

**TRIBHUVAN UNIVERSITY
INSTITUTE OF ENGINEERING**



**LALITPUR ENGINEERING COLLEGE
CHAKUPAT, LALITPUR**

**A PROPOSAL OF MAJOR PROJECT
DefaceLab: DeepFake Detection using ViT**

SUBMITTED BY

**ABHISHEK NEUPANE [LEC076BCT002]
RABINDRA ADHIKARI [LEC076BCT025]
SANJISH MAHARJAN [LEC076BCT032]
SUSHIL KAFLE [LEC076BCT045]**

SUBMITTED TO

DEPARTMENT OF COMPUTER ENGINEERING

Bhadra 2080

DefaceLab: DeepFake Detection using ViT

Submitted by

ABHISHEK NEUPANE [LEC076BCT002]
RABINDRA ADHIKARI [LEC076BCT025]
SANJISH MAHARJAN [LEC076BCT032]
SUSHIL KAFLE [LEC076BCT045]

Project Supervisor
Er. Bisikha Subedi

A project submitted in partial fulfillment of the requirements for the degree of
Bachelor of Computer Engineering

DEPARTMENT OF COMPUTER ENGINEERING
Lalitpur Engineering College
Tribhuvan University

2080-04-01

ABSTRACT

Deepfakes are realistic-looking fake media generated by deep-learning algorithms that iterate through large datasets until they have learned how to solve the given problem (i.e., swap faces or objects in video and digital content). The massive generation of such content and modification technologies is rapidly affecting the quality of public discourse and the safeguarding of human rights. Deepfakes are being widely used as a malicious source of misinformation in court that seek to sway a court's decision. Because digital evidence is critical to the outcome of many legal cases, detecting deepfake media is extremely important and in high demand in digital forensics. As such, it is important to identify and build a classifier that can accurately distinguish between authentic and disguised media, especially in facial-recognition systems as it can be used in identity protection too. This is what we tend to do. In this work, we will be using the quiet recent Vision Transformer Model, as it uses the attention based mechanism. Since, the Vision transformer has its own unique attributes and is very much reliable and provides a lot of significant merits in development compared to others, we plan to implement it for our work, for the detection of the AI generated images.

Keywords: *deepfake detection; digital forensics; media forensics; deep learning; Visual Transformer; AI generated images*

Contents

1	INTRODUCTION	1
1.1	Background	3
1.2	Problem Statement	4
1.3	Objectives	5
1.4	Scope	6
2	LITERATURE REVIEW	7
2.1	Existing Systems	9
2.1.1	Deepware	9
2.1.2	DuckDuckGoose	9
2.2	Proposed Systems	10
3	FEASIBILITY STUDY	11
3.1	Economic feasibility	11
3.2	Operational feasibility	11
3.3	Technical feasibility	11
4	METHODOLOGY	12
4.1	Software Development Life Cycle	12
4.2	System Development Tools	13
4.3	Functional Requirement	13
4.4	Non Functional Requirement	13
4.5	Approach for Deepfake Detection	13
4.5.1	Dataset Collection	14
4.5.2	Preprocessing	17
4.5.3	Vision Transformer Architecture	18
5	BLOCK DIAGRAMS	20
5.1	System Architecture	20
5.2	Use Case Diagram	21
5.3	Sequence Diagram	22
5.4	Dataflow Diagram	23
5.5	Activity Diagram	24
6	Result and Analysis	25
6.1	UI of Project	25
7	EXPECTED OUTCOMES	28

List of Figures

1	Deepware	9
2	DuckDuckGoose	9
3	DefaceLab	10
4	Agile Model	12
5	Video Sample	15
6	Frames Extracted from video	15
7	Frames Extracted from video	16
8	Facial landmarks extraction from video	16
9	Normalization	17
10	Patch Embedding	18
11	Transformer encoder	19
12	Vision Transformer Architecture	19
13	System Architecture	20
14	Use Case Diagram	21
15	Sequence Diagram	22
16	Level 0 DFD	23
17	Level 1 DFD	23
18	Activity Diagram	24
19	Login Page	25
20	Home Page	26
21	Upload image Menu	27

Abbreviations

AI	Artificial Intelligence
CASIA	Chinese Academy of Sciences Institute of Automation
DL	Deep Learning
FPS	Frames Per Second
GANs	Generative Adversarial Networks
ML	Machine Learning
ViT	Vision Transformer

1 INTRODUCTION

Deepfake technology has revolutionized the world of digital media manipulation. By combining artificial intelligence and image/video processing, deepfakes have garnered widespread attention. Deepfakes involve the creation of realistic media portraying individuals in situations they never experienced or saying things they never said. As this technology becomes more sophisticated, concerns arise regarding its impact on politics, entertainment, and personal privacy. This report provides an overview of deepfakes, including their underlying processes, societal implications, ethical challenges and the way of detection. In navigating this landscape, it is crucial to find a balance between innovation and responsible use in our increasingly digitized society.

In the last few years, cybercrime, which accounts for a 67% increase in the incidents of security breaches, has been one of the most challenging problems that national security systems have had to deal with worldwide.[1] Deepfakes, at present time, are being widely used to swap faces or objects in video and digital content. This artificial intelligence-synthesized content can have a significant impact on the determination of legitimacy due to its wide variety of applications and formats that deepfakes present online (i.e., audio, image and video). Given the speed, simplicity, and effects of social media, convincing deepfakes can easily persuade millions of people, ruin the lives of their victims, and have a detrimental effect, persuasive deepfakes can rapidly influence millions of people, destroy the lives of its victims and have a negative impact on society in general [1]. Deepfake technology has been driven by various motivations, including individual attacks, political manipulation, and the spread of false information. Its impact extends beyond personal attacks to manipulating satellite images and using stock images for identity protection. Cyber attackers continuously adapt their strategies, making it challenging to identify deepfake media and stay ahead of evolving threats.

The societal implications of deepfake technology are profound. Misinformation and disinformation fueled by deepfakes erode public trust, damage reputations, and violate privacy at personal and professional levels. Deepfakes can also disrupt democratic processes and contribute to societal polarization. Addressing the legal and ethical concerns surrounding deepfakes requires technological advancements, policy development, media literacy, and careful consideration of privacy rights and the manipulation of visual evidence. To tackle these implications, it is essential to advance deepfake detection methods, bolster cybersecurity measures, promote media literacy for individuals to discern manipulated content, and establish clear legal frameworks governing the responsible use of deepfake technology. By taking a comprehensive approach, we can effectively navigate the ethical challenges and societal impacts posed by deepfakes.

