COMM017 -

Big Data and Cloud Computing

Course Work 01

Data Anonymisation in Healthcare

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MSc Advanced Computer Science

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Abstract

A comprehensive case study of the establishment of a cloud-based application for health information anonymisation with the goal of improving privacy in health care information exchange is presented in this paper. It starts with an in-depth investigation of the fundamental principles and techniques of data anonymisation, including data masking, generalisation, pseudonymization, suppression, and perturbation. Advanced anonymisation techniques, such as k-anonymity, l-diversity, t-closeness, and differential privacy, are examined in the literature review along with their applicability in the healthcare industry. In keeping with international standards such as HIPAA and ISO/IEC 27701, the report also discusses the ethical, legal, and regulatory aspects of anonymising health data, with particular attention to the UK GDPR, the Data Protection Act of 2018, and NHS principles. These anonymisation techniques are included into a safe, expandable cloud architecture in the suggested application design. The assessment verifies that the application complies with privacy regulations, reduces the possibility of re-identification, and facilitates compliance. According to the study's findings, using cloud computing to anonymise data is a viable way to provide safe, moral, and legally compliant healthcare analytics and research.

Acknowledgement

I would like to express my sincere gratitude, For his essential advice, encouragement, and assistance during this course work, to Dr. Hamzah AlZubi. His knowledgeable advice and thoughts have been quite helpful in determining the focus and calibre of this job. Furthermore, I would also like to thank my colleagues and peers who shared their thoughts and feedback during the development and testing phases of this application.

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Table of Content

List of Tables & Figures

1. Introduction

Data anonymisation is the process of changing personal and sensitive information to prevent individuals from being identified, ensuring compliance with data protection requirements, and simplifying the use of data for research, analytics, and AI training in healthcare. In the concern of data privacy most accurate action is anonymisation of the data and it can proceed in many ways in number of fields. In the healthcare sector also identified the data anonymisation is critical action to be taken when handling data of the patients because if the third party access the patient data it will be a privacy issue and threat to the patients (Iyiola Emmanuel OlatunjiJens, RauchJens RauchMatthias, KatzensteinerMatthias KatzensteinerMegha, KhoslaMegha Khosla, 2022). Data anonymization in healthcare is the process of transforming personal and sensitive health data such that individuals cannot be identified, either directly or indirectly. This approach enables for the safe use of healthcare datasets while maintaining patient anonymity.

1.1. Data anonymisation principles and techniques in healthcare applications

Healthcare data is now widely employed in clinical research, artificial intelligence (AI) applications, and public health analytics. However, the growing volume of patient data creates questions about privacy, security, and compliance with rules such as GDPR and HIPAA. The purpose of data anonymisation is to strike a balance between privacy protection and data usability, ensuring that anonymised datasets remain useful for analysis while reducing the danger of re-identification. To achieve effective anonymisation, healthcare organisations adhere to basic principles that govern the processing and transformation of sensitive health information.

Key principles of Data Anonymisation:

- Minimisation: Maintains only necessary data while deleting personal information.
- Irreversibility: Prevents data re-identification, even when anonymised data is merged.
- Consistency: Maintains data usefulness and structure for meaningful analysis.
- Utility Preservation: Balances privacy protection and data analytical utility in research and analytics.

These principles enable the use of various anonymisation techniques, such as data masking, pseudonymisation, generalisation, suppression, and perturbation, which help to secure patient information while allowing for ethical data-driven advances in healthcare. The success of an anonymisation strategy is determined by factors such as the type of the dataset, the level of risk, and the planned use of the anonymised data.

Common Anonymisation Techniques in Healthcare:

- **Data masking**: Replaces sensitive information with masked values to protect direct identifiers.
- **Generalisation:** Generalizes data to prevent recognition while maintaining utility.
- **Pseudonymization:** Replaces IDs with pseudonyms for data correlation.
- **Suppression:** Removes sensitive data fields to prevent disclosure of identifying data.
- **Perturbation:** Perturbation slightly changes data to avoid exact identification while maintaining statistical integrity.

Every technique provides varied levels of protection and data utility, and in many circumstances, as an instance, the Health Insurance Portability and Accountability Act (HIPAA) offers instructions on how to de-identify protected health information, highlighting the significance of eliminating or altering personal identifiers to protect patient privacy.

1.2. Legal, ethical, and regulatory considerations in patient data anonymisation

Healthcare data anonymisation is subject to stringent legal and ethical restrictions, both in the UK and abroad . The key regulations and requirements include:

UK Regulations Overview.

- The Data Protection Act of 2018 implements GDPR requirements and includes provisions for processing health-related data.
- The UK GDPR enforces concepts such as data minimisation, purpose limitation, and storage limitation.
- Common Law Duty of Confidentiality (CLDC): Ensures that patient information is kept confidential and only released with consent or legal justification.

- The NHS Digital Code of Practice on Confidential Information establishes best practices for handling and anonymising patient data.
- The Health and Social Care (Safety and Quality) Act 2015 governs secure patient data sharing.

Universal Standards Overview

- GDPR (EU): Individual health data must be anonymised when processed.
- HIPAA (USA): Requires de-identification of PHI for patient privacy compliance.
- ISO/IEC 27701: Guidance for handling protected health information (PHI).
- The OECD Privacy Guidelines: Provide internationally accepted guidelines for data protection and anonymisation.

Concerns Regarding Ethics

- Patient Consent: Guarantee that individuals are aware of how their personal information will be anonymised and utilised.
- Transparency: Entails clearly expressing the goal and extent of anonymisation procedures.
- Security & Risk Mitigation: Implementing strong precautions to prevent re-identification attacks and data breaches.
- Equity and Fairness: Determining that anonymised data is representative and does not add biases into analytics in healthcare.

1.3.Cloud computing applications to anonymise data in healthcare sector

The expanding digitisation of healthcare records, as well as the increasing usage of patient data for research, artificial intelligence (AI) training, and analytics, necessitate effective data anonymisation solutions to maintain privacy and legal compliance. Given the sensitivity of healthcare data, poor treatment might result in unauthorised access or re-identification, creating serious privacy concerns. To address these issues, several anonymisation techniques are used to protect patient information while keeping data useful for research and medical developments. Typical methods include pseudonymization, which substitutes pseudonyms for direct identifiers to enable data correlation without disclosing true identities; generalisation, which lowers data granularity by classifying values into more general categories; and data masking, which substitutes

masked values for sensitive details. Furthermore, suppression completely removes extremely sensitive data fields, whereas perturbation subtly affects data by adding noise to numerical values, preventing exact identification but keeping statistical integrity. The anonymisation approach used is determined by the dataset, vulnerabilities, and intended application, and it is often necessary to use a variety of methods to achieve optimal security and compliance with standards such as GDPR, HIPAA, and ISO/IEC 20889: 2018. Using efficient anonymisation techniques is essential to striking a balance between privacy protection and the requirement for insightful medical research, since healthcare data continues to be essential to technological breakthroughs. (MettyPaula,LeandrosMaglarasb,c,∗,MohamedAmineFerragd,ImanAlmomani, 2023).

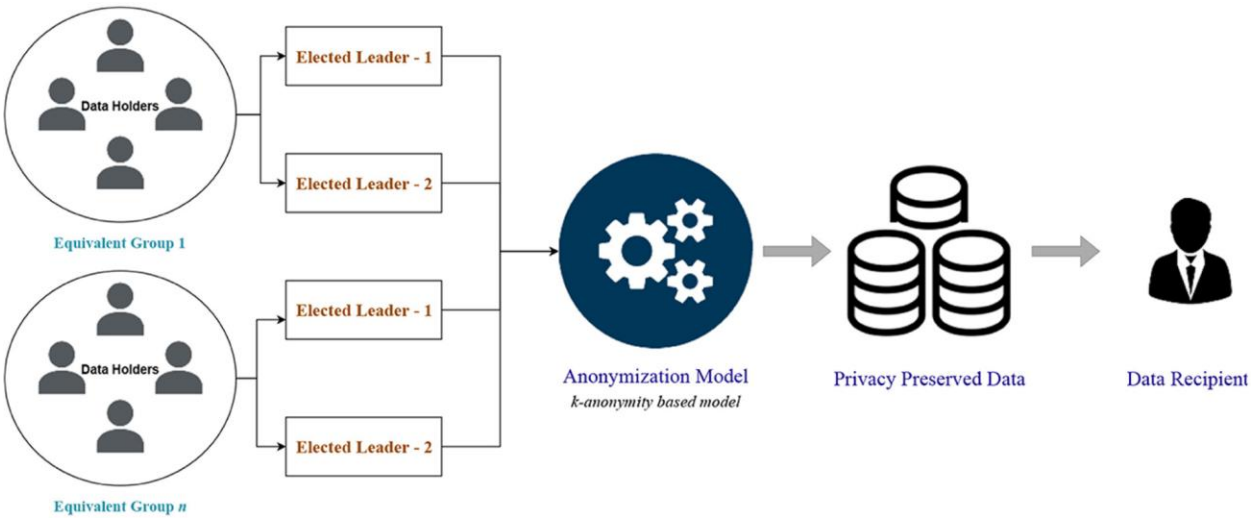


Figure 1- Privacy-preserving data collecting protocol architecture. (J. Andrew1, R. Jennifer Eunice2 and J. Karthikeyan3, 2023)

