FACE RECOGNITION USING CRI AI THERMAL CAMERA

Submitted to:

Georgian

Acknowledgment

Knowledge is a never-ending journey, and we are immensely grateful to those who have been with us through it all. As we reach this significant milestone, we want to express our sincerest gratitude toward everyone who has been a constant source of support and guidance.

Completing any interdisciplinary project requires a collaborative effort that involves combining knowledge, creativity, skills, energy, and time. We are indebted to those who have contributed to this project in ways beyond measure, and we wish to recognize their contributions here.

We would like to express our gratitude to our client for entrusting us with this project and providing us with the opportunity to showcase our skills and abilities.

We are also grateful for the support and well wishes of many others, whose contributions may not have been explicitly acknowledged here but have not gone unnoticed. To all of you, we express our heartfelt thanks.

In conclusion, we want to express our most profound appreciation to everyone who has contributed to the success of this project. Your encouragement, guidance, and support have been vital to our growth and learning.

With Sincere Regards,

Kishan Patel

Tilak Pandya

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CONTENT

Introduction

Computer vision, a subfield of artificial intelligence, focuses on developing algorithms and systems that enable machines to interpret visual information from the world, just as humans do. One of the key applications of computer vision is facial recognition, which involves identifying and verifying individuals based on their facial features. Traditional facial recognition systems primarily rely on visible light images, which can be affected by varying lighting conditions, pose variations, and occlusions. This has led to the development of alternative methods, such as thermal imaging, which has gained attention in recent years for its potential to overcome these limitations.

Thermal imaging technology captures the heat emitted by objects, including the human body, and can provide valuable information about the distribution of temperature on the surface of the skin. CRI-AI (Circulation and Respiration Imaging with Artificial Intelligence) thermal cameras, in particular, have emerged as a promising tool for facial recognition due to their ability to capture the heat signatures emitted by blood vessels beneath the skin. This provides a unique and stable biometric identifier that is less affected by changes in lighting conditions and pose variations compared to visible light images.

Using CRI-AI thermal cameras in facial recognition systems opens up new possibilities for improving accuracy and robustness in challenging scenarios. For instance, in low-light conditions where visible light images may suffer from poor image quality, thermal imaging can still capture reliable facial features based on the heat emitted by blood vessels. Additionally, thermal imaging can be used in scenarios where capturing visible light images is not feasible or socially acceptable, such as in privacy-sensitive areas or for individuals with visual impairments.

Integrating CRI-AI thermal cameras into facial recognition systems requires specialized computer vision techniques. These techniques involve analyzing the thermal images to extract facial properties, such as the heat distribution patterns of blood vessels, and fusing the thermal and RGB (visible light) images to create a comprehensive representation of the individual's face. Deep learning algorithms, utilizing convolutional neural networks (CNNs) and other machine learning techniques, can be trained on labeled datasets of thermal and visible light images to recognize individuals accurately based on the combined information.

The aim of our study is to propose a computer vision-based approach that leverages CRI-AI thermal camera technology to enhance facial recognition accuracy and robustness. Our research focuses on analyzing the region of interest in thermal images for capturing facial properties, fusing the thermal and RGB images, and developing an AI algorithm using computer vision libraries in Python. The proposed algorithm will be trained on a labeled dataset of known individuals to identify similarities and accurately recognize individuals from thermal/visual frontal images.

Problem Statement

With the increasing popularity of facial recognition technology and the availability of high-resolution cameras in smartphones, there is a growing need for reliable and secure facial recognition systems. However, traditional facial recognition systems have limitations in low-light or thermal imaging conditions, leading to inaccurate or ineffective results. Therefore, the problem statement of this project is to develop a facial recognition system using CRI-AI thermal cameras that can overcome these challenges and provide accurate identification of individuals in thermal images. The challenges include developing specialized computer vision techniques, fusing thermal and visible light images, and training deep learning algorithms on labeled datasets

General Objective

The human ability to recognize and identify faces is a complex process that poses significant challenges in visual form analysis and object identification. The general objective of this project is to leverage computer vision techniques and Python libraries to develop an AI-based facial recognition system that can accurately identify individuals from thermal and visual frontal images. By combining proposed methods and additional characteristics, the aim is to create a robust and effective solution that can rival existing methods for person identification.

Specific Objectives:

Objective 1: Determine the region of interest (ROI) in thermal images that effectively captures the facial properties of an individual.

Objective 2: Evaluate the readiness of facial recognition technology for integration into CRI-AI for accurate identification of individuals in thermal and visual images.

Objective 3: Measure the body temperature of an individual for the purpose of thermal screening using blackbody radiation box.

Methodology

The study followed a comprehensive project planning process, with overlapping steps to ensure efficient progress. The scope was divided into six major phases: Project Planning, System Analysis, System Design, System Implementation, System Testing, and Acceptance, Installation, and Deployment. Each phase involved identifying and adding tasks to the project timeline.