The deepfake technology holds importance in several areas. It offers creative expression and entertainment possibilities, enhances research and development in fields like computer vision, and aids forensic analysis in legal investigations. Deepfakes also emphasize the need for media literacy and critical thinking skills, promoting education and awareness. Ethical considerations and policy development are crucial in addressing the responsible use of deepfakes and protecting individuals' rights. Understanding the significance of deepfake technology enables us to navigate its implications effectively and harness its potential while mitigating potential harm.

We cannot dispute the influence deep fakes will have in the next years given all the benefits and cons that have been presented. Therefore, keeping an eye on deepfake content is crucial. This paper will provide an overview of the fundamental organizational structure of our project on how deepfake detections can be done.

1.1 Background

At present context of time, the rapid advancements in mobile camera technology and the widespread use of social media platforms have made it easier than ever to create and share digital pictures. Deep learning has played a crucial role in developing technologies that were previously unimaginable. One notable example is modern generative models, which can produce highly realistic images, speech, music, and video. These models have been applied in various fields, such as enhancing accessibility through text-to-speech technology and generating training data for medical imaging.

The deepfakes are created using deep learning techniques like Generative Adversarial Networks (GANs). These techniques involve two main components: a generator and a discriminator. The generator produces fake content, such as faces or scenes, while the discriminator tries to distinguish between real and fake content. Through an iterative process, the generator improves its ability to create increasingly realistic output, aiming to deceive the discriminator. As training progresses, the generated content becomes more convincing, making it difficult to distinguish whether the content is genuine or artificially created. This technology has both creative potential and serious ethical implications, as it can be used for entertainment purposes but also for generating misleading or harmful content.

Deep fakes are now widely disseminated on social media platforms, which encourages spamming and the spread of false information. Just picture a deep fake image of Donald Trump getting arrested which was trending on twitter or a deep fake of a well-known celebrity assaulting their supporters. These types of misinformation can brainwash the audience and are awful and endanger and mislead the general public.

Deep fake detection plays a crucial part in overcoming such a circumstance. Therefore, we provide a novel deep learning-based method that can successfully separate artificial intelligence-generated fake contents from authentic digital materials. In order to identify deep fakes and stop them from spreading across the internet, it is crucial to develop technology that can detect deepfakes.

1.2 Problem Statement

With the help of visual effects, convincing modifications of digital photographs and videos have been proven for many years. However, new developments in deep learning have dramatically increased the realism of fake content and made it more widely available. These purportedly artificial intelligence-generated works of media are also known as "deepfakes". It is easy to create deep fakes utilizing artificial intelligence techniques. However, it is extremely difficult to identify these Deep Fakes. Globally, it is found out that about 71% of total population using internet do not know what a deepfake is. Just under a third of global consumers of internet say they are aware of deepfakes [8]. In the past, there have been numerous instances of deep fakes being used to effectively incite political unrest, stage terrorist attacks, blackmail individuals, etc. In North America alone, the proportion of deepfakes more than doubled from 2022 to 2023. This proportion jumped from 0.2% to 2.6% in the US. It is up from 0.1% to 4.6% in Canada [7] and is rapidly growing. Therefore, it becomes crucial to identify these deep fakes and monitor their spread through social media. Hence, with the growing curiosity we have taken a step forward in detecting the deep fakes using different transformer based models.

1.3 Objectives

- Our project can help in reduction in spread of false informations, that might mislead the people on the internet.
- Our project will distinguish and classify the images either they are deepfaked or not.

1.4 Scope

At present time there are numerous tools available for creating false videos in the current deepfake technology landscape, but there are few trustworthy tools available for spotting them. The idea creation of a deepfake detection software to solve this variance and stop the widespread dissemination of deepfakes is what our project is based upon. Users will be able to post images through our platform and segregate them as authentic or deepfake. This project can also be developed to include the development of a plugin for browsers that will automatically detect deep fakes. Notably, our idea can be implemented on different social sites as well as in various various governmental organizations. A synopsis of the program with the size of the input, bounds on the input, input validation, input dependency, the i/o state diagram, and the major inputs and outputs are explained in this report.

2 LITERATURE REVIEW

Since 2017, the Transformer has been very renowned as a new type of neural architecture which encodes the given input data into a powerful feature, with the help of attention mechanism. With the research article published in 2017, named "Attention Is All You Need" [6], by taking it as a framework, numerous researches has been done recently upon the visions task as well [3]. This is where the Visual Transformer comes in.

While the Transformer Architecture has been a new standard for Natural Language Processing tasks, its application to computer vision remains limited. From many recent studies and researches done, the common points mentioned was that in vision, either the attention is applied in conjunction with convolutional networks, or used to replace certain components of convolutional network while keeping their overall structure in place [4].

The Transformer-liked architecture has been employed in the computer vision field in present context in three fundamental computer vision tasks, namely classification, detection and segmentation [2]. Our work lies within one of these fundamental tasks i.e the detection of artificially generated images of a human face.

The Visual Transformer has been gaining many contributions in recent years such that its capabilities has increased beyond the old traditional models. As a matter of fact, the Visual Transformer model has clear advantages over traditional models such as CNNs and RNNs in specific situations. It can process whole images in sections, which helps it understand the bigger picture. Also, it is good with working on different image sizes and tasks. Training these models on big datasets first and then adjusting it for specific tasks makes it really flexible compared to the traditional model [5]. One of its key characteristics, self-attention, not only helps us understand how the model works but also reminds us to pick the right model based on the job, data, and what we have.

The deepfakes are created using deep learning techniques like Generative Adversarial Networks (GANs). These techniques involve two main components: a generator and a discriminator. The generator produces fake content, such as faces or scenes, while the discriminator tries to distinguish between real and fake content. Through an iterative process, the generator improves its ability to create increasingly realistic output, aiming to deceive the discriminator.

From recent researches done Vision Transformer (ViT) is deemed more suitable than

Generative Adversarial Networks (GANs) for deepfake detection because Vision Transformer is specifically designed for image analysis tasks like classification. GANs are like artists that make fake pictures, but they're not as good at spotting fakes. Also, the tricks that make GANs create fakes can also fool themselves when looking for fakes. Vision transformer way of looking at pictures makes it a good choice for catching fake ones, because it's good at seeing small things that don't match up.

