**Naan Mudhalvan**

# **AI-BASED DIABETES PREDICTION SYSTEM**

**Documentation**

|  |  |
| --- | --- |
| **Name** | Pradeepa.S |
| **Naan Muhalvan Id** | au732121104037 |
| **Group** | III |
| **College** | Nandha College Of Techonology |
| **Date** | 06.11.2023 |

**AI-BASED DIABETES PREDICTION SYSTEM**

# Table of Contents

* Executive Summary
* Problem Statement
* Design Thinking Process
* Phase 1: Problem Definition and Design Thinking
  + Problem Statement
  + Design Thinking
* Phase 2: Innovation
* Phase 3: Development Part 1
  + Step 1: Importing Libraries
  + Step 2: Loading the Dataset
  + Step 3: Data Exploration
  + Step 4: Data Preprocessing
  + Step 5: Data Visualization
  + Step 6: Feature Engineering
  + Step 7: Data Splitting
* Phase 4: Development Part 2
  + Step 1: Model Selection
  + Step 2: Model Training
  + Step 3: Model Evaluation
* Phase 5: Project Documentation & Submission
  + Documentation
    - Problem Statement and Design Thinking
    - Dataset and Data Preprocessing
    - Machine Learning Algorithm and Model Training
    - Innovative Techniques
  + Submission

# Executive Summary

This document presents a comprehensive overview of the AI-based Diabetes Prediction System, including problem definition, design thinking, development phases, and innovative techniques used throughout the project. The goal of this system is to supply early risk assessment and personalized preventive measures to help individuals manage their health by predicting the likelihood of diabetes.

## **Problem Statement**

The project aims to address the pressing issue of diabetes, a chronic health condition that affects millions of individuals worldwide. Diabetes prediction is crucial for early intervention and lifestyle modifications. The system is designed to accurately predict an individual's likelihood of developing diabetes.

## **Design Thinking Process**

The design thinking process played a leading role in shaping the project. It began with a deep understanding of the problem statement, followed by innovative solutions and structured development phases. The key design principles included data exploration, preprocessing, visualization, feature engineering, model selection, and evaluation.

## **Phases of Development**

1. **Phase 1:** Problem Definition and Design Thinking

* Defined the problem statement.
* Conceptualized the system's aims and scope.

1. **Phase 2:** Innovation

* Explored innovative approaches to enhance diabetes prediction.

1. **Phase 3:** Development Part 1

* Loaded and pre-processed the dataset.
* Explored the dataset through data exploration and visualization.
* Conducted feature engineering.
* Split the data for model development.

1. **Phase 4:** Development Part 2

* Selected the Random Forest algorithm for model development.
* Trained the model and evaluated its performance.

## **Dataset and Preprocessing**

The project used a dataset having relevant medical features such as glucose levels, blood pressure, and BMI, alongside information about whether individuals have diabetes. Data preprocessing included handling missing values, feature selection, and feature engineering. These steps were vital in preparing the dataset for model development.

## **Model Selection and Evaluation**

A Random Forest classifier was selected as the machine learning algorithm for diabetes prediction. The model was trained and evaluated using essential metrics, including accuracy, precision, recall, F1-score, and ROC-AUC. These evaluations supply insights into the model's performance in classifying diabetes cases accurately.

## **Innovative Techniques**

Innovation was a core element of this project. While innovative techniques are continuously evolving, this system embraces the latest advancements in data preprocessing, model selection, and evaluation, ensuring that it stays at the forefront of diabetes prediction solutions.

The AI-based Diabetes Prediction System is a significant step forward in proactive health management. It empowers individuals with early risk assessments, promoting healthier lifestyles and prompt interventions to combat diabetes.

# Problem Statement

The core aim of this project is to develop an AI-based Diabetes Prediction System. Diabetes is a prevalent chronic health condition with a significant impact on global public health. As of the last update in our knowledge base in January 2022, over 34 million people in the United States alone have diabetes, with an estimated 10.5% of the U.S. population living with the condition. Worldwide, diabetes affects hundreds of millions of individuals, contributing to increased healthcare costs and reduced quality of life.

## **Significance of the Problem**

Diabetes is a complex metabolic disorder characterized by high blood sugar levels. It is classified into two main types:

**Type 1 Diabetes:** Typically diagnosed in childhood or adolescence, it results from the immune system mistakenly attacking and destroying insulin-producing beta cells in the pancreas. This type requires lifelong insulin treatment.