The Project Planning phase began with two weeks of research to understand the problem and existing works. This was followed by the System Analysis phase, which focused on defining objectives, identifying use cases, and gathering information about the instruments to be used. The System Design phase involved reading, analyzing, and performing various operations on images from the cameras for training and testing the model. The System Implementation phase aimed at integrating the model with the live camera feed and measuring temperature using a thermal blackbody radiation box. However, due to delays and technical difficulties with the cameras, some tasks had to be scaled down to meet the project deadline. Specifically, cuts were made in the System testing phase as we were getting higher latency while accessing the CRI AI Cameras. Troubleshooting was carried out at every stage of the project to address issues as they arose. The System Testing phase involved thorough testing of the system, and the Acceptance, Installation, and Deployment phase was dedicated to wrapping up deliverables, conducting acceptance testing, and deploying the system.

Further details about the adjustments made to the project plan can be found in the Gantt Chart section.

Project Planning

The initial step in the Software Development Life Cycle is planning, which comprises four key steps:

i. Identifying problems and opportunities
ii. Defining the scope and constraints
iii. Evaluating the benefits
iv. Estimating development time and costs.

i. Identifying problems and opportunities:

Problem:
Despite the significant advancements in facial recognition technology, there are still challenges to be addressed in the field of thermal imaging-based facial recognition. Existing off-the-shelf algorithms often struggle with issues such as low accuracy, poor robustness, and limited performance in challenging environments. The use of thermal images for facial recognition also presents unique challenges, such as variations in thermal patterns due to environmental factors, changes in facial expressions, and differences in thermal emissivity among individuals. These limitations hinder the widespread adoption of thermal facial recognition in real-world applications, where high accuracy and reliability are critical.

Opportunity:
The opportunity lies in leveraging the capabilities of the CRI-AI Thermal Camera to develop a more advanced and reliable facial recognition system. The CRI-AI camera, with its dual lenses capturing thermal and RGB images based on threshold values, provides a unique opportunity to combine the strengths of both modalities and

enhance the accuracy and robustness of facial identification. By developing an AI-based algorithm using computer vision libraries in Python, there is an opportunity to leverage advanced image processing and machine learning techniques to extract meaningful facial features from thermal and visual frontal images. This can result in a more robust and accurate facial recognition system that is capable of identifying individuals with higher confidence levels, even in challenging environments.

Furthermore, the application of thermal imaging-based facial recognition has potential opportunities in various fields, such as security, access control, and authentication. The ability to uniquely identify individuals based on their facial properties can greatly enhance security measures and provide an extra layer of protection when dealing with sensitive data. Additionally, the use of thermal facial recognition in industries such as healthcare, automotive, and surveillance can offer new opportunities for improving safety, efficiency, and convenience in various applications.

By addressing the existing challenges and leveraging the capabilities of the CRI-AI Thermal Camera, this research project aims to capitalize on the opportunity to develop an advanced facial recognition system that can overcome the limitations of current off-the-shelf algorithms and unlock the full potential of thermal imaging-based facial recognition in real-world applications.

ii. Defining the scope and constraints:

Potential Scope:

a. **Improving fusion techniques:** The project can explore and implement advanced fusion techniques to effectively merge the thermal and RGB images from the CRI-AI camera, aiming to enhance the accuracy and reliability of the facial recognition algorithm.

b. **Developing optimized image analytics:** Since real-time processing may not be feasible due to limitations with the TCP-IP protocol, the project can focus on optimizing the image analytics for offline processing, ensuring efficient and accurate facial recognition results.

c. **Exploring potential applications:** The project can explore potential applications of thermal and visual image-based facial recognition in industries beyond access control, such as healthcare, automotive, and surveillance, to identify new opportunities for utilizing this technology.

d. **Enhancing accuracy and robustness:** The use of the CRI-AI Thermal Camera and combining thermal and visual frontal images can potentially result in a more accurate and robust facial recognition system by leveraging advanced image processing and machine learning techniques.

e. **Improving security and access control:** The application of thermal imaging-based facial recognition has the potential to enhance security measures and provide an extra layer of protection in various fields, such as access control, authentication, and data handling.

Constraints:

a. **Limitations of the CRI-AI camera:** The project needs to consider the limitations of the CRI-AI camera, including the restricted access to certain users and the limitation of using image analytics instead of video analytics, which may affect the availability and quality of the data for training and testing the facial recognition model.

b. **Maintaining threshold consistency:** The project needs to ensure consistency in setting threshold limits for thermal signatures to avoid variations that may impact the model's ability to accurately recognize facial features in the merged images.

c. **Maintaining distance consistency:** The project needs to maintain a consistent distance between the camera and the subject's face during both the training and testing phases to minimize potential changes in thermal patterns and ensure reliable facial recognition results.

d. **Ethical considerations:** The project needs to carefully consider and address ethical concerns related to data privacy, surveillance, and potential biases or discrimination associated with facial recognition technology and ensure responsible and ethical use of the technology throughout the project.

e. **Limited accuracy and robustness of existing off-the-shelf algorithms:** Current facial recognition algorithms may face challenges in accuracy and robustness, particularly when dealing with thermal images, due to variations in thermal patterns, facial expressions, and emissivity differences.