In summary, with all these distinct attributes and merits the Vision Transformer imposes itself significantly compared to others at present time, which has led us to select it as the major model for our project development.

2.1 Existing Systems

2.1.1 Deepware

Deepware.ai is an innovative company at the forefront of deepfake detection technology. They specialize in developing advanced AI-driven solutions to combat the spread of manipulated media content. With a team of expert researchers and engineers, Deepware.ai leverages state-of-the-art machine learning algorithms and deep neural networks to accurately identify deepfakes. Their cutting-edge technology, combined with a user-friendly approach, empowers individuals and organizations to protect themselves from the potentially harmful consequences of deepfakes. Deepware.ai's commitment to continuous improvement and staying ahead of evolving deepfake techniques positions them as a trusted leader in the field, offering reliable and scalable solutions that contribute to a safer digital landscape.



Figure 1: Deepware

2.1.2 DuckDuckGoose

DuckDuckGoose offers an open-source browser extension that keeps tabs on all websites you visit and alert you once manipulated media is detected. Users should also appreciate the transparency of the DeepFake detector, as DuckDuckGoose provides detailed explanations for why a video was flagged to give you some insight on what to look for in a DeepFake. The team behind the tool has been dedicated to sharing their research findings and encouraging participants from the community to contribute to building a more reliable model with higher accuracy.



Figure 2: DuckDuckGoose

2.2 Proposed Systems

Our Deepfake Detection System is an online tool designed to help people identify and deal with deepfake content. It focuses on providing strong detection capabilities for deepfakes. Users can use the system to analyze and detect potential deepfakes by submitting images. The system uses advanced algorithms and machine learning techniques to accurately identify manipulated or fake media. This helps users recognize and address the risks that come with deepfakes, such as spreading false information, committing fraud, or violating privacy. The deepfake detection system aims to empower users by giving them the tools they need to protect themselves and others from the harmful effects of encountering deepfakes. With the help of cutting-edge algorithms, the system assists users in detecting and raising awareness about deepfakes, making the digital world a safer and more informed place.



Figure 3: DefaceLab

3 FEASIBILITY STUDY

3.1 Economic feasibility

This is a low-budget project with no development costs. The total expenditure of the project is just computational power. The dataset and computational power required for the project are easily available. The computational power is easily provided by google collab. So, the project is economically feasible. The system will be simple to comprehend and use. As a result, there will be no need of trained personnel to use the system. This system will have the capacity to expand by adding more components.

3.2 Operational feasibility

The project is operationally feasible since after the completion of the project, it can be operated as intended by the user to solve the problems for what it has been developed.

3.3 Technical feasibility

The purpose of technical feasibility is to establish whether the project is possible in terms of software, hardware, manpower, and knowledge to complete. It will take into account determining resources in support of the suggested scheme. The system is platform independent because it is written in Python. Advanced machine learning libraries are available and the technology is cutting-edge. As a result, the system is technically possible.

4 METHODOLOGY

4.1 Software Development Life Cycle

Agile method of Software Development uses iterative approach. Agile method cycles among Planning, Requirement Analysis, Designing, Development and Testing stages. These cycle is called sprints. Each sprints are considered as a miniature project on itself. Using this method allowed us to update various parts of project at any point of project development. In this model an iterative approach was taken where working software was delivered after each iteration some new features is added to main system. It works in incremental and iterative approach. Agile model mainly focuses on customer collaborations, on individuals and iterations and welcomes changes at anytime in SDLC process. We prefer to use agile model in this system as it helps in developing realistic systems and promotes teamwork during software development. Also system is easy to manage and it can accommodate new changes at any stages of software development phase.

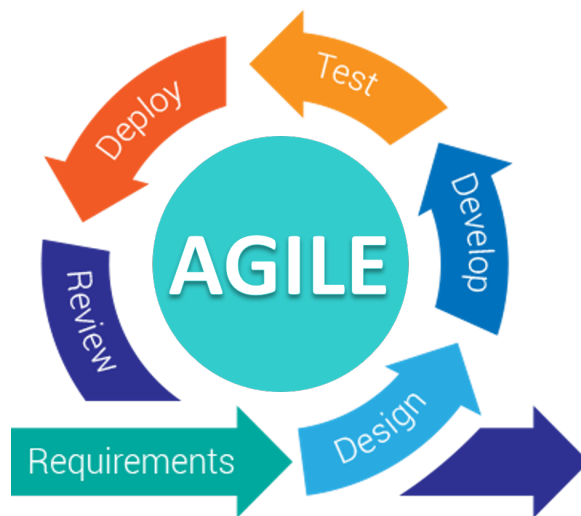


Figure 4: Agile Model

4.2 System Development Tools

Our static Deepfake detection System requires Python, OpenCV, Machine Learning which are listed below:

1. Python
2. Pytorch
3. NumPy
4. OpenCV

4.3 Functional Requirement

The functional requirements of the system are:

1. Accurately distinguish between real and manipulated images.
2. Provide a user-friendly interface for uploading and analyzing images.

4.4 Non Functional Requirement

These requirements are not needed by the system but are essential for the better performance of software. The points below focus on the non-functional requirement of the system.

- Reliability
- Usability
- Security
- Portability
- Speed and responsiveness
- Performance

4.5 Approach for Deepfake Detection

For deepfake detection, our approach combines the power of vision transformers with advanced techniques in computer vision. Vision transformers excel in capturing both global and local features within an image, making them suitable for identifying subtle inconsistencies introduced by deepfake manipulation.

Our approach involves the following steps:

1. **Dataset Collection**
2. **Preprocessing**
3. **Vision Transformer Architecture**
4. **Training**
5. **Evaluation**

4.5.1 Dataset Collection

Our dataset acquisition process involved the following steps:

1. **Public Datasets:** A significant part of our extensive dataset was thoughtfully put together from openly accessible collections of deepfake and authentic images. We carefully chose these datasets to make our deepfake detection model more diverse and applicable. This approach helps us ensure a strong and thorough training and testing process by making the most of these available resources.