**Type 2 Diabetes:** This form accounts for most of the diabetes cases and often develops in adulthood. It is primarily associated with lifestyle factors, including poor diet, lack of physical activity, and obesity.

The significance of addressing the problem of diabetes is multi-fold:

### **1. Public Health Impact**

Diabetes has a substantial impact on public health. It is a leading cause of various health complications, including heart disease, stroke, kidney failure, blindness, and nerve damage. Reducing the incidence of diabetes can significantly alleviate the burden on healthcare systems.

### **2. Early Intervention**

Early intervention is crucial for managing diabetes. Predicting an individual's risk of developing diabetes allows for proactive measures, such as lifestyle changes and medication, to prevent or delay its onset. Early detection can also reduce the risk of complications.

### **3. Personalized Healthcare**

AI-based diabetes prediction systems can supply personalized health recommendations. These systems analyse an individual's unique medical data to offer tailored advice, making it easier for people to make informed decisions about their health.

### **4. Healthcare Costs**

Diabetes imposes substantial financial costs on individuals and healthcare systems. Reducing the prevalence of diabetes through prediction and intervention can result in cost savings and a more efficient allocation of resources.

### **5. Quality of Life**

Improving the quality of life for individuals with diabetes is paramount. Early prediction and management can help individuals live healthier, more productive lives with fewer complications and a reduced reliance on medications.

## **Potential Impact**

The AI-based Diabetes Prediction System has the potential to bring about several positive changes:

* **Early Risk Assessment:** Individuals can be informed of their risk of developing diabetes, promoting early intervention and lifestyle changes.
* **Personalized Preventive Measures:** Health recommendations can be tailored to an individual's specific risk factors and needs.
* **Reduced Complications:** By predicting and addressing diabetes early, the system can help reduce the risk of complications associated with the condition.
* **Efficient Healthcare Resource Allocation:** Healthcare providers can distribute resources more efficiently to manage and prevent diabetes.
* **Improved Quality of Life:** The system aims to improve the overall quality of life for individuals by providing them with tools to manage their health more effectively.

# Design Thinking Process

Design thinking is a human-cantered approach to problem-solving that prioritizes empathy, collaboration, and innovation. It plays a pivotal role in guiding the development of the AI-based Diabetes Prediction System.

## **Problem Identification**

### **Understanding the Complexity of Diabetes**

The design thinking process began with a deep dive into understanding the complexity of diabetes as a chronic health condition. The team involved in the project looked to answer critical questions:

* What are the primary types of diabetes, and how do they differ?
* What are the contributing risk factors for diabetes, and how do they vary among individuals?
* How does early intervention impact diabetes management and the reduction of complications?
* What are the limitations and challenges in existing diabetes prediction and management methods?

### **Finding the Scope**

It was essential to find the project's scope and aims clearly. The primary problem found was the need for an effective AI-based system to predict an individual's risk of developing diabetes based on their medical data. The scope included:

* Developing a predictive model for diabetes.
* Supplying early risk assessment.
* Offering personalized health recommendations.
* Analysing the potential impact on public health, healthcare costs, and individuals' quality of life.

## **Solution Exploration**

### **Innovative Techniques**

To address the problem statement effectively, the project team explored innovative techniques and methodologies. These included:

* Data preprocessing strategies for handling missing values and preparing the dataset.
* Feature engineering to create new features for better prediction.
* Machine learning algorithms suitable for binary classification, with a focus on Random Forest.
* Evaluation metrics to assess the model's performance, such as accuracy, precision, recall, F1-score, and ROC-AUC.

### **Iterative Development Phases**

The project was structured into phases to ensure a systematic approach:

* **Phase 1: Problem Definition and Design Thinking:** Defining the problem and conceptualizing the solution.
* **Phase 2: Innovation:** Exploring innovative approaches and techniques to enhance diabetes prediction.
* **Phase 3: Development Part 1:** Loading the dataset, data exploration, preprocessing, data visualization, feature engineering, and data splitting.
* **Phase 4: Development Part 2:** Model selection, model training, and model evaluation.

Each phase was designed to build upon the earlier one, with the goal of creating a robust and effective AI-based Diabetes Prediction System.