f. **Environmental factors:** Thermal imaging can be influenced by environmental factors such as temperature changes, lighting conditions, and other external variables, which may affect the performance of the facial recognition system.

g. **Technical challenges:** Developing an AI-based algorithm using computer vision libraries in Python may require addressing technical challenges related to image processing, machine learning, and algorithm optimization to achieve the desired accuracy and performance.

iii. **Evaluating the benefits:**

a. **Enhanced security:** The development of a facial recognition algorithm using thermal and visual images can provide improved security measures in access control, authentication, and identity verification, contributing to enhanced safety and protection of individuals and assets.

b. **Technological innovation:** The project's exploration of novel approaches using thermal facial imaging can contribute to technological innovation in the field of facial recognition, advancing the state-of-the-art and expanding the potential applications of this technology.

c. **Improved efficiency and convenience:** The use of facial recognition technology can streamline identification and authentication processes, reducing the need for physical identification cards or credentials and enhancing efficiency and convenience in various settings such as airports, border control, and secure facilities.

d. **Potential for diverse applications:** The project's findings can have implications in diverse fields such as healthcare, automotive, and surveillance, where thermal and visual-based facial recognition can be utilized for enhanced security and identification purposes, benefiting different sectors of society.

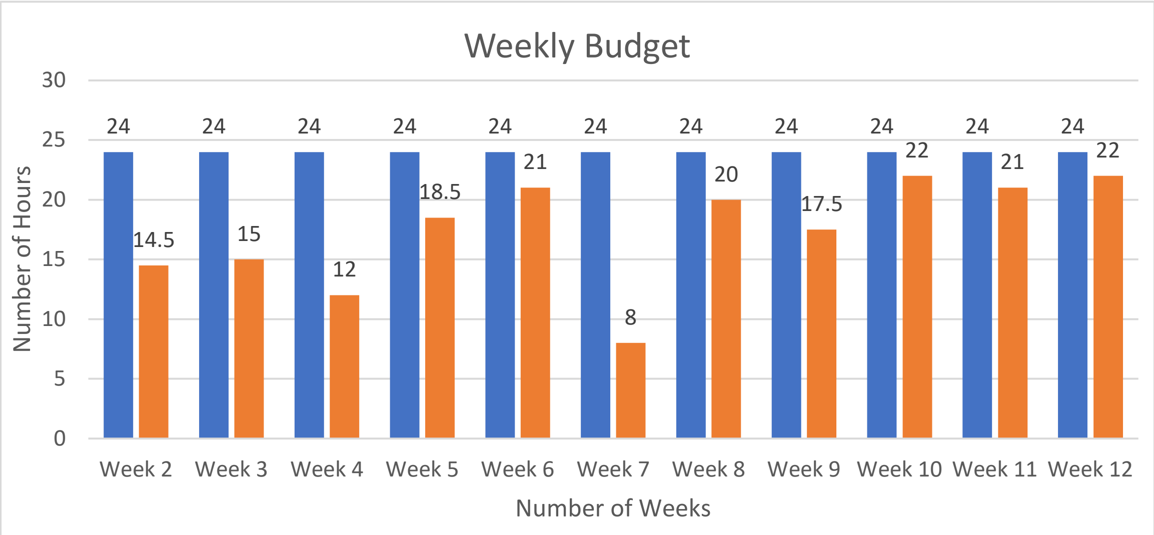
iv. **Estimating the development time and the cost:**

The project on facial recognition using CRI AI Thermal Camera commenced on January 18 and concluded on April 11, 2022, with a total duration of approximately 12 weeks. The team faced some unforeseen delays and technical difficulties in the beginning and middle phases, which resulted in the utilization of approximately 191.5 hours of work time and a budget of $9,575.00 out of the allocated budget of $14,400.00 ($4,800.00 each).

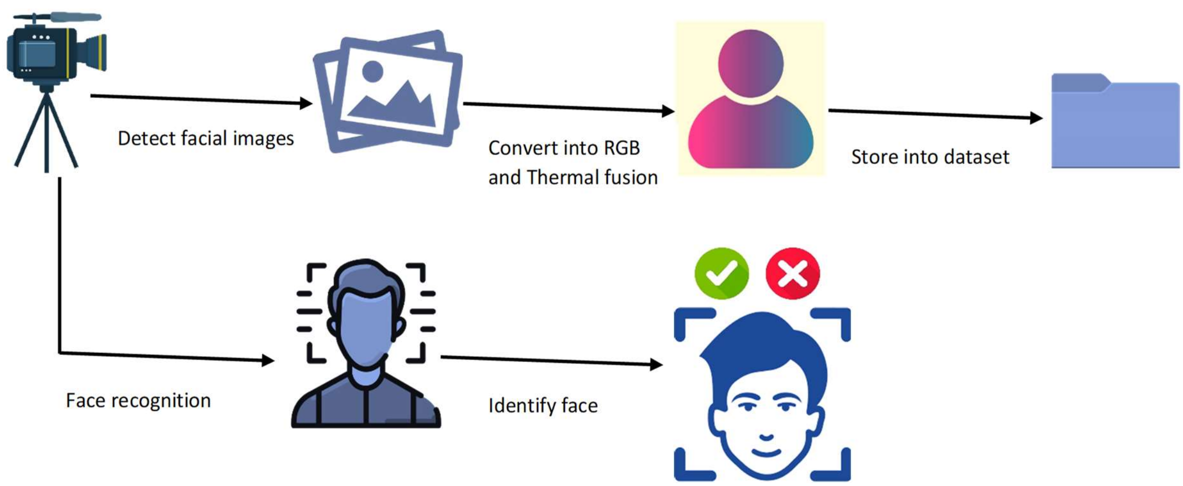
Considering the constraint of each team member being allowed to work 8 hours per week on the project, the total available hours for the project were limited to 288 hours. The team's efforts were focused on maximizing the utilization of available time and budget to achieve the project objectives while also taking into account the hourly pay of $50 per person.