Here's the breakdown of our dataset:

- **Trained:** 70,000 samples
- **Tested:** 5,000 samples
- **Validation:** 15,000 samples

Our dataset contains data from well-known public sources, and each of these sources has a specific role in making our deepfake detection system better :

- (a) **DFDC (DeepFake Detection Challenge) Dataset:** The DFDC dataset offers an invaluable benchmark for detecting deepfake manipulations across a wide spectrum of scenarios and visual contexts. Its meticulous curation and large-scale inclusion of deepfake and real videos enable us to train our model on highly realistic and challenging instances.
- (b) **CelebA Dataset:** By incorporating the CelebA dataset, a prominent repository of celebrity faces in diverse poses and expressions, we bolster our model's capacity to handle variations in lighting conditions, facial orientations, and natural facial expressions – all critical aspects in detecting nuanced manipulations.

(c) **CASIA WebFace Dataset:** With the CASIA WebFace dataset, we tap into a wealth of real facial images sourced from the internet, exposing our model to a plethora of natural variations in appearance, pose, and lighting conditions. This exposure fortifies our model’s ability to discern between real and manipulated facial features in an ever-evolving digital landscape.

2. **Video Conversion:** To include videos in our dataset, we first converted them into individual frames (images) to facilitate compatibility with the vision transformer architecture. This step involved extracting frames at a consistent frame rate from each video, resulting in a sequence of images for each video.



Figure 5: Video Sample



Figure 6: Frames Extracted from video

3. **Frame Selection:** To avoid redundancy and maintain dataset balance, we carefully selected frames from videos to represent various stages of manipulation, expressions, poses, and lighting conditions.



Figure 7: Frames Extracted from video



Figure 8: Facial landmarks extraction from video

4. **Annotation and Labeling:** Each image was labeled as either "real" or "deep-fake." Annotations were done manually to ensure accurate labeling for training and evaluation.

4.5.2 Preprocessing

Before training the model, we preprocess the dataset as follows:

1. **Resize:** All images, whether sourced from videos or other datasets, were resized to a consistent resolution of 112x112 pixels. This resizing ensured a uniform input size for the vision transformer.
2. **Augmentation:** To increase the dataset's diversity and improve the model's ability to generalize, we applied various data augmentation techniques. These techniques included random rotations, horizontal flips, brightness adjustments, and minor deformations.
3. **Normalization:** Pixel values of the images were normalized to a specific range to ensure consistent input for the model during training and inference.

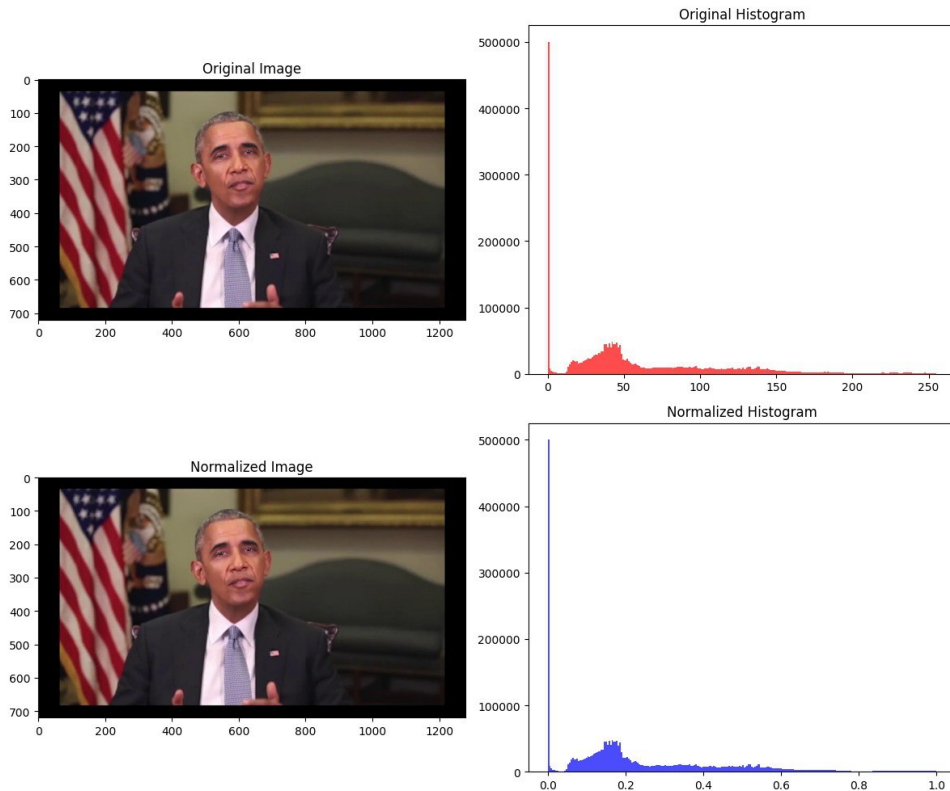


Figure 9: Normalization

By preprocessing the dataset, we enhanced the model's capacity to learn relevant features and intricate patterns required for accurate deepfake detection.

4.5.3 Vision Transformer Architecture

The Vision Transformer (ViT) architecture comprises the following components:

Patch Embedding: The process begins by dividing the input image into non-overlapping patches. Each patch is then transformed into an embedding through a linear projection. These embeddings are further enhanced with positional encodings. Positional encodings are crucial because transformers don't inherently understand the spatial relationships between elements, and these encodings provide information about the patch's position in the image.

