VIRTUAL HR : AI- DRIVEN AUTOMATION FOREFFICIENT AND UNBIASED CANDIDATE RECRUITMENT IN SOFTWARE ENGINEERING ROLE

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ABSTRACT :

Recruitment is an integral part of any HR professional's role and critical for helping an organization build a thriving workforce ready to support business growth. The entire recruitment process is sometimes relatively complex, especially if an HR professional is hiring for multiple roles at once. It's common for HR professionals to face several challenges during the hiring process. To overcome this challenge this project is to develop an AI-driven recruiting platform that aims to make the hiring process more efficient and unbiased. By leveraging artificial intelligence and machine learning, Virtual-HR automates various aspects of the recruitment process, such as candidate sourcing, screening, and engagement. The proposed framework employs an automatic resume analysis system tailored to match candidate profiles with suitable job postings, providing valuable recommendations to employers using content based filtering. The subsequent automated virtual interview process involves three distinct stages: an aptitude test, a programming skill test, and a video calling interview facilitated by Virtual-HR. It uses natural language processing (NLP) to understand, interpret, and respond to user voice inputs in a conversational manner and Attention Mechanism for behavioral prediction during visual interview. The proposed system allows candidates to encounter common interview questions and quantifies how they share their attention (gaze and head rotations) to engage with multiple interviewers based on their conversational role (speaking or listening). The results of these analyses are then provided to HR, who utilizes the insights to make informed and data-driven decisions during the final selection process. The integration of advanced technologies not only expedites the recruitment workflow but also introduces a modern, data-driven dimension to candidate evaluation. The proposed work is focused on software engineering job search and resume upgrades.

1.INTRODUCTION :

1.1 Objectives

The aim of the project is to develop an advanced recruiting platform, named Virtual HR, that harnesses the power of artificial intelligence and machine learning to streamline and optimize the candidate recruitment process for software engineering positions. The project seeks to enhance efficiency, reduce biases, and introduce a data-driven dimension to the entire recruitment workflow.

- To design and implement an AI-driven platform for streamlined candidate recruitment in software engineering roles.
- To implement automatic resume analysis using content-based filtering to match candidates with relevant job postings efficiently.
- To integrate NLP for conversational interactions and attention mechanisms for behavioural prediction during virtual interviews.
- To develop automated aptitude and programming skill assessments for comprehensive candidate evaluation.
- To quantify candidate attention-sharing, including gaze and head rotations during video interviews.
- To generate reports for HR professionals to make informed, data-driven decisions.
- To mitigate biases in the recruitment process, fostering fairness and diversity.
- To enhancing user experience for candidates and HR professionals through a user friendly interface.
- To tailor features and assessments specifically for the unique requirements of software engineering positions..

2.SYSTEM ANALYSIS

2.1 EXISTING SYSTEM

The current job recruitment process in HR often relies on manual and time-consuming methods, presenting various challenges for both HR professionals and candidates.

➢ **Resume Screening**

HR professionals manually review and screen numerous resumes to shortlist potential candidates. This process can be subjective and prone to biases.

➢ **Job Posting and Application Submission**

Employers post job listings on various platforms, and candidates submit their applications. The matching process is typically based on keywords and manual assessments.

 ➢ **Manual Shortlisting**

HR professionals manually shortlist candidates based on their resumes and qualifications, which can be time-consuming and may result in oversight.

 ➢ **Interview Scheduling**

Scheduling interviews involves manual coordination between HR professionals, recruiters, and candidates, leading to potential delays and scheduling conflicts.

 ➢ **Traditional Interviews**

Interviews are conducted in person or over the phone, relying on subjective evaluations. The process lacks standardized assessments and predictive behavioural analysis.

 ➢ **Decision-Making:**

HR professionals make hiring decisions based on a combination of resume evaluations, interviews, and their judgment, introducing potential biases and limiting the depth of candidate insights.

 ➢ **Communication**

Communication with candidates about interview schedules and outcomes is typically done manually, which can lead to delays and lack of transparency.

2.1.1 DISADVANTAGES

- Manual resume screening is time-consuming and prone to oversights and biases.
- Subjective shortlisting may overlook diverse candidate skills and experiences.
- Inefficient interview scheduling leads to delays and conflicts.
- Lack of standardized assessments in traditional interviews hinders objective evaluations.
- Biases in decision-making based on subjective evaluations can impact fairness.
- Manual communication may result in delays and a lack of transparency.
- Limited automation contributes to a slower and error-prone recruitment process.
- Absence of predictive behavioural analysis in interviews limits insights.
- Insufficient use of technology hampers adaptation to industry standards.

2.2 PROPOSED SYSTEM

The Virtual HR project introduces an innovative and efficient system designed to overcome the limitations of traditional job recruitment processes. The proposed Virtual HR system brings numerous advantages, including increased efficiency, objectivity, and transparency to the recruitment process, ultimately leading to improved hiring outcomes and a positive user experience for all stakeholders.

- **AI-Driven Recruiting Platform:** Creating a sophisticated AI-driven recruiting platform that automates various stages of the recruitment process, from candidate sourcing to final selection. This platform enhances workflow efficiency and reduces biases in the decision-making process.
- **Automatic Resume Analysis:** The proposed system incorporates content-based filtering algorithms for automated resume analysis, enhancing efficiency and objectivity in the initial screening process. This module streamlines candidate evaluations and ensures a more accurate matching of skills with job requirements.
- **AI-Driven Candidate Shortlisting:** Introducing HRBot, an AI-driven assistant, to automate candidate shortlisting using advanced content-based filtering algorithms. HRBot provides tailored recommendations to HR professionals, improving the accuracy and speed of candidate selection.
- **Virtual Interview Process:** Implementing a multi-stage virtual interview process that includes aptitude tests, programming skill assessments, and video calling interviews facilitated by HRBot. This approach ensures a standardized evaluation methodology for all candidates.
- **Behavioral Prediction Using Deep Learning:** Leveraging deep learning algorithms to predict and analyze candidate behavior during video interviews. This predictive behavioral analysis, powered by natural language processing (NLP), provides valuable insights into communication skills and engagement.
- **Automated Notifications:** Developing a notification module to automate communication throughout the recruitment process. This module ensures timely updates and interview schedules for candidates, HR professionals, and other stakeholders, improving overall communication efficiency.
- **Candidate Reports:** Generating comprehensive candidate reports that amalgamate assessment results, technical skill evaluations, and behavioural insights. These reports empower HR professionals with data-driven insights, facilitating more informed decision-making during the final selection process.

2.2.1 ADVANTAGES

- Time Efficiency**:** Streamlined processes reduce recruitment timelines.
- Objective Decision-Making: Automation minimizes subjective biases.
- Enhanced Candidate Experience: Automated notifications and user-friendly interfaces improve the candidate journey.
- Improved Accuracy: Predictive analytics and automated matching enhance precision in candidate selection.