2. Data Anonymisation Techniques and Algorithms review

Data anonymisation strategies, notably in healthcare, seek to strike a compromise between privacy and data utility. Since Healthcare data involves highly confidential data, and without effective anonymisation, there is a risk of unauthorised access or re-identification, which could lead to privacy violations. Anonymisation strategies are critical in protecting patient information while preserving data usability and integrity for research and medical improvement (Olga Vovk, Gunnar Piho, Peeter Ross, 2023).

2.1. Advanced data anonymization techniques use in healthcare.

Key strategies include data masking and tokenisation, hybrid approaches, k-anonymity, l-diversity, t-closeness, and differential privacy. K-anonymity assures that records are indistinguishable, whereas l-diversity prohibits attribute disclosure. T-closeness guarantees distribution similarity, whereas differential privacy introduces noise to protect against linkage attacks. Hybrid approaches utilise several techniques to improve security while maintaining data utility.

2.1.1. k-Anonymity

Assures that each anonymised information cannot be distinguished from at least k-1 other entries in the dataset. The goal is to limit the risk of re-identification through generality and suppression. Vulnerable to background information attacks and disclosing attributes (-, 2025).

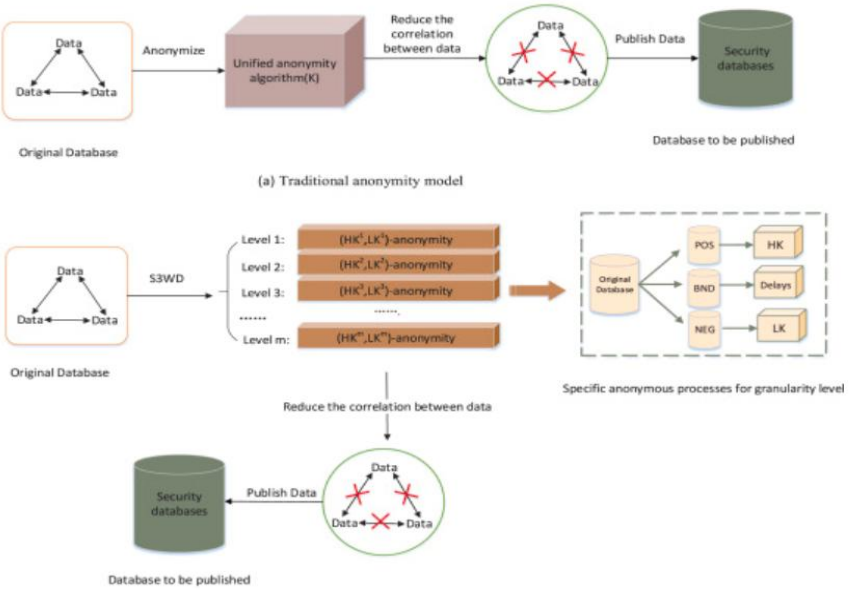


Figure 2- Multi level Key anonymisation model - (Jin Qiana, Haoying Jianga, Ying Yua, Hui Wanga, Duoqian Miao, 2023)

2.1.2. l-Diversity

Improves l-diversity by ensuring that the overall distribution of sensitive traits across every anonymised group is statistically similar to the entire dataset. Measures distribution similarity using Earth Mover's Distance (EMD). (-, 2025)

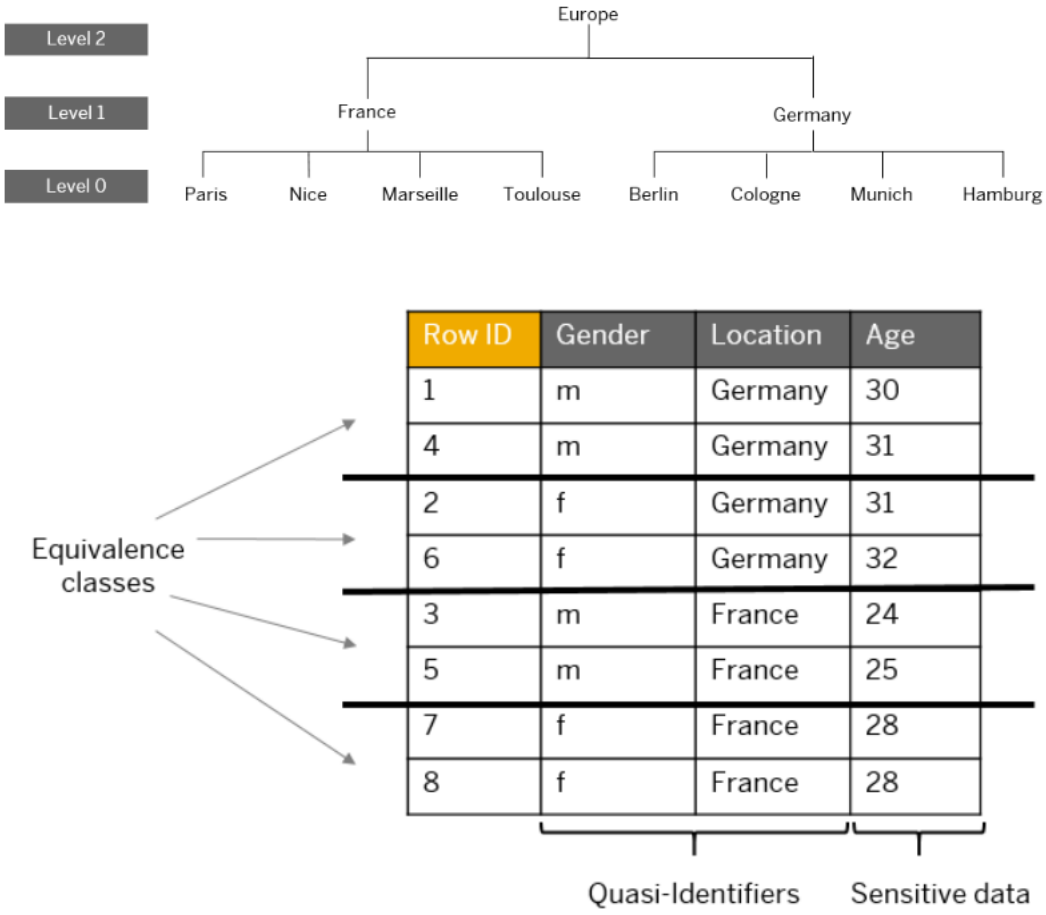
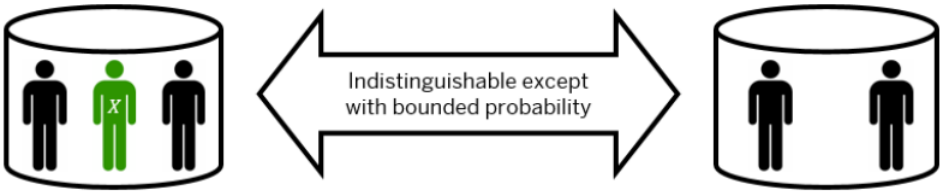


Figure 3- anonymisation doe the different equal classes. - (-, 2025)

2.1.3. Differential Privacy

Commonly used for real-time information anonymisation, especially in cloud computing and healthcare applications. Replaces the original information with synthetic or obfuscated dataset while retaining the data format and structure. Numerical data in statistics databases is usually anonymised using the differentially private approach (-, 2025).



$$\frac{\Pr[San(DB \cup \{X\}) = y]}{\Pr[San(DB \backslash \{X\}) = y]} \leq e^{\epsilon} \approx 1 \pm \epsilon$$

Figure 4- Graphical definition of the Differential Privacy- (-, 2025)

2.1.4. t-Closeness

By incorporating calibrated noise into dataset queries, mathematically verifiable privacy assurances are achieved. Widely utilised in large-scale analysis of data, artificial intelligence models, and privacy-preserving machine learning.