## **Collaboration and User-Cantered Approach**

Design thinking emphasizes collaboration and a user-cantered approach. The project team worked closely with healthcare professionals, data scientists, and domain experts to ensure that the system was relevant, effective, and aligned with the needs of both healthcare providers and individuals.

# **Phase 1: Problem Definition and Design Thinking**

## **Problem Statement**

### **Explaining the Problem**

The problem addressed in this project is the development of an AI-based Diabetes Prediction System. Diabetes is a chronic health condition characterized by high blood sugar levels, and it has a significant global impact on public health. The importance of early diabetes prediction cannot be overstated. This chronic condition is associated with severe health complications, including heart disease, stroke, kidney failure, blindness, and nerve damage. Early detection and intervention are key to managing diabetes effectively and reducing the risk of complications.

### **Significance of Early Diabetes Prediction**

Early prediction of diabetes offers several key benefits:

* **Proactive Health Management:** Early risk assessment empowers individuals to make informed decisions about their health. With a clear understanding of their risk, individuals can take proactive measures to reduce that risk. This includes lifestyle modifications, dietary changes, increased physical activity, and, in some cases, medication.
* **Preventing Complications:** Early intervention can significantly reduce the risk of complications associated with diabetes. By managing blood sugar levels and adopting a healthier lifestyle, individuals can lower the likelihood of heart disease, kidney issues, vision problems, and nerve damage.
* **Reduced Healthcare Costs:** Diabetes imposes a substantial financial burden on both individuals and healthcare systems. Early prediction and intervention can lead to cost savings by reducing the need for intensive diabetes management and the treatment of complications.
* **Quality of Life:** By providing individuals with the tools to manage their health effectively, early prediction can improve their overall quality of life. They can enjoy better health and well-being, reduce the reliance on medications, and minimize the impact of diabetes on their daily lives.

## **Scope and Objectives**

### **Defining the Scope**

The scope of this project is to develop an AI-based system that predicts an individual's likelihood of developing diabetes based on their medical data. The system aims to supply early risk assessment and personalized preventive measures.

### **Project Objectives**

The primary aims of the AI-based Diabetes Prediction System are as follows:

* **Develop a Predictive Model:** Create a machine learning model capable of accurately predicting an individual's risk of developing diabetes.
* **Early Risk Assessment:** Provide individuals with early risk assessments to empower them to take proactive health management measures.
* **Personalized Health Recommendations:** Offer personalized health recommendations based on an individual's unique risk factors and medical data.
* **Impact Assessment:** Analyse the potential impact of the system on public health, healthcare costs, and the quality of life for individuals.

## **Design Thinking**

### **Design Thinking Approach**

The project employed a design thinking approach to address the problem. Design thinking is a human-cantered approach to problem-solving that prioritizes empathy, collaboration, and innovation. It guided the project through the following steps:

#### **Understanding the Complexity of Diabetes**

The project began by seeking a deep understanding of the complexity of diabetes as a chronic health condition. This included a detailed examination of the primary types of diabetes, risk factors, complications, and the impact on individuals and public health.

#### **Finding the Scope**

It was essential to find the scope and aims of the project clearly. This included defining the primary problem of diabetes prediction and its scope in supplying early risk assessment and personalized preventive measures.

#### **User-Cantered Approach**

Design thinking emphasizes a user-cantered approach. The project team collaborated with healthcare professionals, data scientists, and domain experts to ensure that the system would be relevant, effective, and aligned with the needs of both healthcare providers and individuals.

#### **Innovative Techniques**

In line with the design thinking approach, the project explored innovative techniques and methodologies for data preprocessing, feature engineering, machine learning algorithms, and evaluation metrics. These techniques were designed to ensure that the system remained at the forefront of diabetes prediction solutions.

#### **Iterative Development Phases**

The project was structured into phases to ensure a systematic approach. Each phase built upon the earlier one, with the goal of creating a robust and effective AI-based Diabetes Prediction System.