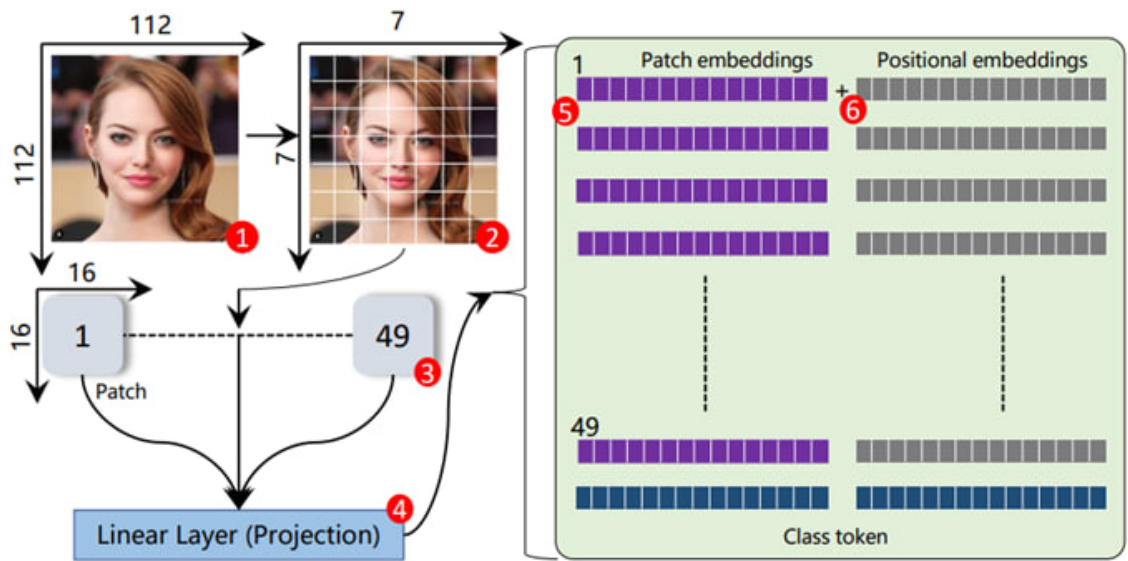


Figure 10: Patch Embedding

Transformer Encoder: The patch embeddings are then processed through a stack of transformer encoder layers. Each of these layers consists of two main components: multi-head self-attention and feedforward neural networks.

1. **Multi-head self-attention:** This mechanism allows the model to consider relationships between different patches, both locally and globally. It assigns different attention weights to different patches based on their relevance to each other. This is particularly powerful as it enables the model to capture long-range dependencies and relationships within the image.
2. **Feedforward neural networks:** After the attention mechanism, the data passes through feedforward neural networks, which are designed to process and transform the information further. This step helps the model learn intricate features and patterns in the image data.

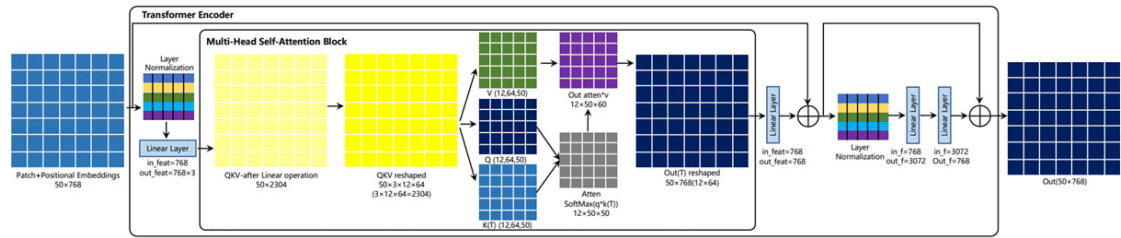


Figure 11: Transformer encoder

Classification Head: At the top of the architecture, there's a classification head. This final layer takes the transformed embeddings and uses them to predict whether an image is real or manipulated. It essentially makes the decision based on the features and patterns the model has learned throughout the previous layers.

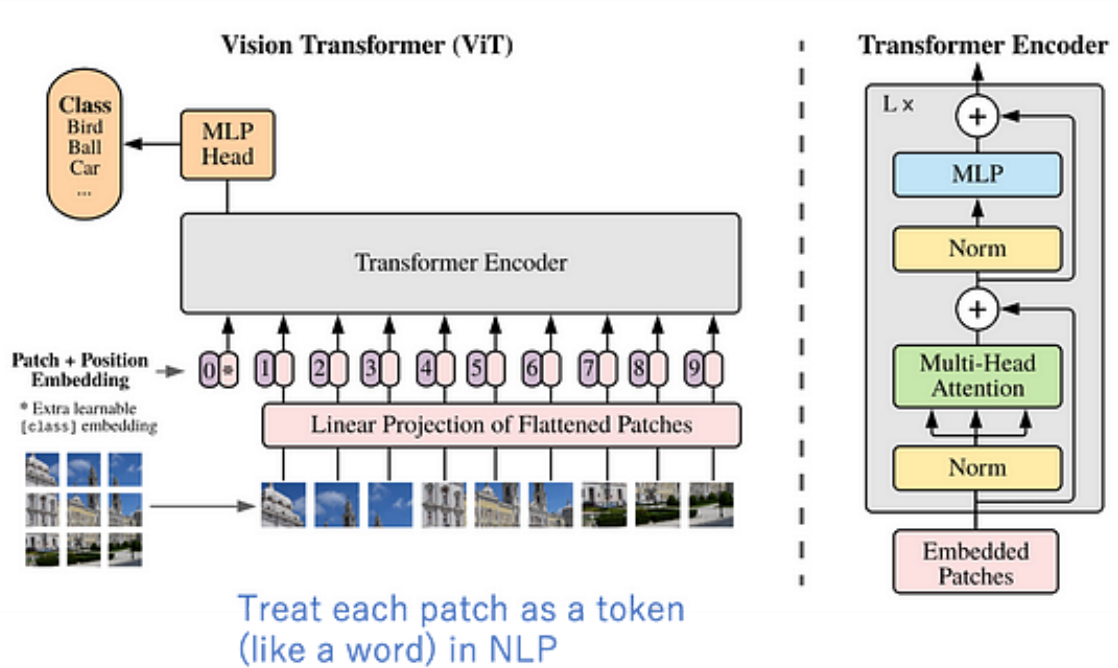


Figure 12: Vision Transformer Architecture

5 BLOCK DIAGRAMS

5.1 System Architecture

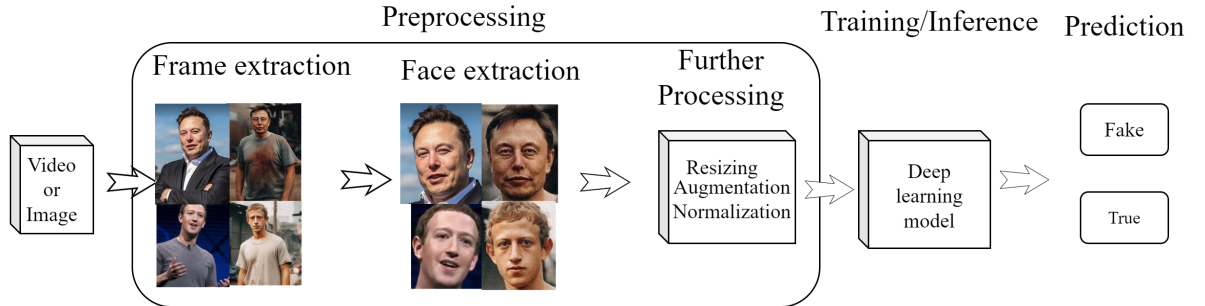


Figure 13: System Architecture

The system architecture of our project involves multiple steps. Initially, frames are extracted from the input video or obtained directly from an image. These frames then undergo face extraction, where faces are identified and cropped using face detection algorithms. The extracted faces are resized to a standardized size and undergo normalization to ensure consistent pixel values. The preprocessed face images are then fed into a deep learning model for classification. The model analyzes the features and patterns in the images to determine whether they are real or fake. Finally, the system produces the output, indicating the authenticity of the input video or image as either real or fake.