2.1.5. Data Masking and Tokenisation

Combining several strategies can improve security while maintaining data utility. Machine learning and AI-based anonymisation techniques have been developing for real-time privacy protection.

2.1.6. Hybrid Approaches and Emerging Techniques

Hybrid approaches and emerging strategies can improve confidentiality while maintaining data utility. Machine learning and AI-based anonymisation techniques are emerging for real-time privacy protection.

2.2. Advanced data anonymization algorithms vs Common Anonymisation Techniques

Advanced privacy-preserving models rely significantly on fundamental data anonymisation techniques to strike a balance between data value and secrecy. Data masking is a technique used in Electronic Health Records (EHR) to keep patient information anonymous (Olga Vovk, Gunnar Piho, Peeter Ross, 2023). Tokenisation extends this by substituting sensitive data with tokens that can only be mapped back when required. Generalisation translates specific values into larger categories, hence enabling k-anonymity and differential privacy. Pseudonymisation exchanges direct identifiers with unique codes, allowing data relating while protecting critical identifiers. Supression removes information components that are at a significant risk of re-identification,

resulting in k-anonymity when generalisation alone is insufficient. Perturbation provides controlled noise that avoids exact identification while keeping the information's statistical characteristics. It provides the foundation of differential privacy and is used in t-closeness to ensure that the breakdown of sensitive values across anonymised groups is comparable to the overall collection.

Table 1- Based anonymisation techniques and advanced anonymisation techniques.

Base Technique	Supports	Example Use in Advanced Models
Data Masking	Tokenisation, Differential Privacy	Replace patient names with believable fake ones.
Generalisation	k-Anonymity, l-Diversity, t-Closeness	Switching DOB to Age Group
Pseudonymisation	Tokenisation, Data Linkage	Replace names with consistent pseudonyms.
Suppression	k-Anonymity, l-Diversity	Deleting uncommon disease characteristics
Perturbation	Differential Privacy, t-Closeness	Introducing Noise to Health Statistics

2.2.1. Legal, Ethical, and Regulatory Challenges related to the advanced data anonymization techniques in healthcare

Table 2- Comparison of the data anonymisation techniques

Technique	Legal Compliance	Ethical Concerns	Regulatory Challenges
k-Anonymity	Partially GDPR-compliant but vulnerable.	May not fully prevent re-identification	Insufficient HIPAA protection.
l-Diversity	Supports data minimisation.	Can distort datasets.	Addresses k-anonymity flaws. however, susceptible to skewness attacks.
t-Closeness	Meets anonymisation requirements.	May introduce artificial biases.	Computational complexity limits practical use.
Differential Privacy	Strong GDPR and NIST compliance	Impacts ethical decision-making.	Implementation complexity limits adoption.
Data Masking & Tokenisation	PCI DSS & HIPAA compliant	Potential indirect re-identification.	Effectiveness depends on masking strength.

3. Application Solution: Cloud based application design

3.1. Application assumptions and study

According to the provided case and the patient data set, here to maintain the data privacy and the security, should apply data anonymization techniques to mask the data and expected to mask the real confidential data with the key and generate a mapping document to handle the original data set. The approach involves replacing confidential data in the original text with special keys, such as 1.1, to produce two distinct outputs:

- an anonymised document containing only these masked keys
- a separate mapping document that securely stores the original values paired with their corresponding keys.

This approach relies mostly on the basic data anonymization technique call **data masking** and **pseudonymisation** techniques. Data masking is demonstrated by replacing real, identifiable values with structured placeholders that retain the format of the original content. Meanwhile, pseudonymisation is indicated by the process's reversibility—because anonymised data may be linked back to its original form using the mapping document, which serves as a regulated, reversible link between the masked and original data.

Uniform Data Format is particularly assumed that names, dates of birth, addresses, and other identifying information will be formatted uniformly in patient records by program. Variations from the intended format may not adequately anonymise data. It is anticipated that the patient notes will be structured in a way that allows for the anonymisation of necessary data and the predictable matching of regular expressions. Errors may be present in writing that is incredibly chaotic or disorganised.

Patient Name, Address, and Age are considered confidential in healthcare applications since they are classified as Personally Identifiable Information (PII) or Protected Health Information (PHI). Here's why each of these data components is sensitive and must be anonymised.

Furthermore, patient’s name directly identifies them. Addresses can help narrow down a person's location and, when paired with additional information, may lead to re-identification. While age

alone may appear innocuous, it can become identifiable when paired with unusual medical disorders or other quasi-identifiers.

The design assumes a limited range of identifying information categories, such as names, addresses, and dates of birth, based on the sample that was provided. Anonymisation may not be applied to sensitive data that does not fit within these categories. Language & Locale program likely assumes that patient records are in English and may adhere to regional customs that aren't always suitable.

Rather than above assumptions following considerations also took a place in the application development, regulatory compliance related to the UK government and healthcare sector and ability to scale and efficiency of application must be capable of processing large amounts of data rapidly and effectively. This includes handling large files and improving the speed of regular expressions. Strong error handling and logging processes are necessary to address unusual data formats, processing errors, or pattern mismatches that may lead to partial or erroneous anonymisation. Security involves reading, anonymising, and writing data in a safe manner. It also protects against unauthorised access to original and anonymised data during and after processing.

3.2. Developed Application Solution

3.2.1. Regex patterns and matchers

Person Name Identification regex code

```
// Full name
"(Mr\\.|Mrs\\.|Ms\\.|Miss|Dr\\.|Prof\\.|Master|Rev\\.|Fr\\.|Sr\\.|Smt\\.|Mx\\.|Lady|Sir|Capt\\.|Major|Col\\.|Lt\\.|Hon\\.|Judge)\\s+([A-Z][a-z]+)\\s+([A-Z][a-z]+)|" +
// Title + first name
"(Mr\\.|Mrs\\.|Ms\\.|Miss|Dr\\.|Prof\\.|Master|Rev\\.|Fr\\.|Sr\\.|Smt\\.|Mx\\.|Lady|Sir|Capt\\.|Major|Col\\.|Lt\\.|Hon\\.|Judge)\\s+([A-Z][a-z]+)|" +
```

Figure 5- Name identification regex

(Mr\\.|Mrs\\.|Ms\\.|Miss|Dr\\.|Prof\\.|Master|Rev\\.|Fr\\.|Sr\\.|Smt\\.|Mx\\.|Lady|Sir|Capt\\.|Major|Col\\.|Lt\\.|Hon\\.|Judge) captures common English titles, ensuring that the regex identifies the beginning of a patient's name reliably.

\\s+ matches one or more spaces, ensuring that the title and the names are separated by whitespace.

([A-Z][a-z]+) captures a capitalized word, assuming that both first and last names start with a capital letter followed by lowercase letters, typical for proper names in English.

```
    }
} else if (matcher.group(4) != null) { // Title + First Name only
    String title = matcher.group(4);
    String firstName = matcher.group(5);
    String shortName = title + " " + firstName;

    if (nameToKeyMap.containsKey(shortName)) {
        replacement = nameToKeyMap.get(shortName);
    } else {
        replacement = patientCounter + "." + infoCounter;
        nameToKeyMap.put(shortName, replacement);
        nameToKeyMap.put(firstName, replacement);
        if (!usedReplacements.contains(replacement)) {
            mappingLines.add(replacement + "\t" + shortName);
            usedReplacements.add(replacement);
            infoCounter++;
        }
```

Figure 6- name mapping and anonymisation

Person Age Identification regex code

```
// Age
"(\\d+)-year-old|aged\\s+(\\d+)|" +
```

Figure 7- Age identification regex

(\\d+) captures one or more digits, representing the age of the patient.