- Cost Savings: Reduced manual efforts and streamlined workflows lead to cost-effective recruitment.
- Consistent Evaluation: Standardized virtual interviews ensure consistent candidate assessments.
- Efficient Communication: Automated notifications enhance communication efficiency.
- Holistic Candidate Insights: Comprehensive reports provide a deeper understanding of candidates.
- Modernized Recruitment: AI-driven tools align with contemporary industry standards.
- Data-Driven Decision-Making: Analytics contribute to informed decision-making during the selection process.

2.3 FEASIBILITY STUDY

2.3.1 ECONOMICAL FEASIBILITY

- Cost Analysis: Evaluate the costs associated with developing, deploying, and maintaining the Virtual HR Web App. This includes expenses related to software development, server hosting, licensing, and ongoing support.
- Return on Investment (ROI): Estimate the potential benefits of the Virtual HR Web App, such as time savings, increased efficiency in recruitment processes, and improved candidate experience. Compare these benefits to the costs to determine the ROI.
- Cost-Benefit Analysis: Assess whether the expected benefits outweigh the costs of implementing the Virtual HR Web App. Consider factors such as cost savings, productivity gains, and competitive advantages.

2.3.2 TECHNICAL FEASIBILITY

Technology Assessment: Evaluate the technical requirements for developing and deploying the Virtual HR Web App, including programming languages, frameworks, databases, and hosting platforms. Ensure compatibility with existing systems and infrastructure.

Scalability: Assess whether the chosen technology stack can support the expected user load and accommodate future growth in usage. Consider factors such as server scalability, database performance, and application architecture.

Integration: Determine the feasibility of integrating the Virtual HR Web App with existing HR systems, databases, and third-party services. Identify potential integration points and assess the complexity of data exchange and synchronization.

2.3.3 OPERATIONAL FEASIBILITY

User Acceptance: Assess the willingness and ability of end users (Web Admins, Candidates, Recruiters, HRBot) to adopt and use the Virtual HR Web App. Gather feedback from stakeholders to identify user requirements and preferences.

Training and Support: Evaluate the need for training programs and support resources to help users learn how to use the Virtual HR Web App effectively. Develop training materials and provide ongoing support to address user needs and issues.

3.SYSTEM SPECIFICATION

3.1 HARDWARE REQUIREMENTS

Server:
- Multi-core processor (minimum dual-core)
- Minimum 8 GB RAM
- 256 GB SSD

Client:
Desktops, laptops, or tablets with modern browsers (Chrome, Firefox, Safari)

3.2 SOFTWARE REQUIREMENTS

Operating System:
Windows, MacOS, or Linux for end-users
Web Browser:
Latest versions of Chrome, Firefox, Safari, or Edge
Database Management System:
MySQL (latest version)
Programming Languages:
Python (latest version)
Web Framework:
Flask (Python web framework)
Frontend Technologies:
HTML5, CSS3, JavaScript (ES6+)

Bootstrap for responsive design
AI and Machine Learning Libraries:
TensorFlow, Pandas, Scitkit Learn, Matplotlib

Natural Language Processing (NLP) libraries
 Web Server:
Apache

Communication Services:

SMTP for email notifications

Pay4SMS for SMS notifications

4. SOFTWARE DESCRIPTION :

4.1 FRONT END

PYTHON 3.7.4

Python is a general-purpose interpreted, interactive, object-oriented, and high-level programming language. It was created by Guido van Rossum during 1985- 1990. Like Perl, Python source code is also available under the GNU General Public License (GPL). This tutorial gives enough understanding on Python programming language.

Python is a high-level, interpreted, interactive and object-oriented scripting language. Python is designed to be highly readable. It uses English keywords frequently where as other languages use punctuation, and it has fewer syntactical constructions than other languages. Python is a MUST for students and working professionals to become a great Software Engineer specially when they are working in Web Development Domain.
Python is currently the most widely used multi-purpose, high-level programming language. Python allows programming in Object-Oriented and Procedural paradigms. Python programs generally are smaller than other programming languages like Java. Programmers have to type relatively less and indentation requirement of the language, makes them readable all the time. Python language is being used by almost all tech-giant companies like – Google, Amazon,
Facebook, Instagram, Dropbox, Uber… etc. The biggest strength of Python is huge collection of standard library which can be used for the following:
- Machine Learning
- GUI Applications (like Kivy, Tkinter, PyQt etc.)
- Web frameworks like Django (used by YouTube, Instagram, Dropbox)
- Image processing (like OpenCV, Pillow)
- Web scraping (like Scrapy, BeautifulSoup, Selenium)
- Test frameworks
- Multimedia
- Scientific computing
- Text processing and many more.

Pandas

   pandas is a fast, powerful, flexible and easy to use open source data analysis and manipulation tool, built on top of the Python programming language. pandas is a Python package that provides fast, flexible, and expressive data structures designed to make working with "relational" or "labeled" data both easy and intuitive. It aims to be the fundamental highlevel building block for doing practical, real world data analysis in Python.

Pandas is mainly used for data analysis and associated manipulation of tabular data in Data frames. Pandas allows importing data from various file formats such as comma-separated values, JSON, Parquet, SQL database tables or queries, and Microsoft Excel. Pandas allows various data manipulation operations such as merging, reshaping, selecting, as well as data cleaning, and data wrangling features. The development of pandas introduced into Python many comparable features of working with Data frames that were established in the R programming language. The panda's library is built upon another library NumPy, which is oriented to efficiently working with arrays instead of the features of working on Data frames.

NumPy

NumPy, which stands for Numerical Python, is a library consisting of multidimensional array objects and a collection of routines for processing those arrays. Using NumPy, mathematical and logical operations on arrays can be performed.

NumPy is a general-purpose array-processing package. It provides a high-performance multidimensional array object, and tools for working with these arrays.

Matplotlib

Matplotlib is a comprehensive library for creating static, animated, and interactive visualizations in Python. Matplotlib makes easy things easy and hard things possible.

Matplotlib is a plotting library for the Python programming language and its numerical mathematics extension NumPy. It provides an object-oriented API for embedding plots into applications using general-purpose GUI toolkits like Tkinter, wxPython, Qt, or GTK.

Seaborn

Seaborn is a library for making statistical graphics in Python. It builds on top of matplotlib and integrates closely with pandas data structures. Visualization is the central part of Seaborn which helps in exploration and understanding of data.

Seaborn offers the following functionalities:
- Dataset oriented API to determine the relationship between variables.
- Automatic estimation and plotting of linear regression plots.
- It supports high-level abstractions for multi-plot grids.
- Visualizing univariate and bivariate distribution.

Scikit Learn

scikit-learn is a Python module for machine learning built on top of SciPy and is distributed under the 3-Clause BSD license.

Scikit-learn (formerly scikits. learn and also known as sklearn) is a free software machine learning library for the Python programming language. It features various classification, regression and clustering algorithms including support-vector machines, random forests, gradient boosting, k-means and DBSCAN, and is designed to interoperate with the Python numerical and scientific libraries NumPy and SciPy.