5.2 Use Case Diagram

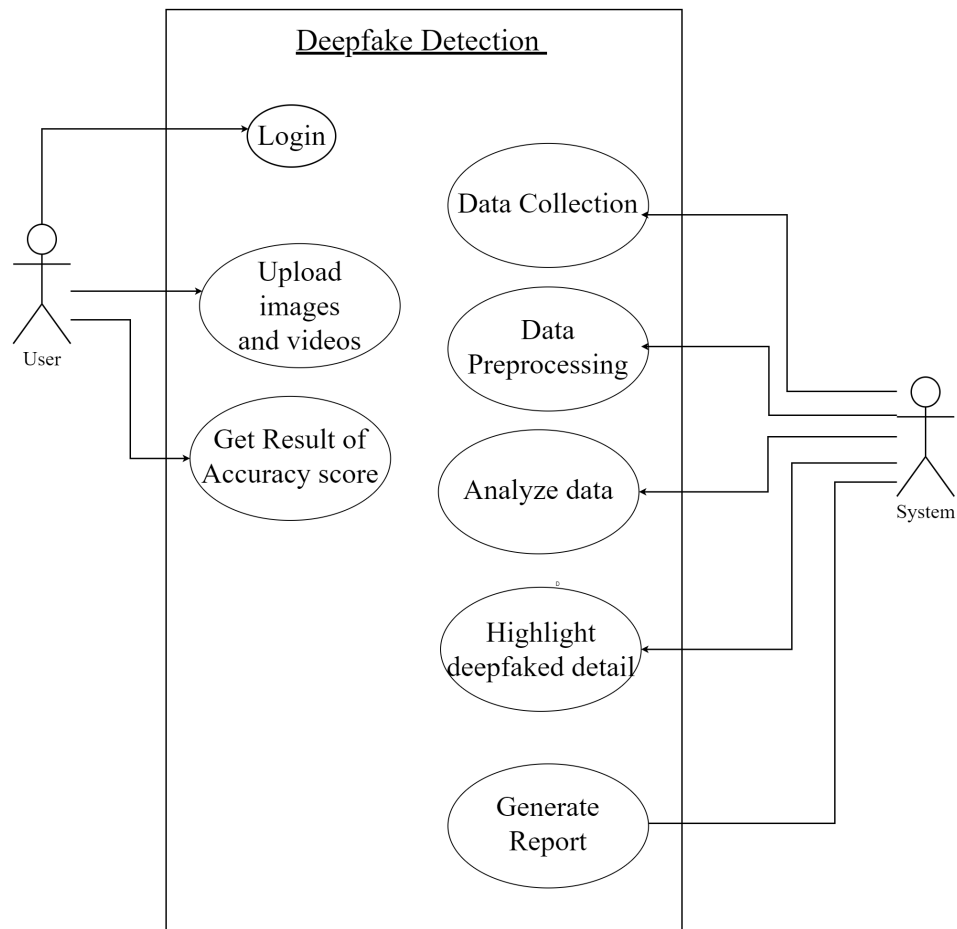


Figure 14: Use Case Diagram

The use case diagram for our system illustrates various interactions and roles of the system's users. The primary actors involved are the "User" and the "System." The User interacts with the system by initiating the deepfake detection process, either by uploading a video or an image. The User can also access the system to view the detection results. On the other hand, the System is responsible for managing the system, including user authentication, system configuration, and monitoring the overall functionality. The use case diagram shows the main use cases, such as "Upload Media," "Detect Deepfake," and "View Results," which represent the key functionalities of the system.

5.3 Sequence Diagram

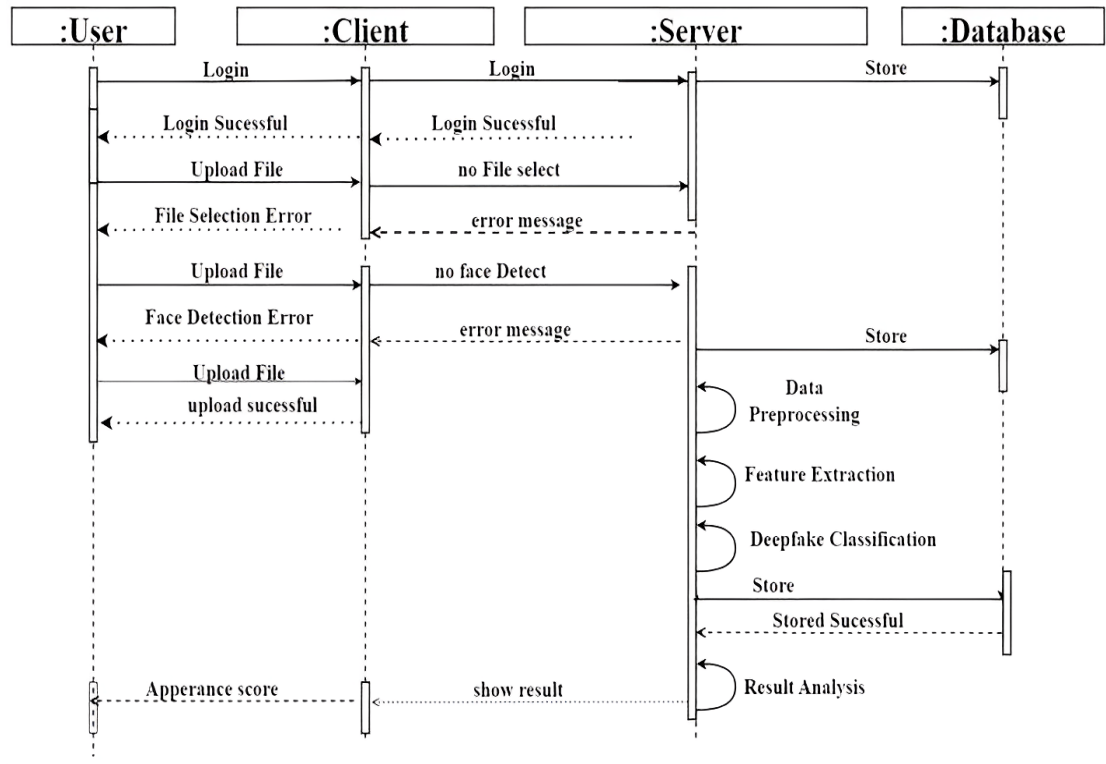


Figure 15: Sequence Diagram

The sequence diagram shows that the user initiates the process by accessing the system and providing their login credentials. The Server checks the login credentials and verifies the user's identity. Once authenticated, the user proceeds to upload a file containing the video or image to be analyzed for deepfakes. Then face detection algorithms are used to detect and extract faces from the uploaded media. This collected data undergoes further processing, including resizing and normalization, to prepare it for deep learning modeling. Finally, the processed data is fed into the deep learning model, which analyzes the features and patterns to classify the media as either real or fake.