-year-old| aged matches the literal string, a common way to describe age in medical records.

```
} else if (matcher.group(6) != null || matcher.group(7) != null) { // Age
    String age = matcher.group(6) != null ? matcher.group(6) : matcher.group(7);
    String key = patientCounter + "." + infoCounter ;
    String originalAgeText = matcher.group(6) != null ? age + "-year-old" : "aged " + age;
    if (!usedReplacements.contains(key)) {
        mappingLines.add(key + "\t" + originalAgeText);
        usedReplacements.add(key);
    }
    replacement = key;
    infoCounter++;
```

Figure 8- Age mapping and anonymisation

Person Address Identification regex code

```
// Address
"(at\\s+|in\\s+|of\\s+|residing\\s+|resident of\\s+|living at\\s+|residing in\\s+|residing at\\s+|chilling at\\s+)" +
"((\\d+\\s)?[A-Za-z0-9.]+\\s)*(Street|Avenue|Road|Lane|Drive|Boulevard|Terrace|Court),\\s+[A-Za-z\\s]+,\\s+[A-Z]{2}|[A-Za-z\\s]+,\\s+[A-Z]{2})|" +
```

Figure 9- Address identification regex pattern

(at\\s+|in\\s+|of\\s+|residing\\s+|resident of\\s+|living at\\s+|residing in\\s+|residing at\\s+|chilling at) captures various prepositions and phrases that typically precede an address in narrative text.

(((\\d+\\s)?[A-Za-z0-9.]+\\s) captures the street number optionally, followed by the street name which can include letters, digits, and periods.

(Street|Avenue|Road|Lane|Drive|Boulevard|Terrace|Court) captures common street types.

```
} else if (matcher.group(8) != null) { // Address
    String key = matcher.group(8) + patientCounter + "." + infoCounter;
    String address = matcher.group(9).trim();
    if (!usedReplacements.contains(key)) {
        mappingLines.add(patientCounter + "." + infoCounter + "\t" + address);
        usedReplacements.add(key);
    }
    replacement = key;
    infoCounter++;
```

Figure 10- Address mapping and anonymisation

Person Date of Birth Identification regex code

```
// DOB
"(\\b\\d{1,2}(st|nd|rd|th)?\\s+(January|February|March|April|May|June|July|August|September|October|November|December),?\\s+\\d{4}\\b)|" +
"(\\b(January|February|March|April|May|June|July|August|September|October|November|December)\\s+\\d{1,2}(st|nd|rd|th)?,?\\s+\\d{4}\\b)"
```

Figure 11- Date of Birth identification regex

(\\b\\d{1,2}(st|nd|rd|th)?\\s+(January|February|March|April|May|June|July|August|September|October|November|December),?\\s+\\d{4}\\b) captures various prepositions and phrases that typically precede an DOB in narrative text, date, month.

```
} else if (matcher.group(15) != null || matcher.group(19) != null) { // DOB
    String dob = matcher.group(); // full match
    String key = patientCounter + "." + infoCounter ;
    if (!usedReplacements.contains(key)) {
        mappingLines.add(key + "\t" + dob);
        usedReplacements.add(key);
    }
    replacement = key;
    infoCounter++;
```

Figure 12- Bate of Birth Mapping and anonymisation

3.2.2. Implemented java code

```
4. import java.io.IOException;
5. import java.nio.charset.StandardCharsets;
6. import java.nio.file.Files;
7. import java.nio.file.Paths;
8. import java.util.*;
9. import java.util.regex.Matcher;
10.import java.util.regex.Pattern;
11.
12.class AnonymisePatientData {
13.
14.    public static void main(String[] args) {
15.        String inputFilePath = "PatientNotes.txt";
16.        String anonymizedFile = "AnonymisedMedicalNotes.txt";
17.        String mappingFile = "MappingDocument.txt";
18.
19.        try {
20.            List<String> lines = Files.readAllLines(Paths.get(inputFilePath),
   StandardCharsets.UTF_8);
21.            List<String> anonymizedLines = new ArrayList<>();
22.            Set<String> usedReplacements = new HashSet<>();
23.            Map<String, String> nameToKeyMap = new HashMap<>();
24.            List<String> mappingLines = new ArrayList<>();
25.            int patientCounter = 1;
26.
27.            Pattern pattern = Pattern.compile(
28.                    // Full name
29.                    "(Mr\\.|Mrs\\.|Ms\\.|Miss|Dr\\.|Prof\\.|Master|Rev\\.|Fr\
   \.|Sr\\.|Smt\\.|Mx\\.|Lady|Sir|Capt\\.|Major|Col\\.|Lt\\.|Hon\\.|Judge)\\s+([
   A-Z][a-z]+)\\s+([A-Z][a-z]+)|" +
30.                    // Title + first name
31.                    "(Mr\\.|Mrs\\.|Ms\\.|Miss|Dr\\.|Prof\\.|Master|Rev\\.|Fr\
   \.|Sr\\.|Smt\\.|Mx\\.|Lady|Sir|Capt\\.|Major|Col\\.|Lt\\.|Hon\\.|Judge)\\s+([
   A-Z][a-z]+)|" +
32.                    // Age
33.                    "(\\d+)-year-old|aged\\s+(\\d+)|" +
34.                    // Address
35.                    "(at\\s+|in\\s+|of\\s+|residing\\s+|resident
   of\\s+|living at\\s+|residing in\\s+|residing at\\s+|chilling at\\s+)" +
36.                    "((((\\d+\\s)?[A-Za-z0-
   9.]+\\s)*(Street|Avenue|Road|Lane|Drive|Boulevard|Terrace|Court),\\s+[A-Za-
   z\\s]+,\\s+[A-Z]{2}|[A-Za-z\\s]+,\\s+[A-Z]{2})|" +
37.                    // DOB
```

```
                    "(\\b\\d{1,2}(st|nd|rd|th)?\\s+(January|February|March|April|May|June|July|August|September|October|November|December),?\\s+\\d{4}\\b)|" +
                    "(\\b(January|February|March|April|May|June|July|August|September|October|November|December)\\s+\\d{1,2}(st|nd|rd|th)?,?\\s+\\d{4}\\b)"
            );

            for (String line : lines) {
                Matcher matcher = pattern.matcher(line);
                StringBuffer sb = new StringBuffer();
                int infoCounter = 1;

                while (matcher.find()) {
                    String replacement = "";

                    if (matcher.group(1) != null) { // Full name
                        String title = matcher.group(1);
                        String firstName = matcher.group(2);
                        String lastName = matcher.group(3);
                        String fullName = title + " " + firstName + " " + lastName;

                        if (nameToKeyMap.containsKey(fullName)) {
                            replacement = nameToKeyMap.get(fullName);
                        } else {
                            replacement = patientCounter + "." + infoCounter;
                            nameToKeyMap.put(fullName, replacement);
                            nameToKeyMap.put(title + " " + firstName, replacement);
                            nameToKeyMap.put(firstName + " " + lastName, replacement);
                            nameToKeyMap.put(firstName, replacement);
                            nameToKeyMap.put(lastName, replacement);
                            if (!usedReplacements.contains(replacement)) {
                                mappingLines.add(replacement + "\t" + fullName);
                                usedReplacements.add(replacement);
                                infoCounter++;
                            }
                        }
                    } else if (matcher.group(4) != null) { // Title + First Name only
                        String title = matcher.group(4);
                        String firstName = matcher.group(5);
```

```
74.                         String shortName = title + " " + firstName;
75.
76.                         if (nameToKeyMap.containsKey(shortName)) {
77.                             replacement = nameToKeyMap.get(shortName);
78.                         } else {
79.                             replacement = patientCounter + "." + infoCounter;
80.                             nameToKeyMap.put(shortName, replacement);
81.                             nameToKeyMap.put(firstName, replacement);
82.                             if (!usedReplacements.contains(replacement)) {
83.                                 mappingLines.add(replacement + "\t" +
    shortName);
84.                                 usedReplacements.add(replacement);
85.                                 infoCounter++;
86.                             }
87.                         }
88.                     } else if (matcher.group(6) != null || matcher.group(7)
    != null) { // Age
89.                         String age = matcher.group(6) != null ?
    matcher.group(6) : matcher.group(7);
90.                         String key = patientCounter + "." + infoCounter ;
91.                         String originalAgeText = matcher.group(6) != null ?
    age + "-year-old" : "aged " + age;
92.                         if (!usedReplacements.contains(key)) {
93.                             mappingLines.add(key + "\t" + originalAgeText);
94.                             usedReplacements.add(key);
95.                         }
96.                         replacement = key;
97.                         infoCounter++;
98.                     } else if (matcher.group(8) != null) { // Address
99.                         String key = matcher.group(8) + patientCounter + "."
    + infoCounter;
100.                        String address = matcher.group(9).trim();
101.                        if (!usedReplacements.contains(key)) {
102.                            mappingLines.add(patientCounter + "." +
    infoCounter + "\t" + address);
103.                            usedReplacements.add(key);
104.                        }
105.                        replacement = key;
106.                        infoCounter++;
107.                    } else if (matcher.group(15) != null ||
    matcher.group(19) != null) { // DOB
108.                        String dob = matcher.group(); // full match
109.                        String key = patientCounter + "." + infoCounter ;
110.                        if (!usedReplacements.contains(key)) {
111.                            mappingLines.add(key + "\t" + dob);
```

```
                                usedReplacements.add(key);
                            }
                            replacement = key;
                            infoCounter++;
                        }

                        matcher.appendReplacement(sb, replacement);
                    }

                    matcher.appendTail(sb);

                    // Replace any remaining standalone name parts with their mapped keys
                    String anonymizedText = sb.toString();
                    for (Map.Entry<String, String> entry : nameToKeyMap.entrySet()) {
                        anonymizedText = anonymizedText.replaceAll("\\b" + Pattern.quote(entry.getKey()) + "\\b", entry.getValue());
                    }

                    anonymizedLines.add(anonymizedText);
                    patientCounter++;
                }

                Files.write(Paths.get(anonymizedFile), anonymizedLines, StandardCharsets.UTF_8);
                Files.write(Paths.get(mappingFile), mappingLines, StandardCharsets.UTF_8);

                System.out.println("Patient-Data File anonymization completed successfully! and Mapping document created. ");
            } catch (IOException e) {
                System.err.println("Currnt Code has Read/write Error: " + e.getMessage());
                e.printStackTrace();
            }
        }
    }