4.2 BACK END

MySQL tutorial provides basic and advanced concepts of MySQL. Our MySQL tutorial is designed for beginners and professionals. MySQL is a relational database management system based on the Structured Query Language, which is the popular language for accessing and managing the records in the database. MySQL is open-source and free software under the GNU license. It is supported by Oracle Company. MySQL database that provides for how to manage database and to manipulate data with the help of various SQL queries. These queries are: insert records, update records, delete records, select records, create tables, drop tables, etc. There are also given MySQL interview questions to help you better understand the MySQL database.

MySQL is currently the most popular database management system software used for managing the relational database. It is open-source database software, which is supported by Oracle Company. It is fast, scalable, and easy to use database management system in comparison with Microsoft SQL Server and Oracle Database. It is commonly used in conjunction with PHP scripts for creating powerful and dynamic server-side or web-based enterprise applications. It is developed, marketed, and supported by MySQL AB, a Swedish company, and written in C programming language and C++ programming language. The official pronunciation of MySQL is not the My Sequel; it is My Ess Que Ell. However, you can pronounce it in your way. Many small and big companies use MySQL. MySQL supports many Operating Systems like Windows, Linux, MacOS, etc. with C, C++, and Java languages.

WAMPSERVER

WampServer is a Windows web development environment. It allows you to create web applications with Apache2, PHP and a MySQL database. Alongside, PhpMyAdmin allows you to manage easily your database.

WAMP Server is a reliable web development software program that lets you create web apps with MYSQL database and PHP Apache2. With an intuitive interface, the application features numerous functionalities and makes it the preferred choice of developers from around the world. The software is free to use and doesn't require a payment or subscription.

BOOTSTRAP 5

Bootstrap is a free and open-source tool collection for creating responsive websites and web applications. It is the most popular HTML, CSS, and JavaScript framework for developing responsive, mobile-first websites.

It solves many problems which we had once, one of which is the cross-browser compatibility issue. Nowadays, the websites are perfect for all the browsers (IE, Firefox, and Chrome) and for all sizes of screens (Desktop, Tablets, Phablets, and Phones). **Easy to use**: Anybody with just basic knowledge of HTML and CSS can start using Bootstrap
Responsive features: Bootstrap's responsive CSS adjusts to phones, tablets, and desktops
Mobile-first approach: In Bootstrap, mobile-first styles are part of the core framework
Browser compatibility: Bootstrap 5 is compatible with all modern browsers (Chrome, Firefox, Internet Explorer 10+, Edge, Safari, and Opera)

FLASK

Flask is a web framework. This means flask provides you with tools, libraries and technologies that allow you to build a web application. This web application can be some web pages, a blog, a wiki or go as big as a web-based calendar application or a commercial website.

Using an IDE

As good as dedicated program editors can be for your programming productivity, their utility pales into insignificance when compared to Integrated Developing Environments (IDEs), which offer many additional features such as in-editor debugging and program testing, as well as function descriptions and much more.

Flask is often referred to as a micro framework. It aims to keep the core of an application simple yet extensible. Flask does not have built-in abstraction layer for database handling, nor does it have formed a validation support. Instead, Flask supports the extensions to add such functionality to the application. Although Flask is rather young compared to most Python frameworks, it holds a great promise and has already gained popularity among

Python web developers. Let's take a closer look into Flask, so-called "micro" framework for Python. Flask was designed to be easy to use and extend. The idea behind Flask is to build a solid foundation for web applications of different complexity. From then on you are free to plug in any extensions you think you need. Also you are free to build your own modules. Flask is great for all kinds of projects. It's especially good for prototyping. Flask is part of the categories of the micro-framework. Micro-framework is normally framework with little to no dependencies to external libraries. This has pros and cons. Pros would be that the framework is light, there are little dependency to update and watch for security bugs, cons is that sometime you will have to do more work by yourself or increase yourself the list of dependencies by adding plugins.

5. PROJECT DESCRIPTION :

5.1 PROBLEM DEFINITION :

HR Professionals have many tasks in organizations, including work planning, recruitment, training and development, performance management, compensation and benefits allocation, etc. However, managing these tasks is not easy, and HR professionals must strive to ensure organizations achieve their objectives. This also means that employees must be comfortable and have access to the right tools that contribute to maximum productivity. While human resource management faces plenty of challenges, it is essential that you fully understand them to be prepared to tackle them as they arise before affecting your business' bottom line. One of the major challenges faced by human resource managers is recruitment and selection. HR professionals find it challenging to find a suitable candidate who fits job requirements and adapt to technological changes. Finding a suitable candidate for the job from a large number of applicants is a basic problem for the human resource manager. Recruiters have to take time to screen each and every application to check for relevance. Hence, to avoid unmatched / irrelevant applications, the recruiters have to be very clear and specific in what they post about the prerequisites such as the roles, duties, experience and qualifications. The easiest way to screen them is by conducting telephonic interview /discussions, which turns out to be cost effective than an in- person meeting. Candidates who have qualified in the telephonic discussions may have to travel for a face- to – face meeting with the panels, which could bring in a dilemma of whether the candidates are really serious about relocating and joining as soon as possible. If they are not interested, the valuable time of the panels goes for a waste and possibly the money as well Another major struggles that the recruiters these days' encounter is the requirement of resources to be hired in a very short span of time. With very little time candidates are made to go through multiple rounds screening and interviews, but the need of good calibre and talent is very important at the same time. Also with multiple projects coming up with huge requirements of resources as the companies are growing enormously in size, it is very challenging for the recruiters to meet the expectations with hiring the required numbers and talent as well. HR Managers don't allot specific amount of time to follow an effective way of screening and short listing of candidates for the opportunities that come up. This most often leads to hiring of candidates who may be under qualified, which will in turn lead to terminating candidates within a very short span of time. The absence of a standardized and automated system can lead to a lack of transparency and fairness in candidate evaluation. Furthermore, the absence of predictive behavioural analysis during interviews limits the insights available to HR professionals, potentially leading to suboptimal hiring decisions. The need for a modern, data-driven approach to recruitment is evident, one that addresses these challenges, enhances efficiency, and ensures a fair and unbiased candidate evaluation process. The existing methods are often complex, time-consuming, and prone to bias. The need for a more streamlined, efficient, and unbiased recruitment process led to the development of Virtual HR. This innovative system aims to automate and enhance various aspects of recruitment, including resume analysis, candidate shortlisting, and virtual interviews, using advanced technologies like artificial intelligence and deep learning.

5.2 OVER VIEW OF THE PROJECT

An interview is a meeting of people in a face-to-face situation. In common parlance, the word interview refers to a one-on-one conversation. This is done with one person acting in the role of interviewer and another in the role of the interviewee. The interviewer is the person taking the interview, he/she asks the questions and seek an answer to the questions. The interviewee is the respondent and answers all the questions.

5.2.1. Importance of Interviews

Interviews make all of us nervous since these are the deciding factor in whether you will get the job or not. We will be discussing the details of an interview in this article. Interviews make an important part of the recruitment process. They are meant to assess the candidate on different parameters including the following:

Is the candidate the right fit for the organization's work culture?

