and secure solution that meets the evolving needs of the gemstone market.

6.1.1 Milestones Achieved

The Gemzon project has marked several significant milestones, signifying a transformative journey in the gemstone trading industry. From conceptualization to execution, each stage has been meticulously planned and executed, resulting in the development of a cutting-edge platform that redefines gemstone trading. The successful integration of blockchain, AI, hardware, and frontend components into a

cohesive ecosystem demonstrates our team's proficiency in leveraging technology to address industry challenges.

6.1.2 Technological Innovation

Through the adoption of emerging technologies such as blockchain and artificial intelligence, Gemzon has pioneered new standards of transparency, security, and authenticity in gemstone trading. The implementation of blockchain ensures immutable records of gemstone ownership, while AI-powered verification enhances trust and confidence among users. The integration of hardware components further enhances the user experience, providing innovative features for gemstone imaging and analysis.

However, as the size of the gemstone industry continues to expand, driven by increasing demand and evolving consumer preferences, there is still much more work to be done. Future endeavors may include further enhancements to platform functionality, expansion of market reach, and continued research and development to stay ahead of industry trends. With dedication and innovation, Gemzon remains poised to lead the way in shaping the future of the gemstone trading landscape.

6.2 Future work

Future plans for the Gemzon project are focused on continuous improvement and expansion to meet the growing demands of the gemstone industry. Building upon the foundation laid by the current functionalities, our roadmap includes several key initiatives aimed at enhancing user experience, expanding market reach, and staying ahead of industry trends.

6.2.1 Gemstone Classification

The current AI module focuses on identifying gemstones based on images. Our next step involves implementing advanced algorithms to classify gemstones into their

respective types. This classification will consider various factors such as color, clarity, cut, and carat weight, providing users with detailed insights into the characteristics of each gemstone.

6.2.1.1 Upgradation for Jewelry Items

While the AI module currently works well with raw gemstone photos, we recognize the need to extend its capabilities to identify gemstones set in jewelry items. This upgrade will involve developing algorithms capable of recognizing gemstones in different settings, such as rings, necklaces, and earrings, enhancing the platform's versatility and usability.

6.2.1.2 Addition of Crypto Wallet

To accommodate the growing trend of cryptocurrency adoption, we plan to integrate a crypto wallet into the Gemzon platform. This wallet will allow users to securely store, manage, and transact digital assets, providing a seamless and efficient payment experience for gemstone transactions. Additionally, integrating blockchain technology into the payment gateway will enhance security and transparency in financial transactions.

6.2.1.3 Blockchain Traceability

Building on the existing blockchain functionality, we aim to expand the platform's traceability features to include more comprehensive ownership histories for gemstones. By enabling multi-owner tracing, users will gain insights into the entire lifecycle of a gemstone, from its origin to its current ownership status. This increased transparency will foster trust and confidence among buyers and sellers on the platform.

6.2.1.4 Integrated Camera in Hardware

As part of our hardware enhancement efforts, we intend to integrate a high-resolution camera directly into the Gemzon device. This integrated camera will automatically capture images of gemstones placed within its vicinity, eliminating the need for users to manually capture photos using their mobile devices. This streamlined process will enhance efficiency and convenience, making gemstone listing and verification faster and more seamless.

6.2.1.5 Enhanced User Experience

In addition to the technical enhancements mentioned above, we are committed to continually improving the overall user experience of the Gemzon platform. This includes refining the user interface, optimizing performance, and incorporating user feedback to address pain points and enhance usability.

By pursuing these future plans, Gemzon aims to solidify its position as a leading platform in the gemstone trading industry. Through innovation, technological advancement, and a dedication to user satisfaction, we are confident that Gemzon will continue to thrive and meet the evolving needs of gemstone enthusiasts worldwide.

6.3 Future work

Future plans for the Gemzon project are focused on continuous improvement and expansion to meet the growing demands of the gemstone industry. Building upon the foundation laid by the current functionalities, our roadmap includes several key initiatives aimed at enhancing user experience, expanding market reach, and staying ahead of industry trends.

- **Gemstone Classification:** The current AI module focuses on identifying gemstones based on images. Our next step involves implementing advanced

algorithms to classify gemstones into their respective types. This classification will consider various factors such as color, clarity, cut, and carat weight, providing users with detailed insights into the characteristics of each gemstone.

- **Upgradation for Jewelry Items:** While the AI module currently works well with raw gemstone photos, we recognize the need to extend its capabilities to identify gemstones set in jewelry items. This upgrade will involve developing algorithms capable of recognizing gemstones in different settings, such as rings, necklaces, and earrings, enhancing the platform's versatility and usability.

- **Addition of Crypto Wallet:** To accommodate the growing trend of cryptocurrency adoption, we plan to integrate a crypto wallet into the Gemzon platform. This wallet will allow users to securely store, manage, and transact digital assets, providing a seamless and efficient payment experience for gemstone transactions. Additionally, integrating blockchain technology into the payment gateway will enhance security and transparency in financial transactions.

- **Blockchain Traceability:** Building on the existing blockchain functionality, we aim to expand the platform's traceability features to include more comprehensive ownership histories for gemstones. By enabling multi-owner tracing, users will gain insights into the entire lifecycle of a gemstone, from its origin to its current ownership status. This increased transparency will foster trust and confidence among buyers and sellers on the platform.

- **Integrated Camera in Hardware:** As part of our hardware enhancement efforts, we intend to integrate a high-resolution camera directly into the Gemzon device. This integrated camera will automatically capture images of gemstones placed within its vicinity, eliminating the need for users to manually capture photos using their mobile devices. This streamlined process will enhance efficiency and convenience, making gemstone listing and verification faster and

more seamless.

- **Enhanced User Experience:** In addition to the technical enhancements mentioned above, we are committed to continually improving the overall user experience of the Gemzon platform. This includes refining the user interface, optimizing performance, and incorporating user feedback to address pain points and enhance usability.

By following these future plans, Gemzon aims to consolidate its position as a leading platform in the gemstone trading industry. Through innovation, technological advancement, and a commitment to user satisfaction, we are confident that Gemzon will continue to prosper and meet the changing needs of gemstone enthusiasts worldwide.

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