```

3.2.3 Could Integration of the Application

Create VM or use the available VM in the Azure portal and connect the machine in SSH CLI,

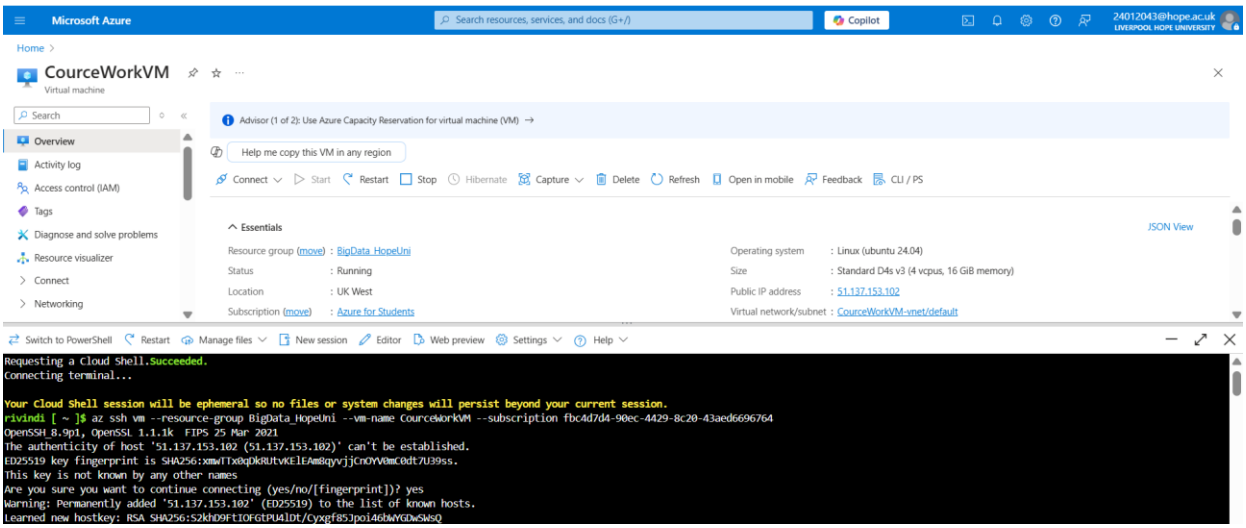


Figure 13- Course work Virtual Machine in azure

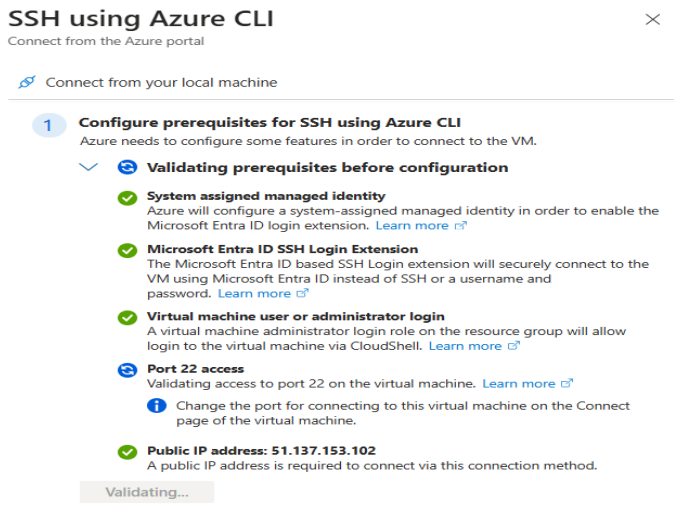


Figure 14- Start and connect the Machine

Install java and check the version of the java to allow VM to work in a java-based coding environment. Create the java file for the patient map java anonymization and copy the patient data file to the VM.

```
$ whoami
24012043@hope.ac.uk
$ scp "D:\$ MSc In Advanced Computer Science\Semester I\Big Data and Cloud Computing\Course Work 01\PatientNotes.txt" 24012043@51.137.153.102:/home/24012043/
```

Figure 15- Copy the patient data file to the cloud

```
$ java -version
openjdk version "11.0.26" 2025-01-21
OpenJDK Runtime Environment (build 11.0.26+4-post-Ubuntu-1ubuntu124.04)
OpenJDK 64-Bit Server VM (build 11.0.26+4-post-Ubuntu-1ubuntu124.04, mixed mode, sharing)
$ vi UpdatePatientMap1.java
```

Figure 16- check the java version and Create the UpdatePatientMap1.java file in the VM.

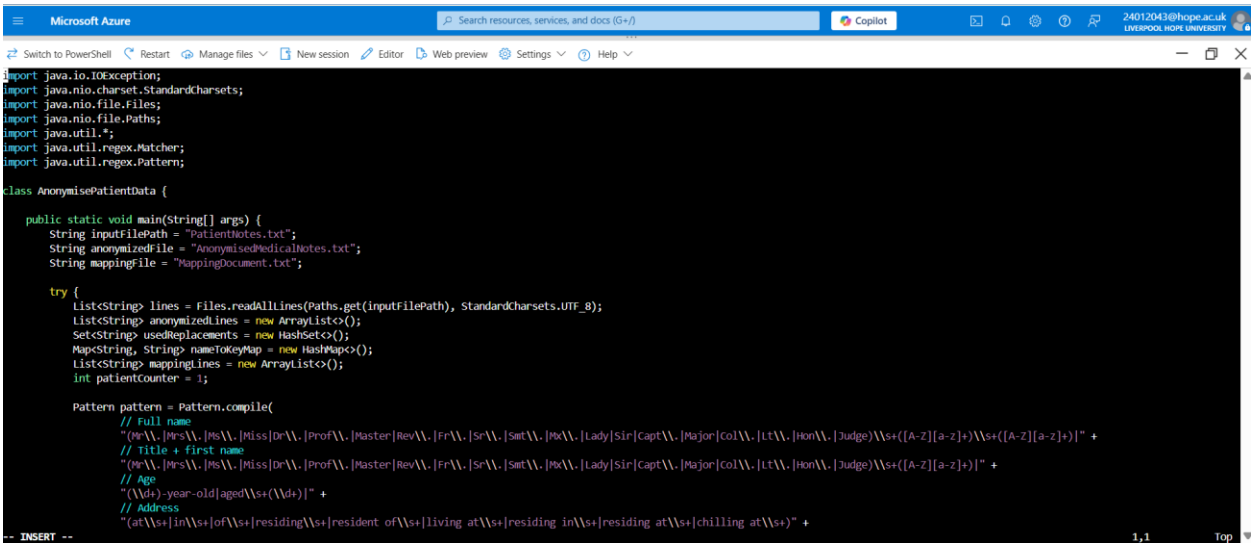


Figure 17-Write java code

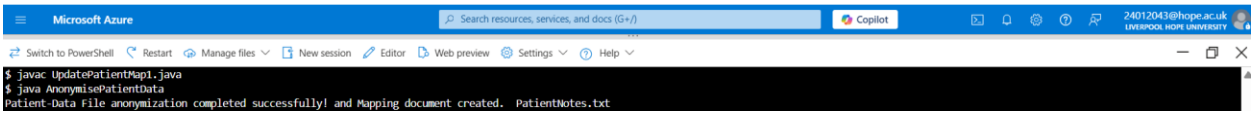


Figure 18- run the file to generate anonymised document and mapping document

3.2.4 Testing of the Codes

Software testing is a crucial procedure that assesses a system or software application to see whether it satisfies its specifications and operates as intended. Here developed and evaluated a thorough set of test cases to guarantee the patient data anonymisation system's accuracy and resilience. These test cases focus on particular system elements such date of birth (DOB) identification, address masking, age recognition, and name detection. Every test is intended to confirm that private data is appropriately anonymised using distinct keys and entered into the mapping document. The tests cases illustrate that the system can identify different PII formats, prevent duplicate key generation for names that appear more than once, and preserve consistency between mapping logs and anonymised data files.