This is an important point of judgement since the candidate must be a fit in the organization's work culture. This ensures that there are no fundamental conflicts between the company and employees. It also helps the candidate to easily adapt to the company policies and guidelines. This ensures a healthy work environment.

Does the candidate have the required skillset?

Through different interview rounds, you will be able to assess if the candidate has the required skill set for the job profile. This is the most important part of the assessment. It ensures that the company is hiring the most capable employee for that job role.

Is the resume in alignment with the candidate's profile?

Through various stages of the interview process, the recruitment team can tell if the candidate's skillsets and experience justify the resume. The team will be able to pinpoint the areas of conflict while assessing the candidate through different interview rounds.

5.2.2. Software Engineer Interview

A software engineer interview is a process by which potential employers get to know a candidate to see if they're a good fit for a software engineering role. This typically involves answering questions about your work history, experience with different technology and personality, plus tests that determine your skill level for specific programming languages or software creation. The type of questions and the number of interviewers often depend on the size and purpose of the company and the level of the role for which you're applying.

5.2.3. Types of software engineer interviews

Most software engineer interviews consist of a few different types of interview sections that help employers get a fuller understanding of your ability to fit into their job opening. Examine the following types of interviews you may encounter during the software engineer hiring process to help you better prepare

- **Phone screens**

The phone screening portion of a software engineer interview usually begins with a brief conversation with a recruiter. The recruiter may ask you for information about your interest in the role and discuss the basic requirements. Then, the recruiter helps you schedule the following interview for the company, which is often another phone screen but with the hiring manager. This section of the interview process allows you to ask more specific questions to learn about the company, the role and the responsibilities. The hiring manager may ask you some introductory questions and learn about your special skills and talents.

- **On-site personality questions**

After talking with the hiring manager, they may schedule a series of on-site interviews for you, and one portion of those interviews may involve questions about your personality. This shows employers how you may act in the workplace and whether you'd be a good match for their work environment. The interviewer may split personality questions into these two sections:

- **Behavioural questions:**

Behavioural interview questions are often similar across industries because their purpose is to determine how a candidate may behave in the workplace. These questions may ask about what you would do in certain situations, how you view your skills and what you find important about work.

Company culture-fit questions

Company culture-fit interview questions often differ from one company to another because they're specific to the culture and work environment of the company to which you're applying. An interviewer may ask you culture-fit questions regarding what you want from a workplace and how you value the wo rk the company does.

On-site skill tests

Many software engineer interviews also require on-site skills tests for candidates to ensure you can complete the work of the role effectively. Various employees from the company may ask you questions about the work they do and supervise you as you complete coding problems. Although the specifics of the skill tests depend on the company and the role, they often involve these topics:

Problem-solving

It's typical for a software engineer interview to include coding problems for candidates to solve in front of interviewers so potential employers can understand your thinking process, strengths and applied knowledge. During this portion of your interview, you may solve two to three coding problems while explaining your work to interviewers.

Software architecture

Another test for many software engineering roles is how you understand and apply knowledge about software architecture. For these tests or questions, interviewers may expect you to describe how you would design a system when given a broad concept and a set of parameters or limitations to keep your idea within.

Language knowledge

With so many programming languages with which you can code, interviewers may want to test your ability to use a specific language or multiple languages. If the job for which you're applying requires knowledge of a specific language, you may answer questions about your experience with that language and solve problems using that language.

5.2.4. Human Resource

Human resources (HR) is the set of people who make up the workforce of an organization, business sector, industry, or economy. An HR department is an essential component of any business, regardless of an organization's size. It is tasked with maximizing employee productivity and protecting the company from any issues that may arise within the workforce. HR responsibilities include compensation and benefits, recruitment, retention, firing, and keeping up to date with any laws that may affect the company and its employees.

Recruitment and Staffing

Staffing and recruiting cannot exist without each other, but they are not the same. Recruiting is the process of searching and obtaining prospective candidates for the job. The best candidate is chosen through the selection process, which is a part of staffing. Companies can use internal or external recruiting teams to attract, engage and hire the top candidates. In internal recruitment, current employees can be offered promotions or other positions within the organization. External recruitment methods include job postings, employee referrals, recruitment programs and more. Staffing encompasses all the processes involved in building and retaining the workforce.

5.2.5.ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) is the theory and development of computer systems capable of performing tasks that historically required human intelligence, such as recognizing speech, making decisions, and identifying patterns. AI is an umbrella term that encompasses a wide variety of technologies, including machine learning, deep learning, and natural language processing (NLP). At the simplest level, machine learning uses algorithms trained on data sets to create machine learning models that allow computer systems to perform tasks like making song recommendations, identifying the fastest way to travel to a destination, or translating text from one language to another. Artificial Intelligence History

The term artificial intelligence was coined in 1956, but AI has become more popular today thanks to increased data volumes, advanced algorithms, and improvements in computing power and storage.


Ways of Implementing AI

- **Machine Learning**

It is machine learning that gives AI the ability to learn. This is done by using algorithms to discover patterns and generate insights from the data they are exposed to.

- **Deep Learning**

Deep learning, which is a subcategory of machine learning, provides AI with the ability to mimic a human brain's neural network. It can make sense of patterns, noise, and sources of confusion in the data.

Content based Filtering

Content-based filtering is a type of recommendation system that is able to give each user a very personalized item recommendation. Content-based filtering in recommender systems recommends items to users based on their previous actions or preferences. It analyzes item metadata to identify items with similar characteristics to those that the user has interacted with before. This approach examines the characteristics of the items users have expressed an interest in to recommend similar items, unlike collaborative filtering, which finds similarities among users. Content-based filtering is widely used in e-commerce, news feeds, music, and movie recommendations.
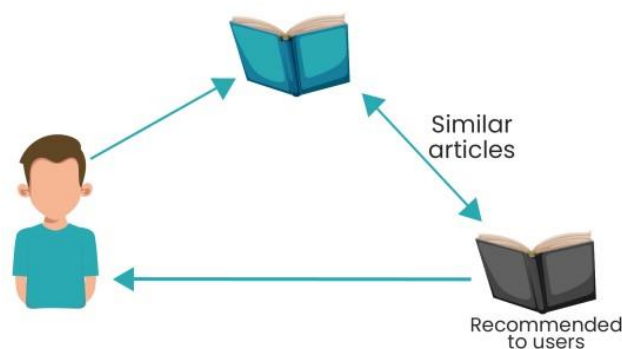
Natural Language Processing

Natural Language Processing (NLP) is a branch of Artificial Intelligence focused on the relationship between human language and machines, based on the use of natural language. Both NLP and Machine Learning are part of AI, and both share techniques, algorithms, and applications. In fact, Chatbots with Artificial Intelligence involve a combination of natural language processing and Machine Learning. What is expressed in writing or orally generates a large amount of data and information. Humans can communicate and interpret this information through the tone, the structure of a sentence, idioms, and other linguistic elements, and the choice of certain words, expressions, and punctuations. And machines can understand that complex set of data and information through natural language processing.