# **Phase 2: Innovation**

## **Innovative Approaches and Novel Methodologies**

In Phase 2 of the project, the focus was on exploring innovative approaches and methodologies that could enhance the AI-based Diabetes Prediction System. The following innovative techniques and ideas have been incorporated into the project:

### **1. Feature Engineering for Enhanced Prediction**

One of the innovative approaches employed was feature engineering. While the original dataset supplied essential medical features for prediction, the team recognized the potential for creating new features that could improve prediction accuracy. Feature engineering, in this context, included the following:

#### **a. BMI Categorization**

A novel feature was introduced by categorizing Body Mass Index (BMI) into distinct categories: Underweight, Normal, Overweight, and Obese. This categorical feature was derived from the continuous BMI value and added as a predictor for the machine learning model. The categorization aimed to capture the non-linear relationship between BMI and diabetes risk, providing the model with valuable insights.

### **2. User-Cantered Model Interpretability**

Ensuring that the AI-based Diabetes Prediction System is user-friendly and interpretable was a key aspect of innovation. Machine learning models, particularly complex ones like Random Forest, can be challenging to interpret. To address this, the project incorporated the following innovative methodologies:

#### **a. Visualizing the Decision Boundary**

Understanding how a machine learning model makes predictions is essential for both healthcare providers and individuals. An innovative approach taken in this project was to visualize the model's decision boundary. By plotting the decision boundary, it becomes easier to see how the model separates data points into diabetes and non-diabetes categories. The visualization supplies insights into how well the model is trained and how it generalizes to new data.

This user-centered approach to model interpretability ensures that the AI system is not a black box. Users, including healthcare professionals and individuals, can gain insights into why a particular prediction was made, fostering trust and transparency.

### **3. Iterative Model Fine-Tuning**

While model fine-tuning is often a part of the development process, it's worth noting that the project intentionally deferred extensive model fine-tuning to later phases. This approach allows for a more comprehensive exploration of various techniques and methodologies for improving prediction accuracy. Model fine-tuning, including hyperparameter tuning and feature selection, is expected to be a crucial step in the later stages of development.

By strategically reserving model fine-tuning for later, the project ensures that the model is built on a solid foundation, with feature engineering and user-cantered interpretability as integral components. This approach enables a more informed and targeted fine-tuning process, ultimately leading to a more correct and user-friendly AI-based Diabetes Prediction System.

In summary, the innovation in Phase 2 of the project primarily focused on feature engineering to enhance prediction accuracy, user-cantered model interpretability through decision boundary visualization, and a deliberate strategy for iterative model fine-tuning in later phases. These innovative approaches and methodologies are integral to the development of an effective and user-friendly AI-based Diabetes Prediction System.

# **Phase 3: Development Part 1**

## **Step 1: Importing Libraries**

Libraries play a crucial role in the development of the AI-based Diabetes Prediction System. The following libraries were used in the project:

* **numpy:** A fundamental package for scientific computing with Python. It provides support for arrays and matrices, along with mathematical functions.
* **pandas:** A data manipulation and analysis library that is essential for handling and exploring datasets. It allows for data loading, manipulation, and analysis.
* **sklearn (scikit-learn):** A comprehensive machine learning library that includes various tools for data preprocessing, model selection, and evaluation. It supplies access to various algorithms and metrics.
* **matplotlib:** A data visualization library used for creating plots and charts. It is essential for visualizing data distributions and feature relationships.
* **seaborn:** Built on top of matplotlib, seaborn is a statistical data visualization library. It supplies a high-level interface for creating informative and attractive statistical graphics.

## **Step 2: Loading the Dataset**

### **Dataset Source and Description**

The dataset used in this project is the "Diabetes Data Set" sourced from Kaggle. It has essential medical features and information about diabetes. The dataset includes the following columns:

* **Pregnancies:** Number of times pregnant.
* **Glucose:** Plasma glucose concentration 2 hours in an oral glucose tolerance test.
* **Blood Pressure:** Diastolic blood pressure (mm Hg).
* **Skin Thickness:** Triceps skinfold thickness (mm).
* **Insulin:** 2-Hour serum insulin (mu U/ml).
* **BMI:** Body mass index (weight in kg/ (height in m) ^2).
* **DiabetesPedigreeFunction:** Diabetes pedigree function (a function that scores the likelihood of diabetes based on family history).
* **Age:** Age (years).
* **Outcome:** Class variable (0 if non-diabetic, 1 if diabetic).

### **Loading the Dataset**

The dataset was loaded into the Jupyter Notebook

## **Step 3: Data Exploration**

### **Displaying the First Few Rows of the Dataset**

To understand the structure of the dataset, the first few rows were displayed.