5.4 Dataflow Diagram

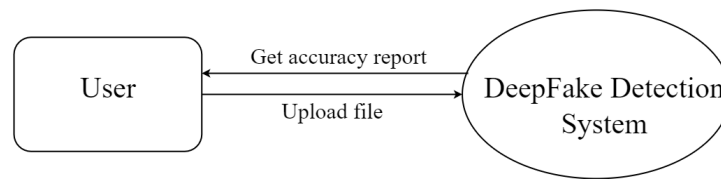


Figure 16: Level 0 DFD

DFD level – 0 indicates the basic flow of data in the system.

- User: User input to the system is uploading video.
- System: In system it shows all the details of the Video and output shows the fake video or not.
and output flow

Hence, the data flow diagram indicates the visualization of system with its input feed to the system by User.

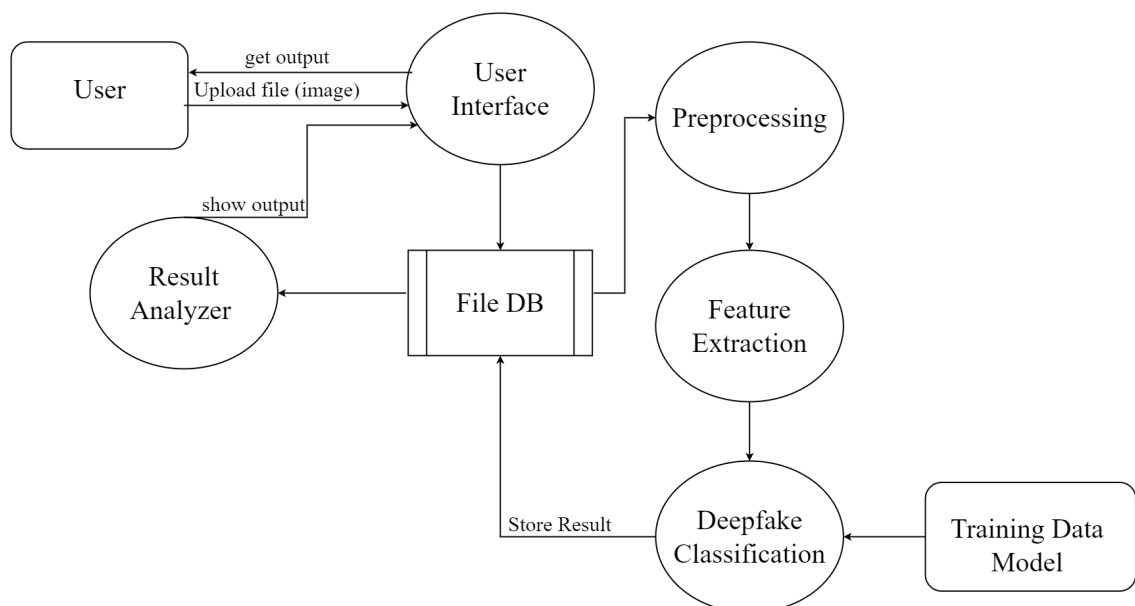


Figure 17: Level 1 DFD

DFD Level – 1 gives more in and out information of the system. Where system gives detailed information of the procedure taking place.