Despite the challenges and constraints, the team was able to make significant progress in developing the facial recognition algorithm using thermal and visual images from the CRI AI Thermal Camera. However, due to the limited time and budget, some planned tasks had to be cut off. Nonetheless, the team managed to complete the project within the available resources, with an average of approximately 5.32 hours of work per team member.

The team's diligent efforts and efficient utilization of time and budget resulted in the successful completion of the project, albeit with some adjustments to the original plans. The experience gained from this project has provided valuable insights into the challenges and opportunities associated with facial recognition using thermal imaging and has laid the foundation for further advancements in this field.



System Analysis and Design



In our initial setup, due to unavailability, we had to resort to using our laptop's webcam to capture and test the model. To adapt the webcam images for our purposes, we converted them from RGB to grayscale and thermal images.

Once we obtained access to the desired instruments, a HiKVision Camera and blackbody radiation box, we configured them and implemented our model using them. We ran the code to detect faces and stored our own images as we did not have access to a pre-existing dataset. To capture detailed facial features, we fused RGB and thermal images. These images were then used to train our model, and relevant information such as names and student IDs were stored for reference.

With the trained model, we were able to recognize the stored faces effectively. To provide a more user-friendly experience, we developed a User Interface (UI) to enhance the overall application. The UI added a polished and professional look to the application, making it more accessible and user-friendly.

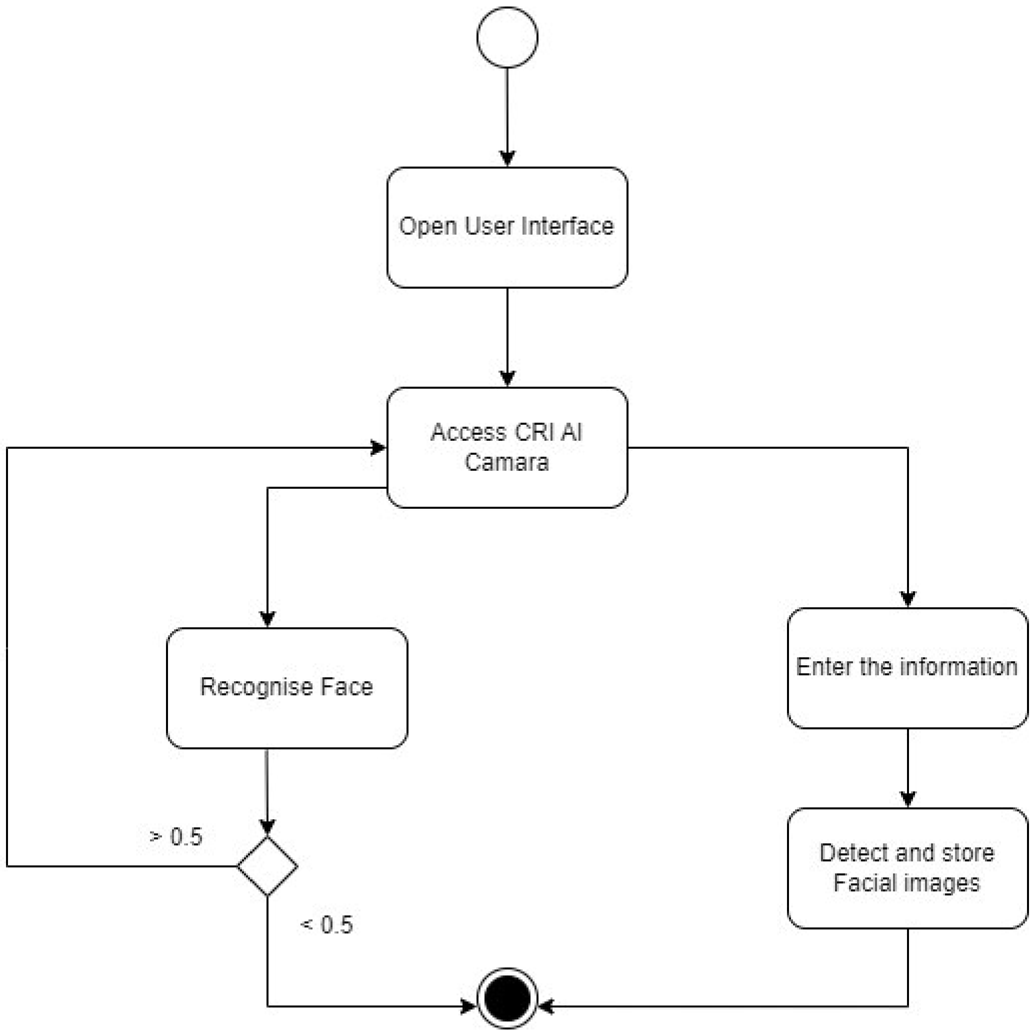
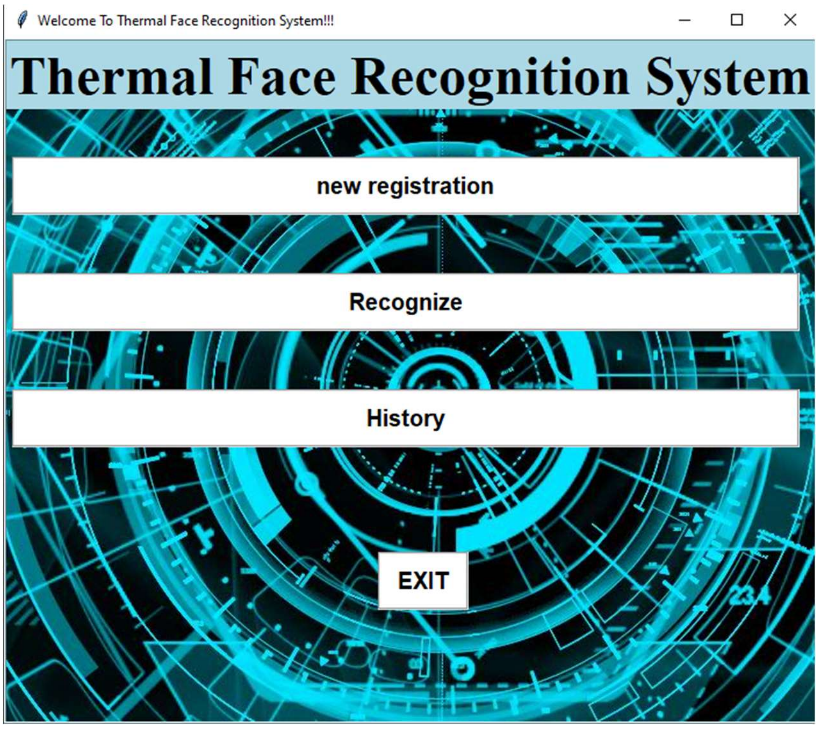