Basic NLP tasks include tokenization and parsing, lemmatization/stemming, part-of-speech tagging, language detection and identification of semantic relationships.

Content categorization: - A linguistic-based document summary, including search and indexing, content alerts and duplication detection.

Topic discovery and modelling: - Accurately capture the meaning and themes in text collections, and apply advanced analytics to text, like optimization and forecasting. **Contextual extraction:-** Automatically pull structured information from text-based sources. **Sentiment analysis :-** Identifying the mood or subjective opinions within large amounts of text, including average sentiment and opinion mining.

Speech-to-text and text-to-speech conversion: - Transforming voice commands into written text, and vice versa.

**Document summarization: -** Automatically generating synopses of large bodies of text.

Machine translation: - Automatic translation of text or speech from one language to another.

Attention Mechanism

Attention is one of the most researched concepts in the domain of deep learning for problems such as neural machine translation and image captioning. There are certain supporting concepts that help better explain the attention mechanism idea as a whole, such as Seq2Seq models, encoders, decoders, hidden states, context vectors, and so on.

Attention in Sequence to Sequence Models

The Seq2Seq learning model is what gave rise to the attention mechanism. A better explanation is that attention was introduced to resolve the main issue with Seq2Seq models. To begin with, Seq2Seq models utilize the encoder-decoder architecture to solve a problem, be it translating a sentence or identifying the elements of an image.
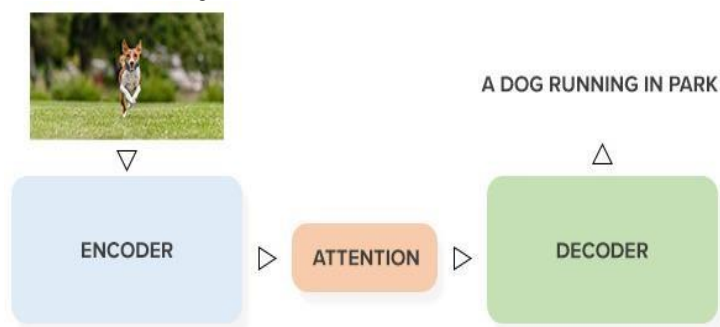
Long input sequences and images with more than one element are often difficult for these models to process accurately. Each element of an input sequence is turned into a hidden state in an encoder to be fed into the next element. During the decoding process, only the last hidden state with some weighted component is used to set the context for the corresponding element of the output sequence.

With an attention model, the hidden states of the input sequence are all retained and utilized during the decoding process. A unique mapping is created between each time step of the decoder output and the encoder input. Each element of the output sequence coming out of the decoder has access to the entire input sequence to select the appropriate elements for the output.

5.3 MODULE DESCRIPTION

1. Virtual HR Web App

The VirtualHR web app is design and develop using Python, Flask, MySQL, and Bootstrap to create a dynamic and efficient recruitment platform. The Candidate Registration module allows candidates to effortlessly create profiles. Job Posting Management facilitates HR professionals in posting and managing job vacancies. Resume Analysis automates the initial screening of resumes, enhancing candidate-job alignment accuracy. Automated Virtual Interviews conduct aptitude tests, programming skill assessments, and video interviews for a comprehensive evaluation. NLP Integration ensures a conversational interface during interviews. The Attention Mechanism predicts and analyses candidate behaviour, providing insights into engagement. The Common Interview Questions Module presents standardized questions for consistent evaluations. These modules collectively contribute to an effective and user-friendly VirtualHR web app, streamlining the recruitment workflow.

2. End User Dashboard

The end user interface of the VirtualHR web app is designed to cater to different roles, ensuring a user-friendly experience for administrators, candidates, recruiters, and HRBot.

2.1. Web Admin

Login: The web admin interface allows administrators to securely log in, ensuring access to the admin dashboard.
Approve Employers Registration: Admins can review and approve employer registrations, facilitating the on boarding process.
User Management: The admin dashboard includes user management features, allowing administrators to manage and oversee user accounts.
Aptitude Question Management:

Web Admins can add, edit, and delete aptitude questions, ensuring a dynamic assessment pool.
Programming Question Management:
Web Admins can add, edit, and delete programming questions for an adaptable question repository.

System Maintenance

Regular maintenance activities conducted by Web Admins ensure optimal platform performance and security.

2.2. Candidate

Register: Candidates can easily register by providing necessary information to create their profiles.
Login: A secure login feature allows candidates to access their profiles.
Update Profile: Candidates can update their profiles with relevant information.
Upload Resume: The platform enables candidates to upload their resumes for job applications.
Receive Interview Notification: Candidates receive notifications about upcoming interviews.
Attend Interview: The interface allows candidates to attend virtual interviews seamlessly.

2.3. Recruiters

Register the Company: Recruiters can register their companies through a straightforward registration process.

Receive Registration Approval: After registration, recruiters await approval from administrators.

Login: Recruiters can log in securely to access the recruiter dashboard.

Job Postings: Recruiters can post job vacancies, specifying roles and requirements. **Receive Shortlisted Resumes:** Recruiters receive resumes that match their job postings through the platform.

Select Resumes from Shortlisted: Recruiters can review and select resumes from the shortlisted candidates.

Receive Selected Candidate Lists with Assessment Report: The platform provides recruiters with a list of selected candidates along with assessment reports.

2.4. HRBot

Shortlist Candidates using Content-Based Filtering: HRBot utilizes content-based filtering to shortlist candidates automatically.

Send List to Recruiters: The HRBot communicates with recruiters by sending shortlisted candidate lists.

Receive Selected Resumes: Recruiters send back their selections to the HRBot for further processing.

Announce and Notify Interview Dates: HRBot announces interview dates and notifies candidates through email and SMS, containing a secure URL with login credentials.

Conduct Aptitude Tests: HRBot conducts aptitude tests for candidates.

Conduct Skill Test Interview: Candidates who pass the aptitude test undergo skill test interviews.

Conduct Virtual Interview: Virtual interviews with audio and video features are conducted for candidates who clear the skill test.

Select the Best Candidate: HRBot selects the best candidates based on assessments and interviews.

Send Report to Recruiters: The HRBot sends comprehensive reports to recruiters, including assessment reports of the selected candidates.

3. Resume Short Listing

The Resume Shortlisting Module utilizing Content-Based Filtering to streamlining the initial phase of candidate selection. The process begins with analysis of resume content, extracting relevant keywords, and identifying key skills and qualifications through sophisticated natural language processing techniques. Recruiters then specify job requirements, outlining the necessary criteria for a particular position. Both candidate resumes and job specifications undergo vectorization, transforming them into numerical representations using techniques like TF-IDF.The core of the module involves calculating the similarity between vectorised resumes and job specifications using algorithms like cosine similarity. Based on these similarity scores, candidates are ranked, and the system shortlists those whose resumes closely align with the specified job requirements. The content-based filtering algorithm continuously learns and adapts based on recruiter feedback, enhancing its accuracy over time. Integrated seamlessly into the overall recruitment workflow, this module ensures an efficient transition from resume shortlisting to subsequent stages such as interviews and final candidate selection, contributing to a streamlined and effective talent acquisition process in the VirtualHR system.