5.5 Activity Diagram

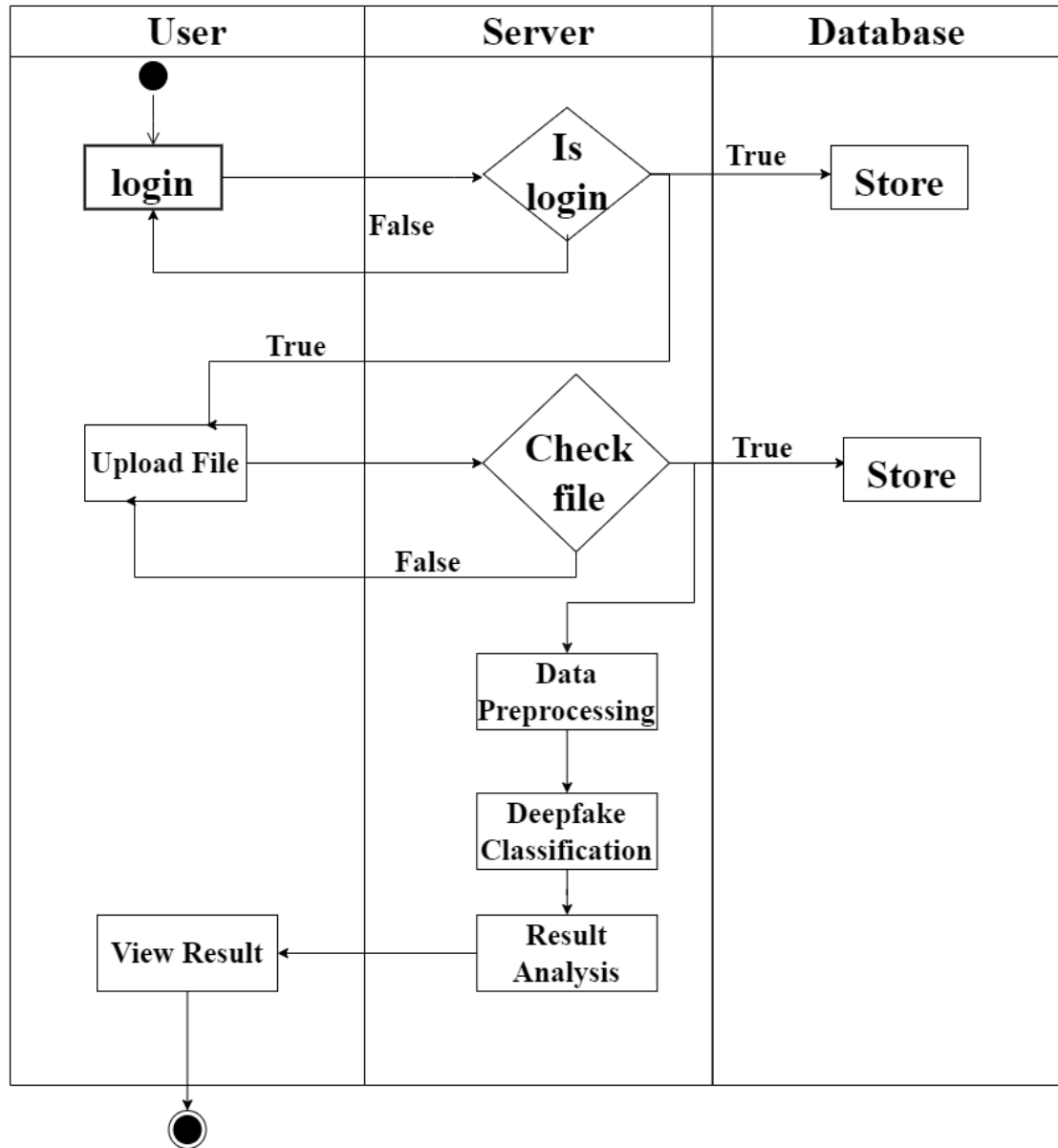


Figure 18: Activity Diagram

The activity diagram shows that the user initiates the process by accessing the system and providing their login credentials. The Server checks the login credentials and verifies the user's identity. Once authenticated, the user proceeds to upload a file containing the video or image to be analyzed for deepfakes.

6 Result and Analysis

6.1 UI of Project

We have used Flutter and Django to develop the mobile application in which we prepared a UI with user authentication, login page and home page where we can upload images to be classified as fake and real.

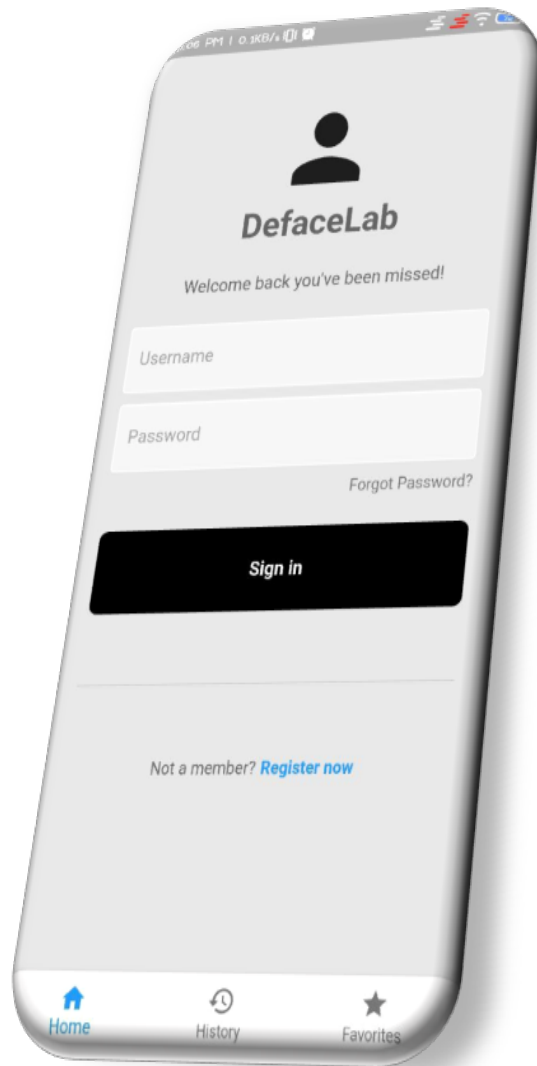


Figure 19: Login Page



Figure 20: Home Page



Figure 21: Upload image Menu

7 EXPECTED OUTCOMES

- User-friendly interface for easy upload and clear result presentation.
- Accurate identification of manipulated media content.
- Robust performance against different deepfake techniques and adversarial attacks.

References

- [1] Andreas Rossler, Davide Cozzolino, Luisa Verdoliva, Christian Riess, Justus Thies, Matthias Nießner, "FaceForensics++: Learning to Detect Manipulated Facial Images"
- [2] Y. Liu et al., "A Survey of Visual Transformers," in IEEE Transactions on Neural Networks and Learning Systems.
- [3] Han, K., Xiao, A., Wu, E., Guo, J., XU, C., and Wang, Y. (2021). "Transformer in Transformer".
- [4] Dosovitskiy, A., Beyer, L., Kolesnikov, A., Weissenborn, D., Zhai, X., Unterthiner, T., Dehghani, M., Minderer, M., Heigold, G., Gelly, S., Uszkoreit, J., and Houlsby, N. (2021). "An Image is Worth 16x16 Words: Transformers for Image Recognition at Scale. In International Conference on Learning Representations"
- [5] Yang Liu, Yao Zhang, Yixin Wang, Feng Hou, Jin Yuan, Jiang Tian, Yang Zhang, Zhongchao Shi, Jianping Fan, Zhiqiang He. (2021). "A Survey of Visual Transformers".
- [6] Vaswani, A., Shazeer, N., Parmar, N., Uszkoreit, J., Jones, L., Gomez, A. N. and Polosukhin, I. (2017). "Attention is all you need. In Advances in neural information processing systems (Vol. 30)".

||||| HEAD

- [7] Douglas Blakey, "Forced verification and AI/deepfake cases multiply at alarming rates: Sumsb" (2023). <https://www.electronicpaymentsinternational.com/news/forced-verification-and-ai-deepfake-caeses/> =====
- [8] Douglas Blakey, "Forced verification and AI/deepfake cases multiply at alarming rates: Sumsb" (2023). <https://www.electronicpaymentsinternational.com/news/forced-verification-and-ai-deepfake-caeses-sumsub/877f7fb35d1be614bf0d8dd0d491ed47fdbc9c5e>
- [9] iproov, "How To Protect Against Deepfakes – Statistics and Solutions" (2022). <https://www.iproov.com/blog/deepfakes-statistics-solutions-biometric-protection>