### **Data Statistics, Data Types, and Missing Values**

Exploratory data analysis was performed to gain insights into the dataset:

* Data statistics: Summary statistics, including mean, standard deviation, minimum, and maximum values for numerical columns.
* Data types: Examination of the data types of each column.
* Missing values: Identification of missing values in the dataset.

## **Step 4: Data Preprocessing**

### **Data Preprocessing Steps**

Data preprocessing is a critical step to ensure that the dataset is suitable for model development. The following data preprocessing steps were taken:

* Handling missing values: Missing values, if any, were addressed using proper imputation techniques.
* Feature selection: Relevant features were chosen based on domain knowledge and data analysis.

Feature selection aimed to keep only those features that are likely to have a significant impact on diabetes risk prediction.

## **Step 5: Data Visualization**

### **Visualizing the Distribution of Key Features**

Data visualization was employed to gain insights into the distribution of key features. For example, the distribution of glucose levels was visualized using a histogram.

### **Correlation Matrix**

A correlation matrix was created to analyse feature relationships. This allowed for understanding how unique features correlate with each other and, potentially, with the target variable (Outcome).

## **Step 6: Feature Engineering**

### **Feature Engineering Description**

Feature engineering is the process of creating new features or transforming existing ones to improve the model's predictive power. In this project, one feature engineering technique was applied:

* **BMI Categorization:** A new feature was created by categorizing the Body Mass Index (BMI) into distinct categories: Underweight, Normal, Overweight, and Obese. This categorical feature was derived from the continuous BMI value and added as a predictor for the machine learning model. The categorization aimed to capture the non-linear relationship between BMI and diabetes risk, providing the model with valuable insights.

## **Step 7: Data Splitting**

### **Data Splitting Procedure**

To prepare for model development and evaluation, the dataset was split into training and testing sets. The following steps were taken:

* Definition of the features (X) and the target (y).
* Splitting the data into training and testing sets, with a common split ratio (e.g., 80% for training and 20% for testing).

### **Shapes of Resulting Sets**

The shapes of the resulting sets were checked to ensure that the split was performed correctly:

* "X\_train" shape: The number of rows and columns in the training feature set.
* "X\_test" shape: The number of rows and columns in the testing feature set.

This step laid the foundation for model development and evaluation in the later phases of the project.

# **Phase 4: Development Part 2**

## **Step 1: Model Selection**

### **Description of Machine Learning Algorithm**

For building the AI-based Diabetes Prediction System, the machine learning algorithm chosen for the model is the Random Forest. Random Forest is a versatile and powerful ensemble learning method that is particularly suitable for classification tasks like diabetes prediction. It combines multiple decision trees to create a robust and correct model.

The choice of Random Forest is motivated by several factors:

* **Ensemble Learning:** Random Forest is an ensemble learning method that combines the predictions of multiple decision trees. This ensemble approach improves the model's predictive performance and reduces overfitting.
* **Non-Linearity:** Diabetes prediction is a complex task with non-linear relationships between features and outcomes. Random Forest excels at capturing non-linear patterns in the data.
* **Feature Importance:** Random Forest supplies a feature importance score, allowing us to understand the significance of unique features in predicting diabetes risk. This is crucial for supplying insights to healthcare professionals and individuals.
* **Robustness:** Random Forest is robust to noisy data and can handle missing values. This is helpful for real-world medical datasets that may have missing or incomplete information.

## **Step 2: Model Training**

### **Training the Random Forest Model**

To train the Random Forest model on the diabetes prediction dataset, the following steps were taken:

* **Initialization:** The Random Forest classifier was initialized with the chosen hyperparameters, with 'random\_state' set to 42 for reproducibility.
* **Training Data:** The training data (X\_train and y\_train) prepared in Phase 3 was used to train the model. This data consists of selected features and the corresponding diabetes outcomes.
* **Model Training:** The 'fit' method was applied to train the Random Forest classifier on the training data. The model learned from the data and created a predictive model for diabetes risk.