4. Schedule Bot

The Schedule Bot Module in VirtualHR is designed to automate and streamline the scheduling process for virtual interviews. With a focus on optimizing efficiency, the Schedule Bot dynamically coordinates interview schedules by considering the availability of both candidates and interviewers. This smart coordination ensures interviews are scheduled at convenient times, enhancing the overall candidate experience. The bot sends automated notifications to candidates, providing details such as date, time, and platform links. Additionally, the module integrates seamlessly with calendar systems, preventing conflicts and allowing for real-time updates. Offering flexibility, the Schedule Bot accommodates rescheduling requests and proposes alternative times when needed. Its communication features keep HR professionals and interviewers informed throughout the process.

5. Automated Virtual HR

This module encompasses three integral stages: Aptitude Testing, Programming Skill Assessment, and Video Calling Interviews facilitated by HRBot.

5.1. Aptitude Test

The Aptitude Test Module within VirtualHR is designed to systematically assess candidates' cognitive abilities, problem-solving skills, and critical thinking. HRBot, the intelligent assistant, automates the administration of aptitude tests to candidates who have successfully passed the initial screening stages. Candidates access the tests through a user-friendly interface, enabling them to take the assessments remotely. As candidates complete the aptitude tests,
HR Bot scores their responses in real-time, providing immediate feedback on their performance.

5.2. Programming Skill Test

The Programming Skill Test Module within VirtualHR is designed to assess candidates' coding proficiency and problem-solving skills. This module employs tailored programming challenges to objectively evaluate a candidate's ability to write efficient and correct code. HRBot, the intelligent assistant,

automates the administration of programming skill tests to candidates who have successfully cleared the aptitude testing stage. Candidates access the coding challenges through an intuitive interface, providing them with a platform to showcase their programming prowess. As candidates submit their code solutions, the module features real-time code evaluation. HRBot assesses correctness, efficiency, and adherence to coding standards instantly. Immediate feedback is provided, offering candidates insights into their coding performance. Candidates receive detailed feedback on their code submissions, highlighting areas of strength and improvement. Results of the test is provided to the HR professionals with valuable insights for the candidate selection process.

5.3. Video Calling Interview

The final stage involves video interviews facilitated by VirtualHR, introducing a humanlike interaction through natural language processing (NLP). The module utilizes audio and video capabilities to record candidates' responses, capturing both verbal and non-verbal cues. Candidates, in turn, engage with HRBot using spoken language, creating an interactive and dynamic interview environment that closely mirrors human-to-human interaction. By leveraging NLP, the system can comprehend the semantics of candidate responses, allowing for a conversational flow that goes beyond the traditional question-and-answer format. This approach contributes to a more human-like interview experience, fostering engagement and enabling candidates to express themselves naturally. Advanced NLP techniques are employed to understand, interpret, and respond to candidates' answers, ensuring a dynamic and engaging interview experience. This technology empowers the system to not only understand the spoken language of candidates but also to interpret the nuances, context, and subtleties within their responses.

5.4. Behavioural Prediction

The Behavioural Prediction Module is designed to offer insights into candidates' interpersonal dynamics through the use of the Attention Mechanism. This mechanism plays a central role in predicting candidate behaviour by analysing key non-verbal cues, such as gaze, attitude, and head rotations, during virtual interviews. These behavioural predictions contribute significantly to a comprehensive assessment, providing HR professionals with additional layers of understanding beyond traditional evaluations.
Gaze analysis tracks the direction of a candidate's attention, offering insights into their focus and engagement levels. Attitude assessment interprets candidates' body language and postures, providing context on their overall demeanour. Head rotation monitoring actively observes how candidates engage with the interview conversation, indicating responsiveness and interest. This module is instrumental in aiding HR professionals in making informed decisions regarding team fit, communication style, and overall compatibility with the organizational culture.

6. Candidates Report

The Candidate Reports Module is designed to deliver a consolidated and detailed overview of candidates' capabilities, performance, and suitability for specific roles. This module seamlessly integrates assessment results from various stages, including aptitude tests, programming skill evaluations, and behavioural predictions derived from the Attention Mechanism during virtual interviews. The inclusion of behavioural insights offers HR professionals a nuanced understanding of candidates' engagement levels, communication skills, and overall demeanour. This module facilitates efficient decision-making during the candidate selection process.

7. Notification

The Notification Module in VirtualHR stands as a central pillar for streamlined and timely communication throughout the recruitment journey. By automating communication processes, this module ensures that stakeholders, including candidates, HR professionals, and interviewers, receive relevant updates in a prompt and consistent manner. Candidates benefit from automated notifications at key stages, such as application acknowledgment, test invitations, interview schedules, and final outcomes. These notifications are delivered through diverse channels, including email, SMS, and in-app messages, accommodating candidates' communication preferences. For interviewers and HR professionals, the module offers timely notifications regarding upcoming interviews, changes in schedules, and updates on candidate progress. These notifications include pertinent details, such as candidate profiles and interview formats, facilitating a well-informed assessment process.

6. SYSTEM DESIGN

6.1 UNIT TESTING

Unit testing involves the examination of individual units or components of a software application in isolation. It is typically performed by developers during the coding phase to ensure each unit functions as intended.

6.2 INTEGRATION TESTING

Integration testing verifies the interaction and collaboration between different components or systems within the software. The goal is to detect any issues arising from the integration of these components.

6.3 VAILDATION TESTING

Validation testing is a critical phase of software testing that ensures the software meets the intended requirements and specifications and satisfies the needs of its users. This type of testing focuses on verifying that the software delivers the expected functionality and performs as intended in the real-world environment.

6.4 SYSTEM TESTING

Software testing is a crucial phase in the software development life cycle (SDLC) that focuses on verifying and validating that a software application or system meets specified requirements and functions correctly. The primary objective is to identify and rectify defects or bugs before the software is released to end-users, ensuring a high-quality product.