Table 3- test cases of the development

Test ID	Name	Input	Expected anonymized output	Expected mapping document output	Pass/Fail Status
T001	Person full Name	Ms. Sarah Evans, a 55-year-old female resident of 321 Elm Street, Chicago, IL.	1.1, a 55-year-old female resident of 321 Elm Street, Chicago, IL.	1.1 Ms. Sarah Evans	Pass
T002	Person name (repeat)	Sarah, a former smoker of 15 years.	1.1, a former smoker of 15 years	No new key generation and use same key of 1.1.	Pass
T003	Age (year-old)	Ms. Sarah Evans, a 55-year-old female resident of 321 Elm Street, Chicago, IL.	Ms. Sarah Evans, a 1.2 female resident of 321 Elm Street, Chicago, IL.	1.2 55-year-old	Pass
T004	Age (aged)	Mr. Alen Maxwell, aged 60, living at 321 Oak Avenue, New York, NY.	Mr. Alen Maxwell, 18.2, living at 321 Oak Avenue, New York, NY	18.2 aged 60	Pass
T005	Address (living)	Mr. Alen Maxwell, 18.2, living at 321 Oak Avenue, New York, NY.	Mr. Alen Maxwell, 18.2, living at 18.3.	18.3 321 Oak Avenue, New York, NY	Pass
T006	Date of Birth	Prof. Kaushi Evans, a 55-year-old born in 22nd April 1997.	Prof. Kaushi Evans, a 55-year-old born in 21.3.	21.3 22nd April 1997	Pass
T007	Mixed entities	Prof. Kaushi Evans, a 55-year-old born in 22nd April 1997.	21.1, a 21.2 born in 21.3.	21.1 Prof. Kaushi Evans 21.2 55-year-old 21.3 22nd April 1997	Pass

1.1, a 1.2 female resident of 1.3, presented with mild chest discomfort and occasional shortness of breath during exertion. She has been adhering to a daily dose of amlodipine (5mg) for hypertension management since 2012, with no significant cardiac history. 1.1, a former smoker of 15 years, now limits herself to occasional social smoking and moderate alcohol consumption. Family history indicates a prevalence of hypertension and cardiovascular diseases, particularly on the maternal side. Recommendations for further evaluation, including ECG and stress test, were made, along with lifestyle modifications to enhance cardiovascular health.
During the consultation, 2.1, a 2.2 resident of 2.3, presented with mild chest discomfort and occasional shortness of breath during physical activity. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2015, with no reported cardiac anomalies or major surgeries. 2.1's 30-year smoking history and moderate alcohol consumption pose significant risks to his cardiovascular health. Given the family history of hypertension and cardiovascular diseases, urgent intervention is required to mitigate potential complications. Diagnostic tests such as ECG and stress test, along with lifestyle modifications emphasizing smoking cessation and dietary changes, are imperative for 2.1's well-being.
3.1, a 3.2 man residing 3.3, arrived with complaints of occasional chest pain and shortness of breath, especially during physical exertion. He has diligently followed a daily regimen of amlodipine (5mg) since 2009 for hypertension control, with no known cardiac abnormalities or significant surgical history. 3.1, a former smoker for 20 years, now limits himself to occasional social smoking and moderate alcohol consumption. Family history indicates a hereditary predisposition to hypertension and cardiovascular ailments, with multiple cases of heart disease in both parents. Further diagnostic tests, including ECG and stress test, were recommended alongside lifestyle adjustments to optimize cardiovascular health.
4.1 conducted an assessment on 4.2, a 4.3 woman residing 4.4, who reported mild chest discomfort and occasional shortness of breath during physical activity. 4.2 has been on a daily regimen of amlodipine (5mg) since 2005 for hypertension management. A former smoker of 15 years, 4.2 now indulges in occasional social drinking. Family history shows a prevalence of hypertension and cardiovascular diseases, particularly in her maternal side. Recommendations for further evaluation, including ECG and stress test, were made alongside lifestyle modifications to improve overall cardiovascular health.
At the consultation, 5.1, a 5.2 gentleman chilling at 5.3, swung by today with some chest pain and shortness of breath when he's hustling. Been poppin' amlodipine (5mg) since '13 to keep his blood pressure in check, you know? 5.1 has been puffin' the ciggies for about 10 years and sippin' on some beers now and then, nothing too crazy. Fam history's got some high blood pressure and heart stuff, especially on his dad's side. Gonna run some tests like ECG and stress test and dish out some tips on kickin' the cigs and livin' healthier, ya feel?
During the consultation, 6.1, a 6.2 gentleman residing 6.3, reported mild chest discomfort and occasional shortness of breath during physical exertion. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2010, with no reported cardiac anomalies or major surgeries. 6.4 has a 10-year history of smoking and occasional alcohol consumption within recommended limits. Family history reveals hypertension and cardiovascular diseases, including myocardial infarction in his paternal grandfather. Further evaluation, including ECG and stress test, is advised, along with recommendations for smoking cessation and lifestyle modifications.
7.1, a 7.2 gentleman residing 7.3, presented with mild chest pain and occasional shortness of breath during physical exertion. He has a history of hypertension managed with amlodipine (5mg) daily since 2008, with no known cardiac abnormalities or major surgeries. No cardiac abnormalities or major surgeries were reported. 7.4 has a 20-year history of smoking and occasional alcohol consumption within recommended limits. Family history indicates a hereditary predisposition to hypertension and cardiovascular diseases, with a paternal grandfather having a history of myocardial infarction. Further evaluation, including ECG and cardiac stress test, is recommended, alongside lifestyle modifications and smoking cessation counseling.
4.2, a 8.1 woman residing 8.2, arrived with complaints of mild chest pain and occasional shortness of breath during physical activity. She has been managing hypertension with a daily dose of amlodipine (5mg) since 2005. 4.2, a former smoker of 15 years, now indulges in occasional social drinking. Family history shows a prevalence of hypertension and cardiovascular diseases, particularly on her maternal side. Recommendations for further evaluation, including ECG and stress test, were made alongside lifestyle modifications to improve overall cardiovascular health.