Fig. Project flow diagram

User Interface (UI):

- **Splash Screen:**

- **Main Layout**



System Implementation:

The flow diagrams mentioned above show the overall system design and the flow of the tasks.

Due to the unavailability of instruments, Initially, we used a laptop's webcam to detect the face. And we converted RGB images to grayscale and thermal images manually to train the model meanwhile. After getting the required instruments, First, we had to set up the PROVIX-N20915 HikVision camera, tripod, and blackbody radiation box.

The camera has two wireless antennas, which allow users to access them via 192.168.1.64 as the default IP address with admin12345 as the password.

To access the camera view, we have used the software named iVMS-4200. On organizing the camera input into these four screens in the windowpane, we can observe on the top the RGB image as well as the Thermal Image on the bottom with a bounded box over the face.

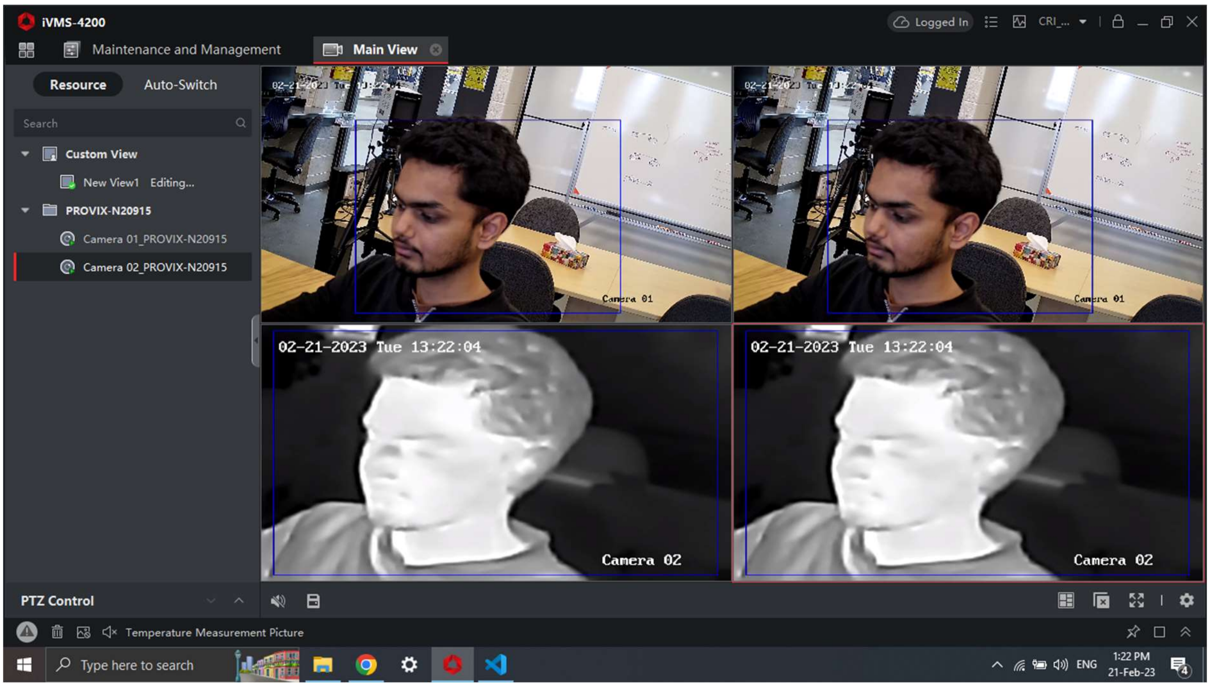


Fig. Access to the PROVIX-N20915 HikVision using iVMS-4200

The hot surface has the highest frequency illuminating the body as white, whereas the cold surface is grey and black with less frequency.

After getting access, we changed some configurations in iVMS-4200.

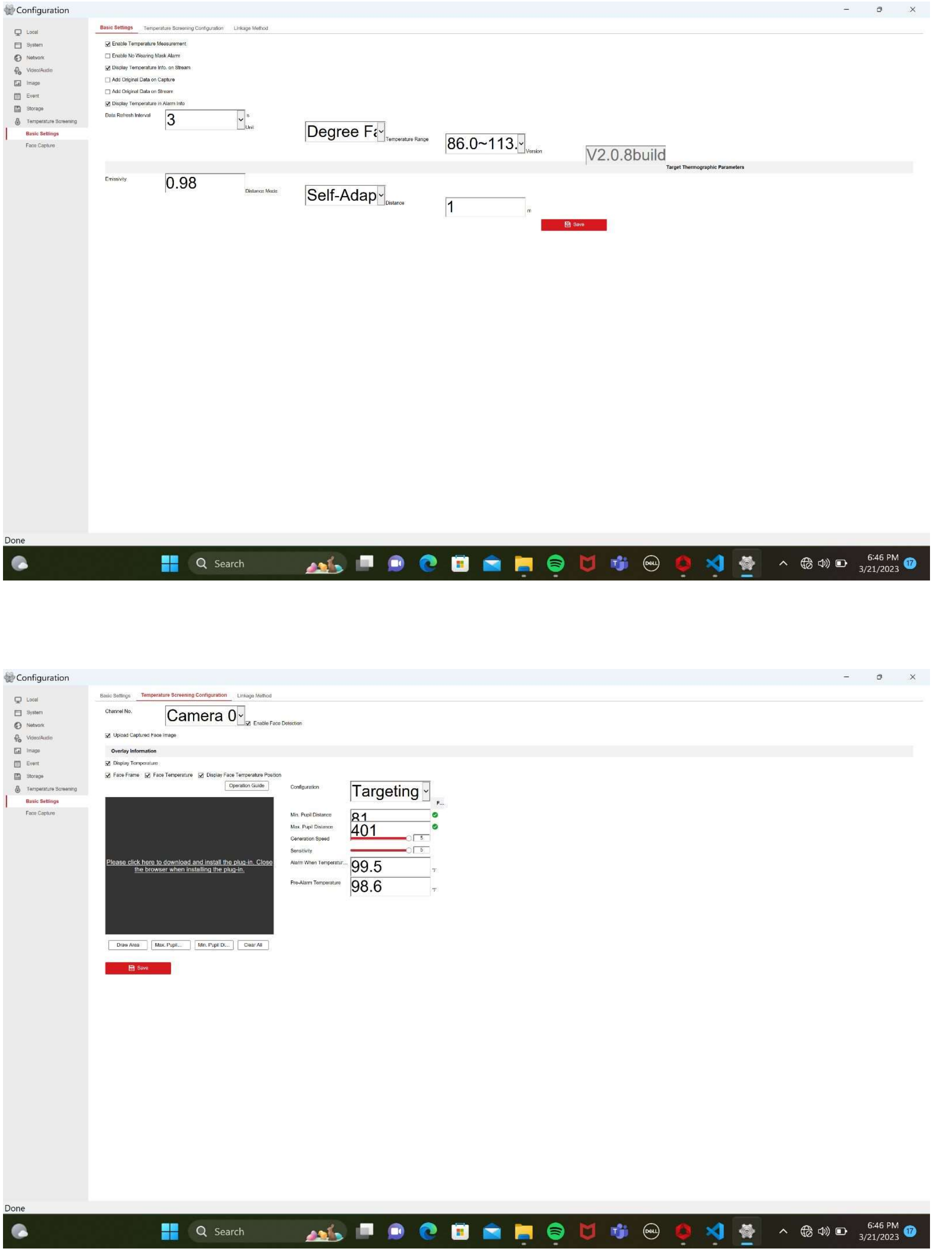


Fig. System Configuration change

Face Detection:

Face detection is a challenging task that involves categorizing image windows into two classes: those containing faces and those containing background clutter. This task is complicated by the variability in faces, such as age, skin color, and facial expression, as well as differences in lighting conditions, image qualities, geometries, and possible occlusions and disguises. An ideal face detector should be able to accurately detect faces under any lighting conditions and on any background. The face detection process can be divided into two steps. The first step is a classification task that takes an arbitrary image as input and outputs a binary value (yes or no) indicating the presence of faces in the image. The second step is the face localization task, which aims to identify the location of faces within the image using bounding box coordinates (x, y, width, height).

The face detection system typically involves several steps. The first step is pre-processing, where images are processed to reduce variability in faces. This may include cropping images to include only the front view of faces and correcting for lighting using standard algorithms. The second step is classification, where neural networks are implemented to classify images as either faces or non-faces. This is done by training the neural networks on examples of positive (face) and negative (non-face) images. Different network configurations may be experimented with to optimize results. Finally, the third step is localization, where the trained neural network is used to search for faces in an image and, if present, localize them using bounding boxes. Various facial features, such as position, scale, orientation, and illumination, may be considered in the localization process.

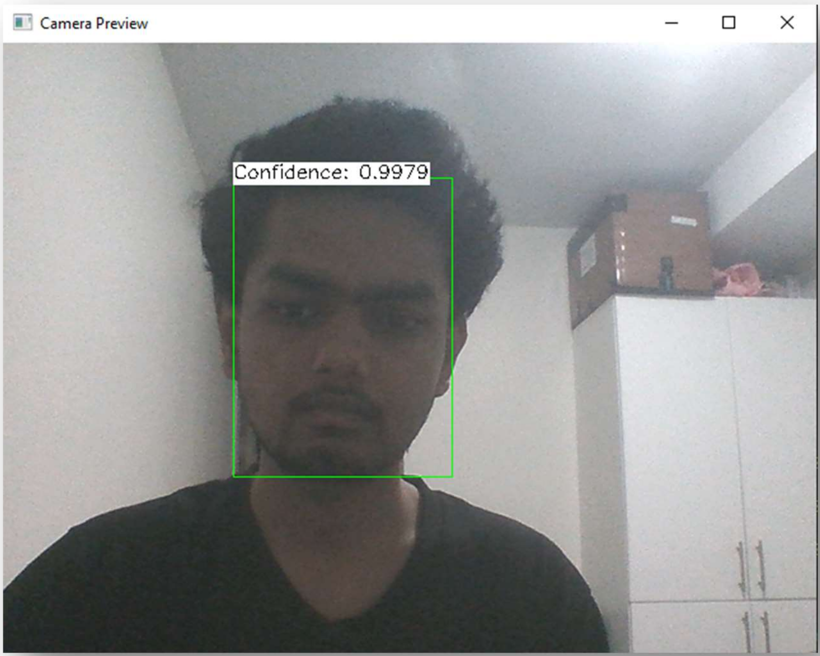


Fig. Face detected with confidence rate and bounding box

Above shown image is taken using a webcam to detect the face. We have drawn the green bounding box around the face if detected. The confidence rate shows how confident our algorithm is in detecting the face in the frame. The given image shows a confidence rate of 99.79%, meaning our algorithm is 99.79% sure that it has detected the face accurately.

These images are then stored in the dataset folder. The path is used to retrieve these images as and when required (while facial recognition).