TEST CASES

Test Case ID: 1.1 - Web Admin Login

- **Input:** Valid admin username and password.
- **Expected Result:** Successful login, redirecting to the admin dashboard.
- **Actual Result:** Admin dashboard displayed after successful login.
- **Status:** Pass

Test Case ID: 1.2 - Approve Employers Registration

- **Input:** List of employer registrations pending approval.
- **Expected Result:** Successful approval and notification sent to employers.
- **Actual Result:** Employers approved, and notifications sent.
- **Status:** Pass

Test Case ID: 1.3 - User Management

- **Input:** Admin interface to manage user accounts.
- **Expected Result:** Successful management of user accounts (add/edit/delete).
- **Actual Result:** User accounts managed successfully.
- **Status:** Pass

Test Case ID: 1.4 - Aptitude Question Management

- **Input:** Adding, editing, and deleting aptitude questions.
- **Expected Result:** Dynamic assessment pool with updated questions.
- **Actual Result:** Aptitude questions managed successfully.
- **Status:** Pass

Test Case ID: 1.5 - Programming Question Management

- **Input:** Adding, editing, and deleting programming questions.
- **Expected Result:** Adaptable question repository with updated programming questions.
- **Actual Result:** Programming questions managed successfully.
- **status:** Pass

Test Case ID: 1.6 - System Maintenance

- **Input:** Regular maintenance activities performed by Web Admins.
- **Expected Result:** Optimal platform performance and security.
- **Actual Result:** Maintenance activities completed successfully.
- **Status:** Pass

Test Case ID: 2.1.- Candidate Register

- **Input:** Candidate registration form with necessary information.
- **Expected Result:** Successful creation of a candidate profile.
- **Actual Result:** Candidate profile created successfully.
- **Status:** Pass

Test Case ID: 2.2 - Candidate Login

- **Input:** Candidate username and password.

- **Expected Result:** Successful login, redirecting to the candidate's profile.

- **Actual Result:** Candidate logged in successfully.

- **Status:** Pass

Test Case ID: 2.3 - Update Profile

- **Input:** Candidate profile update with relevant information.

- **Expected Result:** Successful update of the candidate's profile.

- **Actual Result:** Candidate profile updated successfully.

- **Status:** Pass

Test Case ID: 2.4 - Upload Resume

- **Input:** Candidate uploads a resume for job applications.

- **Expected Result:** Successful upload of the resume.

- **Actual Result:** Resume uploaded successfully.

- **Status:** Pass

Test Case ID: 2.5 - Receive Interview Notification

- **Input:** Candidate receives an interview notification.

- **Expected Result:** Notification with interview details received by the candidate.

- **Actual Result:** Interview notification received successfully.

- **Status:** Pass

Test Case ID: 2.6 - Attend Interview

- **Input:** Candidate attends a virtual interview.

- **Expected Result:** Seamless attendance at the virtual interview.

  - **Actual Result:** Candidate attended the interview successfully.

Test Case ID: 3.1 - Register the Company

- **Input:** Recruiter registration form with company details.

- **Expected Result:** Successful registration of the company.

- **Actual Result:** Company registered successfully.

- **Status:** Pass

Test Case ID: 3.2 - Receive Registration Approval

- **Input:** Recruiters awaiting approval from administrators.

- **Expected Result:** Successful approval of recruiter registration.

- **Actual Result:** Registration approved successfully.

- **Status:** Pass

Test Case ID: 3.3 - Login

- **Input:** Recruiters log in securely to access the recruiter dashboard.

- **Expected Result:** Successful login to the recruiter dashboard.

- **Actual Result:** Recruiters logged in successfully.

- **Status:** Pass

Test Case ID: 3.4 - Job Postings

- **Input:** Recruiters post job vacancies with roles and requirements.

- **Expected Result:** Successful posting of job vacancies.

- **Actual Result:** Job vacancies posted successfully.

- **Status:** Pass

Test Case ID: 3.5 - Receive Shortlisted Resumes

- **Input:** Recruiters receive resumes that match their job postings.

- **Expected Result:** Resumes matching job postings received by recruiters.

- **Actual Result:** Resumes received successfully.

- **Status:** Pass

Test Case ID: 4.1 - HRBot Shortlist Candidates using Content-Based Filtering

- **Input:** Candidate profiles and job requirements.

- **Expected Result:** HRBot uses content-based filtering to shortlist candidates automatically.
- **Actual Result:** Candidates shortlisted based on content-based filtering.

- **Status:** Pass

Test Case ID: 4.2 - HRBot Send List to Recruiters

- **Input:** HRBot communicates with recruiters by sending shortlisted candidate lists.

- **Expected Result:** Recruiters receive the list of shortlisted candidates.

  - **Actual Result:** List sent to recruiters successfully.

- **Status:** Pass

Test Case ID: 4.3 - Recruiters Receive Selected Resumes

- **Input:** Recruiters send back their selections to the HRBot for further processing.

- **Expected Result:** HRBot receives the selections made by recruiters.

- **Actual Result:** Selections received successfully.

- **Status:** Pass

Test Case ID: 4.4 - HRBot Announce and Notify Interview Dates

- **Input:** HRBot announces interview dates and notifies candidates through email and SMS.
- **Expected Result:** Candidates receive interview notifications with secure URLs.

- **Actual Result:** Notifications sent successfully.

- **Status:** Pass

Test Report

   Introduction: The Virtual HR System is a comprehensive recruitment platform that utilizes AI-driven technologies to streamline and automate the hiring process. This report provides an overview of the testing activities conducted to ensure the reliability and functionality of the system.

   Test Objective: The primary objective of the testing phase was to verify the accuracy, efficiency, and robustness of the Virtual HR System. Specific objectives included validating user interfaces, assessing functionality across modules, and ensuring seamless communication between system components.

   Test Scope: The testing scope covered various modules, including Web Admin, Candidate, Recruiters, and HRBot. Each module's functionalities, such as registration, login, interview scheduling, and candidate shortlisting, were thoroughly tested.

Test Environment: The testing environment consisted of the following components:

- Web browsers: Chrome, Firefox, Safari

- Operating Systems: Windows 10, macOS, Linux

- Database: MySQL

- Hardware: Standard PC configurations

Test Conclusion

   The testing phase confirmed the Virtual HR System's overall functionality and reliability. The system successfully passed various test scenarios, ensuring that it meets the specified requirements. Any identified issues were addressed and resolved, contributing to the system's overall robustness.
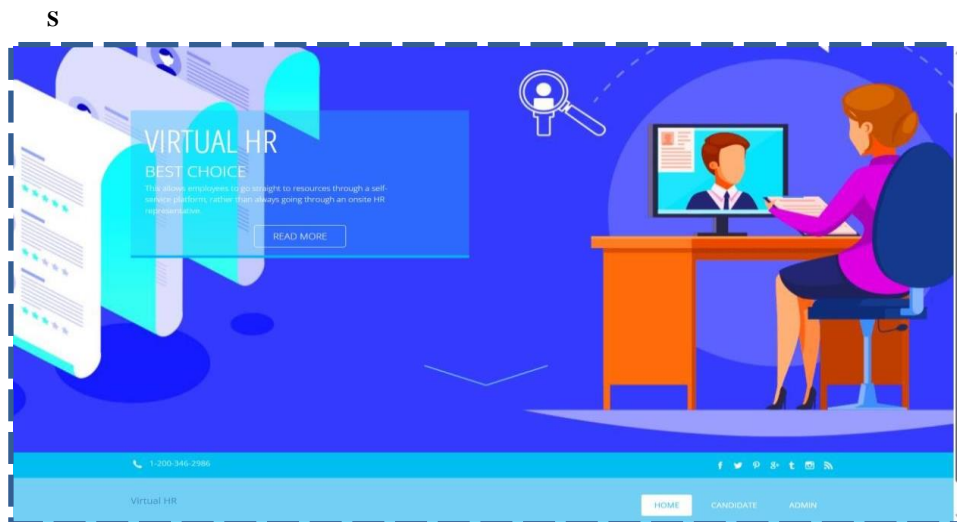
7. SYSTEM IMPLEMENTATION