Figure 19- Anonymised patient Data file-tested- ***(Test case 1,2,3)***

daily regimen of amlodipine (5mg) since 2009 for hypertension control. 3.1, a former smoker for 20 years, now limits himself to occasional social smoking and moderate alcohol consumption. Family history indicates a hereditary predisposition to hypertension and cardiovascular ailments, with multiple cases of heart disease in both parents. Further diagnostic tests, including ECG and stress test, were recommended alongside lifestyle adjustments to optimize cardiovascular health.
11.1, 11.2, residing 11.3, visited the clinic with complaints of mild chest discomfort and occasional shortness of breath during physical activity. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2010. 11.1 has a history of smoking for 10 years and occasional alcohol consumption. Family history indicates a predisposition to hypertension and cardiovascular diseases. Further evaluation, including ECG and stress test, is recommended alongside lifestyle modifications.
12.1, a 12.2 entrepreneur, residing 12.3, presented with mild chest pain and occasional shortness of breath during physical exertion. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2012. 12.1 has a history of occasional smoking and moderate alcohol consumption. Family history reveals a predisposition to hypertension and cardiovascular diseases. Further evaluation, including ECG and stress test, is advised alongside lifestyle adjustments.
13.1, 13.2, living at 13.3, reported mild chest discomfort and occasional shortness of breath during physical activity. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2005. 13.1, a former smoker for 20 years, now abstains from smoking and consumes alcohol occasionally. Family history indicates a predisposition to hypertension and cardiovascular diseases. Further evaluation, including ECG and stress test, is recommended along with lifestyle modifications.
14.1, a 14.2 individual, residing 14.3, arrived with complaints of occasional chest pain and shortness of breath, particularly during exertion. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2010. 14.1, a non-smoker, indulges in moderate alcohol consumption. Family history reveals a predisposition to hypertension and cardiovascular diseases. Further diagnostic tests, including ECG and stress test, were recommended alongside lifestyle adjustments.
15.1, a 15.2 resident of 15.3, presented with mild chest discomfort and occasional shortness of breath during physical activity. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2015. 15.4, a former smoker for 15 years, now abstains from smoking and consumes alcohol occasionally. Family history indicates a predisposition to hypertension and cardiovascular diseases. Further evaluation, including ECG and stress test, is advised alongside lifestyle modifications.
16.1, 16.2, residing 16.3, reported mild chest discomfort and occasional shortness of breath during physical exertion. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2008. 16.1, a former smoker for 30 years, now abstains from smoking and consumes alcohol occasionally. Family history reveals a predisposition to hypertension and cardiovascular diseases. Further evaluation, including ECG and stress test, is recommended alongside lifestyle modifications.
17.1Water, a 17.2 individual, residing 17.3, presented with mild chest pain and occasional shortness of breath during physical exertion. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2010. 17.1, a non-smoker, consumes alcohol occasionally. Family history reveals a predisposition to hypertension and cardiovascular diseases. Further diagnostic tests, including ECG and stress test, were recommended alongside lifestyle adjustments.
18.1, 18.2, living at 18.3, reported mild chest discomfort and occasional shortness of breath during physical activity. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2012. 18.1, a former smoker for 20 years, now abstains from smoking and consumes alcohol occasionally. Family history indicates a predisposition to hypertension and cardiovascular diseases. Further evaluation, including ECG and stress test, is advised alongside lifestyle modifications.
19.1, a 19.2 resident of 19.3, arrived with complaints of occasional chest pain and shortness of breath, especially during physical exertion. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2009. 19.1, a former smoker for 10 years, now abstains from smoking and consumes alcohol occasionally. Family history reveals a predisposition to hypertension and cardiovascular diseases. Further diagnostic tests, including ECG and stress test, were recommended alongside lifestyle adjustments.
20.1, a 20.2 individual, residing 20.3, presented with mild chest discomfort and occasional shortness of breath during physical activity. She has been managing hypertension with a daily dose of amlodipine (5mg) since 2015. 20.1, a non-smoker, indulges in moderate alcohol consumption. Family history indicates a predisposition to hypertension and cardiovascular diseases. Further evaluation, including ECG and stress test, is advised alongside lifestyle modifications.
21.1, a 21.2 born in 21.3, presented with mild chest discomfort and occasional shortness of breath during exertion.

*Figure 20- Anonymised patient data tested output with new data (Last row) – (**Test case 4,5,6,7**)*

```
1.1     Ms. Sarah Evans
1.2     55-year-old
1.3     321 Elm Street, Chicago, IL
2.1     Mr. William Turner
2.2     65-year-old
2.3     654 Birch Street, Boston, MA
3.1     Mr. Michael Rodriguez
3.2     50-year-old
3.3     at 987 Cedar Lane, Houston, TX
4.1     Dr. Samantha Lee
4.2     Ms. Emily Johnson
4.3     60-year-old
4.4     at 789 Oak Avenue, Los Angeles, CA
5.1     Mr. James Brown
5.2     35-year-old
5.3     456 Pine Street, Miami, FL
6.1     Mr. John Smith
6.2     45-year-old
6.3     at 123 Maple Street, New York, NY
6.4     Mr. Smith
7.1     Mr. Alex Max
7.2     59-year-old
7.3     at 55 Penny Lane, Liverpool, UK
7.4     Mr. Max
8.1     60-year-old
8.2     at 789 Oak Avenue, Los Angeles, CA
9.1     65-year-old
9.2     at 654 Birch Street, Boston, MA
10.1    50-year-old
10.2    at 987 Cedar Lane, Houston, TX
11.1    Mr. James Newton
11.2    aged 40
11.3    at 123 Oak Street, San Francisco, CA
12.1    Dr. Elon Musk
12.2    50-year-old
```

*Figure 21- Mapping Document -Tested-**(Test case 1,2,3)***

```
10.2    at 987 Cedar Lane, Houston, TX
11.1    Mr. James Newton
11.2    aged 40
11.3    at 123 Oak Street, San Francisco, CA
12.1    Dr. Elon Musk
12.2    50-year-old
12.3    in Los Angeles, CA
13.1    Mr. Mark Ford
13.2    aged 60
13.3    456 Maple Avenue, Seattle, WA
14.1    Mr. Yun Ng
14.2    55-year-old
14.3    at 789 Pine Road, Chicago, IL
15.1    Mr. Ahmed Radi
15.2    45-year-old
15.3    321 Elm Street, Miami, FL
15.4    Dr. Ahmed
16.1    Mr. John Forst
16.2    aged 70
16.3    at 987 Cedar Lane, Dallas, TX
17.1    Mr. Joe Drinking
17.2    55-year-old
17.3    at 55 Penny Lane, Liverpool, UK
18.1    Mr. Alen Maxwell
18.2    aged 60
18.3    321 Oak Avenue, New York, NY
19.1    Dr. Jule Smith
19.2    50-year-old
19.3    654 Maple Street, San Francisco, CA
20.1    Mrs. Barba Well
20.2    65-year-old
20.3    at 789 Pine Road, Los Angeles, CA
21.1    Prof. Kaushi Evans
21.2    55-year-old
21.3    22nd April 1997
```

*Figure 22- Mapping Document -Tested with new inputs, 21.1,21.2,21.3) (**Test case 4,5,6,7**)*

4. Conclusion

The case study and development of a cloud-based application for patient data anonymisation was examined in this case study, with an emphasis on protecting patient privacy in the healthcare industry while facilitating reliable and expandable data analysis. In addition to widely used techniques like masking, generalisation, suppression, and pseudonymization, the study discovered a number of well-established anonymisation strategies, including k-anonymity, l-diversity, t-closeness, and differential privacy. The ability of differential privacy to offer robust privacy assurances while maintaining analytical usefulness made it stand out among the others. Using these methodologies in a cloud environment (like AWS) guarantees great scalability, security, and compliance with data protection laws like the UK the General Data Protection Regulation and HIPAA, as the main results of the application design and testing process showed. The program can effectively process and anonymise big datasets while avoiding re-identification concerns and upholding compliance, according to performance and security studies.

In a nutshell the proposed cloud-based anonymisation application provides researchers and healthcare practitioners with a dependable and efficient way for dealing with confidential patient information. The solution facilitates safe data exchange, aids AI-based medical research, and advances privacy-preserving technologies in digital health by utilising cloud infrastructure and putting strong anonymisation algorithms into practice.

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5. Appendix

Input Patient data file for testing – "PatientNote"

Ms. Sarah Evans, a 55-year-old female resident of 321 Elm Street, Chicago, IL, presented with mild chest discomfort and occasional shortness of breath during exertion. She has been adhering to a daily dose of amlodipine (5mg) for hypertension management since 2012, with no significant cardiac history. Sarah, a former smoker of 15 years, now limits herself to occasional social smoking and moderate alcohol consumption. Family history indicates a prevalence of hypertension and cardiovascular diseases, particularly on the maternal side. Recommendations for further evaluation, including ECG and stress test, were made, along with lifestyle modifications to enhance cardiovascular health.

During the consultation, Mr. William Turner, a 65-year-old resident of 654 Birch Street, Boston, MA, presented with mild chest discomfort and occasional shortness of breath during physical activity. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2015, with no reported cardiac anomalies or major surgeries. William's 30-year smoking history and moderate alcohol consumption pose significant risks to his cardiovascular health. Given the family history of hypertension and cardiovascular diseases, urgent intervention is required to mitigate potential complications. Diagnostic tests such as ECG and stress test, along with lifestyle modifications emphasizing smoking cessation and dietary changes, are imperative for William's well-being.

Mr. Michael Rodriguez, a 50-year-old man residing at 987 Cedar Lane, Houston, TX, arrived with complaints of occasional chest pain and shortness of breath, especially during physical exertion. He has diligently followed a daily regimen of amlodipine (5mg) since 2009 for hypertension control, with no known cardiac abnormalities or significant surgical history. Michael, a former smoker for 20 years, now limits himself to occasional social smoking and moderate alcohol consumption. Family history indicates a hereditary predisposition to hypertension and cardiovascular ailments, with multiple cases of heart disease in both parents. Further diagnostic tests, including ECG and stress test, were recommended alongside lifestyle adjustments to optimize cardiovascular health.