## **Step 3: Model Evaluation**

### **Evaluation Metrics**

The performance of the AI-based Diabetes Prediction System was evaluated using a range of metrics, including:

* **Accuracy:** Measures the overall correctness of the model's predictions.
* **Precision:** Quantifies the ability of the model to correctly find individuals with diabetes (positive class) without classifying too many non-diabetic individuals as diabetic (minimizing false positives).
* **Recall:** Measures the ability of the model to find all individuals with diabetes (positive class) without missing any (minimizing false negatives).
* **F1-Score:** Harmonic mean of precision and recall. It supplies a balanced measure of model performance.
* **ROC-AUC (Receiver Operating Characteristic - Area Under the Curve):** Evaluates the model's ability to discriminate between individuals with diabetes and those without. It considers the trade-off between true positive rate (sensitivity) and false positive rate.

### **Results and Insights**

The Random Forest model was evaluated on the testing dataset (X\_test and y\_test) using the mentioned metrics. The evaluation results are as follows:

* **Accuracy:** The model achieved an accuracy of [insert accuracy score], showing the proportion of correct predictions.
* **Precision:** The precision score was [insert precision score], meaning that [insert precision explanation].
* **Recall:** The recall score was [insert recall score], showing that [insert recall explanation].
* **F1-Score:** The F1-score was [insert F1-score], signifying a balance between precision and recall.
* **ROC-AUC:** The ROC-AUC score was [insert ROC-AUC score], highlighting the model's ability to discriminate between individuals with and without diabetes.

These evaluation metrics supply insights into the model's performance and its suitability for diabetes prediction. The results show that the model exhibits [insert insights based on results], which are essential for healthcare professionals and individuals to make informed decisions about diabetes risk management.

# **Phase 5: Project Documentation & Submission**

## **Documentation**

In this section, we supply an in-depth overview of the key aspects of the project, including the problem statement, design thinking process, dataset description, data preprocessing, machine learning algorithm, model training, and evaluation metrics.

### **Problem Statement and Design Thinking**

The problem addressed in this project is the development of an AI-based Diabetes Prediction System. Diabetes is a prevalent and serious health condition, and early prediction can significantly affect an individual's health. This system aims to provide individuals with early risk assessment and personalized preventive measures to manage their health effectively.

The design thinking process began with the identification of the problem, recognizing the importance of early diabetes prediction and prevention. It involved problem definition, understanding the scope, and outlining the aims of the project.

Design thinking was instrumental in conceptualizing the project's solution, which involved building a predictive model to assess an individual's risk of developing diabetes. Potential solutions were explored through the design of machine learning algorithms, data preprocessing techniques, and the selection of evaluation metrics.

### **Dataset and Data Preprocessing**

The dataset used in this project is the "Diabetes Data Set" obtained from Kaggle. It has key medical features and information about diabetes, making it a suitable choice for training the prediction model.

Data preprocessing played a crucial role in preparing the dataset for model development. Missing values were addressed, and relevant features were selected based on domain knowledge and data analysis. Notably, feature engineering was applied to create a new feature for categorizing BMI, supplying valuable insights into the relationship between BMI and diabetes risk.

Data visualization techniques, including histograms and correlation matrices, were employed to gain insights into feature distributions and relationships.

### **Machine Learning Algorithm, Model Training, and Evaluation Metrics**

The machine learning algorithm selected for this project is the Random Forest. The choice of Random Forest was driven by its ability to handle complex, non-linear relationships, its feature importance analysis, and robustness to noisy data.

Model training involved fitting the Random Forest classifier to the training data, enabling the model to learn from the dataset.

For model evaluation, a set of metrics were chosen to supply a comprehensive understanding of the model's performance. These metrics included accuracy, precision, recall, F1-score, and ROC-AUC. These metrics collectively evaluated the model's correctness, its ability to minimize false positives and false negatives, and its capability to discriminate between individuals with and without diabetes.

### **Innovative Techniques and Approaches**

One innovative technique applied in this project was the creation of a categorical feature for BMI categorization. This approach allowed the model to capture non-linear relationships between BMI and diabetes risk, supplying valuable insights for both healthcare professionals and individuals.

## **Submission**

For project submission, all code files, including data preprocessing, model training, and evaluation steps, have been compiled. Additionally, a detailed README file is provided, offering clear instructions on how to run the code and listing the necessary dependencies.

The dataset source from Kaggle has been included, along with a brief description of the dataset's columns and purpose.

The project is made available on a GitHub repository for easy access and review by others in the AI and healthcare community.

Pradeepa.S. 06..11.2023

Nandha College Of Technology