System implementation in the development lifecycle of the Virtual HR system. This phase involves putting the designed system into action, making it accessible to users, and ensuring that it functions according to the specified requirements. Below are the key steps and considerations involved in the implementation of the Virtual HR system

1. **Deployment Planning:** Develop a comprehensive deployment plan outlining tasks, responsibilities, and timelines. Ensure effective coordination among the development team, system administrators, and other relevant stakeholders.
2. **Server and Infrastructure Setup:** Configure servers, databases, and infrastructure components to support Virtual HR. Prioritize scalability, security, and optimal performance during this phase.
3. **Database Population:** Populate the database with initial data, including user accounts and system configurations. Verify data integrity and alignment with system requirements.
4. **Software Deployment:** Deploy the Virtual HR application on the designated web server.
   Ensure all necessary files, scripts, and configurations are in place for proper functionality.
5. **User Training:** Conduct training sessions for end users, administrators, and stakeholders. Provide guidance on system navigation, feature utilization, and role-specific responsibilities.
6. **Data Migration:** If applicable, migrate data from existing systems to Virtual HR. Ensure a seamless transition of relevant data while maintaining accuracy.
7. **Integration Testing:** Perform integration testing to ensure cohesive functionality among system components. Identify and address issues related to module interactions or external system integrations.
8. **User Acceptance Testing (UAT):** Conduct UAT sessions with representative users to evaluate system performance and usability. Gather feedback for adjustments before the system goes live.

only addresses the challenges of the current recruitment landscape but also sets the stage for future advancements. By incorporating AI, NLP, and Attention Mechanism, Virtual HR emerges as a transformative tool, redefining how organizations approach talent acquisition. The project's user-centric design, data-driven decision-making, and continuous learning mechanisms position it as a valuable asset in the evolving field of HR technology. This project stands as a beacon, paving the way for future advancements in the field.

8.SCREENSHOTS

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8.1 HOME PAGE

8.2 CANDIDATE REGISTRATION

8.3 CANDIDATE DETAILS

8.4 HR JOB POSTED

8.5 JOB VACANCIES
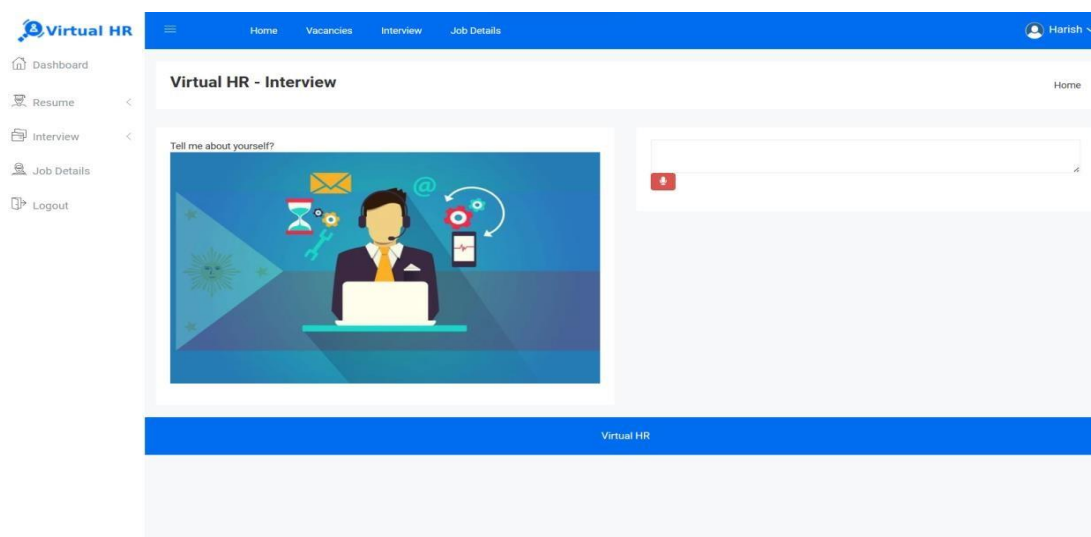
9. CONCLUSION :

In conclusion, the Virtual HR project represents a transformative leap in modernizing the recruitment process. By harnessing advanced technologies such as artificial intelligence, natural language processing, and adaptive algorithms, the project has successfully created a comprehensive and user-centric solution. The user-friendly web app, coupled with specialized modules and an Automated Virtual HR system, streamlines every aspect of the recruitment workflow. Key highlights include the innovative use of NLP for conversational interviews, content-based filtering for AI-driven shortlisting, and the Schedule Bot for efficient interview coordination. The project's emphasis on data-driven decision-making, continuous learning mechanisms, and a holistic approach to candidate assessment positions it at the forefront of HR technology. With its ability to provide in-depth candidate insights, streamline communication through the Notification module, and enhance overall efficiency, Virtual HR sets new standards in talent acquisition. This project not only addresses the challenges of the current recruitment landscape but also sets the stage for future advancements. By incorporating AI, NLP, and Attention Mechanism, Virtual HR emerges as a transformative tool, redefining how organizations approach talent acquisition. The project's user-centric design, data-driven decision-making, and continuous learning mechanisms position it as a valuable asset in the evolving field of HR technology. This project stands as a beacon, paving the way for future advancements in the field.

10. REFERENCE:

[1] G. Bied, S. Nathan, E. Perennes, M. Hoffmann, P. Caillou, B. Crépon, et al., "Toward Job Recommendation for All", *Thirty-Second Internat ional Joint Conference on Artificial Intelligence {IJCAI-23}*, pp. 5906-5914, 2023. H. Wang, W. Yang, J. Li, J. Ou, Y. Song and Y. Chen, "An improved heterogeneous graph convolutional network for job recommendation", *Engineering Applications of Artificial Intelligence*, vol. 126, pp. 107147, 2023.

[2] S. Bera, B. Ghosh and D. Vanusha, "Resume classification using bidirectional lstm and attention mechanism", *Ambient Communications and Computer Systems*, pp. 233-241, 2022.

[3] S. Eliyas and P. Ranjana, "Recommendation systems: Content-based filtering vs collaborative filtering", *2022 2nd International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE)*, pp. 1360-1365, 2022.

[4] A. Gardiner, C. Aasheim, P. Rutner and S. Williams, "Skill requirements in big data: A content analysis of job advertisements", *J. Comput. Inf. Syst.*, vol. 58, no. 4, pp. 374384, 2018.

[5] A. Köchling and M. C. Wehner, "Discriminated by an algorithm: a systematic review of discrimination and fairness by algorithmic decision-making in the context of HR recruitment and HR development", *Bus. Res*, vol. 13, no. 3, pp. 795-848, 2020.