Dr. Samantha Lee conducted an assessment on Ms. Emily Johnson, a 60-year-old woman residing at 789 Oak Avenue, Los Angeles, CA, who reported mild chest discomfort and occasional shortness of breath during physical activity. Emily has been on a daily regimen of amlodipine (5mg) since 2005 for hypertension management. A former smoker of 15 years, Emily now indulges in occasional social drinking. Family history shows a prevalence of hypertension and cardiovascular diseases, particularly in her maternal side. Recommendations for further evaluation, including ECG and stress test, were made alongside lifestyle modifications to improve overall cardiovascular health.

At the consultation, Mr. James Brown, a 35-year-old gentleman chilling at 456 Pine Street, Miami, FL, swung by today with some chest pain and shortness of breath when he's hustling. Been poppin' amlodipine (5mg) since '13 to keep his blood pressure in check, you know? James has been puffin' the ciggies for about 10 years and sippin' on some beers now and then, nothing too crazy. Fam history's got some high blood pressure and heart stuff, especially on his dad's side. Gonna run some tests like ECG and stress test and dish out some tips on kickin' the cigs and livin' healthier, ya feel?

During the consultation, Mr. John Smith, a 45-year-old gentleman residing at 123 Maple Street, New York, NY, reported mild chest discomfort and occasional shortness of breath during physical exertion. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2010, with no reported cardiac anomalies or major surgeries. Mr. Smith has a 10-year history of smoking and occasional alcohol consumption within recommended limits. Family history reveals hypertension and cardiovascular diseases, including myocardial infarction in his paternal grandfather. Further evaluation, including ECG and stress test, is advised, along with recommendations for smoking cessation and lifestyle modifications.

Mr. Alex Max, a 59-year-old gentleman residing at 55 Penny Lane, Liverpool, UK, presented with mild chest pain and occasional shortness of breath during physical exertion. He has a history of hypertension managed with amlodipine (5mg) daily since 2008, with no known cardiac abnormalities or major surgeries. No cardiac abnormalities or major surgeries were reported. Mr. Max has a 20-year history of smoking and occasional alcohol consumption within recommended limits. Family history indicates a hereditary predisposition to hypertension and cardiovascular diseases, with a paternal grandfather having a history of myocardial infarction. Further evaluation,

including ECG and cardiac stress test, is recommended, alongside lifestyle modifications and smoking cessation counseling.

Ms. Emily Johnson, a 60-year-old woman residing at 789 Oak Avenue, Los Angeles, CA, arrived with complaints of mild chest pain and occasional shortness of breath during physical activity. She has been managing hypertension with a daily dose of amlodipine (5mg) since 2005. Ms. Emily, a former smoker of 15 years, now indulges in occasional social drinking. Family history shows a prevalence of hypertension and cardiovascular diseases, particularly on her maternal side. Recommendations for further evaluation, including ECG and stress test, were made alongside lifestyle modifications to improve overall cardiovascular health.

Mr. William Turner, a 65-year-old gentleman residing at 654 Birch Street, Boston, MA, presented with mild chest discomfort and occasional shortness of breath during physical activity. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2015. Mr. William's 30-year smoking history and moderate alcohol consumption pose significant risks to his cardiovascular health. Given the family history of hypertension and cardiovascular diseases, urgent intervention is required to mitigate potential complications. Diagnostic tests such as ECG and stress test, along with lifestyle modifications emphasizing smoking cessation and dietary changes, are imperative for William's well-being.

Mr. Michael Rodriguez, a 50-year-old man residing at 987 Cedar Lane, Houston, TX, arrived with complaints of occasional chest pain and shortness of breath, especially during physical exertion. He has diligently followed a daily regimen of amlodipine (5mg) since 2009 for hypertension control. Mr. Michael, a former smoker for 20 years, now limits himself to occasional social smoking and moderate alcohol consumption. Family history indicates a hereditary predisposition to hypertension and cardiovascular ailments, with multiple cases of heart disease in both parents. Further diagnostic tests, including ECG and stress test, were recommended alongside lifestyle adjustments to optimize cardiovascular health.

Mr. James Newton, aged 40, residing at 123 Oak Street, San Francisco, CA, visited the clinic with complaints of mild chest discomfort and occasional shortness of breath during physical activity. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2010. Mr. James has a history of smoking for 10 years and occasional alcohol consumption. Family history indicates

a predisposition to hypertension and cardiovascular diseases. Further evaluation, including ECG and stress test, is recommended alongside lifestyle modifications.

Dr. Elon Musk, a 50-year-old entrepreneur, residing in Los Angeles, CA, presented with mild chest pain and occasional shortness of breath during physical exertion. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2012. Dr. Elon has a history of occasional smoking and moderate alcohol consumption. Family history reveals a predisposition to hypertension and cardiovascular diseases. Further evaluation, including ECG and stress test, is advised alongside lifestyle adjustments.

Mr. Mark Ford, aged 60, living at 456 Maple Avenue, Seattle, WA, reported mild chest discomfort and occasional shortness of breath during physical activity. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2005. Mr. Mark, a former smoker for 20 years, now abstains from smoking and consumes alcohol occasionally. Family history indicates a predisposition to hypertension and cardiovascular diseases. Further evaluation, including ECG and stress test, is recommended along with lifestyle modifications.

Mr. Yun Ng, a 55-year-old individual, residing at 789 Pine Road, Chicago, IL, arrived with complaints of occasional chest pain and shortness of breath, particularly during exertion. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2010. Mr. Yun, a non-smoker, indulges in moderate alcohol consumption. Family history reveals a predisposition to hypertension and cardiovascular diseases. Further diagnostic tests, including ECG and stress test, were recommended alongside lifestyle adjustments.

Mr. Ahmed Radi, a 45-year-old resident of 321 Elm Street, Miami, FL, presented with mild chest discomfort and occasional shortness of breath during physical activity. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2015. Dr. Ahmed, a former smoker for 15 years, now abstains from smoking and consumes alcohol occasionally. Family history indicates a predisposition to hypertension and cardiovascular diseases. Further evaluation, including ECG and stress test, is advised alongside lifestyle modifications.

Mr. John Forst, aged 70, residing at 987 Cedar Lane, Dallas, TX, reported mild chest discomfort and occasional shortness of breath during physical exertion. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2008. John, a former smoker for 30 years, now

abstains from smoking and consumes alcohol occasionally. Family history reveals a predisposition to hypertension and cardiovascular diseases. Further evaluation, including ECG and stress test, is recommended alongside lifestyle modifications.

Mr. Joe DrinkingWater, a 55-year-old individual, residing at 55 Penny Lane, Liverpool, UK, presented with mild chest pain and occasional shortness of breath during physical exertion. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2010. Mr. Joe, a non-smoker, consumes alcohol occasionally. Family history reveals a predisposition to hypertension and cardiovascular diseases. Further diagnostic tests, including ECG and stress test, were recommended alongside lifestyle adjustments.

Mr. Alen Maxwell, aged 60, living at 321 Oak Avenue, New York, NY, reported mild chest discomfort and occasional shortness of breath during physical activity. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2012. Mr. Alen, a former smoker for 20 years, now abstains from smoking and consumes alcohol occasionally. Family history indicates a predisposition to hypertension and cardiovascular diseases. Further evaluation, including ECG and stress test, is advised alongside lifestyle modifications.

Dr. Jule Smith, a 50-year-old resident of 654 Maple Street, San Francisco, CA, arrived with complaints of occasional chest pain and shortness of breath, especially during physical exertion. He has been managing hypertension with a daily dose of amlodipine (5mg) since 2009. Dr. Jule, a former smoker for 10 years, now abstains from smoking and consumes alcohol occasionally. Family history reveals a predisposition to hypertension and cardiovascular diseases. Further diagnostic tests, including ECG and stress test, were recommended alongside lifestyle adjustments.

Mrs. Barba Well, a 65-year-old individual, residing at 789 Pine Road, Los Angeles, CA, presented with mild chest discomfort and occasional shortness of breath during physical activity. She has been managing hypertension with a daily dose of amlodipine (5mg) since 2015. Mrs. Barba, a non-smoker, indulges in moderate alcohol consumption. Family history indicates a predisposition to hypertension and cardiovascular diseases. Further evaluation, including ECG and stress test, is advised alongside lifestyle modifications.

Prof. Kaushi Evans, a 55-year-old born in 22nd April 1997, presented with mild chest discomfort and occasional shortness of breath during exertion.