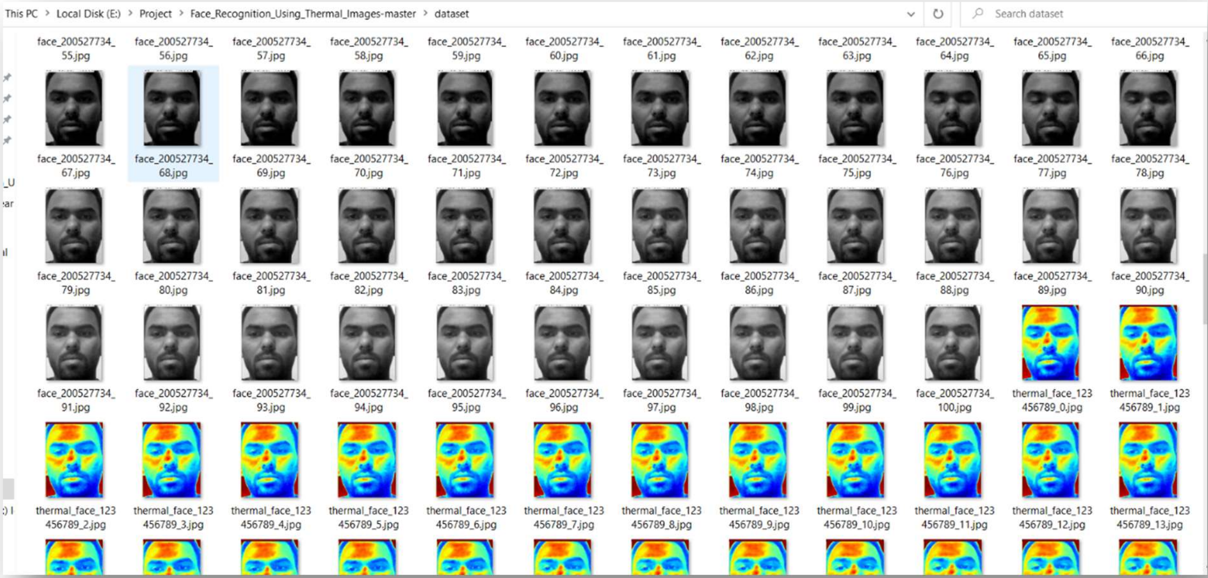


Fig. Images stored in the dataset folder.

These are the images captured as new registration of the face and stored in the folder named dataset. We are storing the information of the person in the CSV file, so while recognizing the face, important information can be retrieved from that CSV file too.

Index	Full_Name	Id	Deleted
1	Kishan	200345124	0
2	Namra	200343123	0
3	Tilak	200343234	0

This is the CSV file where we store the person's name and student id to fetch the information while recognizing his/her face. We are adding an index to use it as a primary key. (Unique key).

After successfully storing the information, we fused the RGB and thermal images manually using code so that we could identify more complex facial features.

Fig. Fusion of the RGB and Thermal Image

Face Recognition

The crucial component of the project involves face recognition from thermal cameras, and it entails the following stepwise process:

1. Data Training with RGB Images: We collect RGB images from the dual-lens thermal camera, which also captures RGB images, and utilize them as the training dataset for our model.

2. Model Selection: We employ a face recognition library, such as Recognize, to manipulate and recognize faces using Python or the command line. Recognization is built with adlib's cutting-edge deep learning-based face recognition technology and utilizes a DNN architecture with multiple layers to achieve superior accuracy.

3. Temperature Screening: We have implemented the blackbody radiation box to measure the body temperature of the face detected.

4. Evaluation: The model uses the images stored in the dataset folder and matches the information stored in the CSV file, and then it recognizes the faces accordingly.

System Testing

The trained model is being tested on live images.

The person is recognized as Namra successfully since his information was stored in the dataset.

The person is not recognized (Annotated as Unknown) since his information was not stored in the dataset.

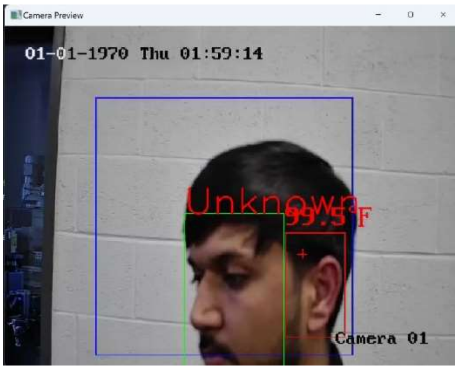


Fig. Thermal Screening

Above mentioned images show the implementation of a blackbody radiation box, which detects the temperature of the human body measured from the thermal features of the human face. While performing the temperature screening, a person's face was not stored in the dataset; therefore, it is showing 'Unknown'.

While testing the final outcomes, we incurred the issue of latency. The issue could have been raised due to the following reasons:

- **Device incompatibility:** GPUs are designed to perform complex mathematical computations and can accelerate the performance of the face recognition model.
- **Parallel Processing:** Asynchronous processing allows the camera to continue capturing frames while the face recognition model processes the previous frame. This can reduce latency by processing images in the background.
- **Network Latency:** Network latency can cause delays in the transmission of video frames. This can be fixed by optimizing network settings, using a faster network connection, or reducing the video resolution to reduce network latency.

After troubleshooting, we have spotted that a system with a higher GPU can implement these algorithms and access cameras easily to reduce latency.

Acceptance, Installation, and Deployment

The acceptance phase involved ensuring that the project met the specified requirements and was ready for deployment. This included verifying the accuracy and performance of the facial recognition algorithm using thermal and visual images from the CRI AI Thermal Camera. Rigorous testing and validation were performed to ensure that the model met the desired accuracy and reliability criteria.

After successful acceptance testing, the project moved on to the installation phase parallelly throughout the system implementation phase, where the necessary software packages and libraries were installed using pip in Python. This allowed for the seamless integration of the facial recognition algorithm into the project environment.

Once the installation was complete, the team focused on deployment, which involved creating a User Interface (UI) using the Tkinter library. The UI provided a user-friendly interface for interacting with the facial recognition system, allowing for easy input of images, processing of thermal and visual data, and displaying the results of the facial recognition algorithm.

Throughout the process, the team worked diligently to ensure that the project adhered to the established timeline and budget constraints. The utilization of OpenCV and Tkinter libraries, along with the efficient installation and deployment of the project, contributed to the successful completion of the facial recognition project using CRI AI Thermal Camera.

Required Tools:

PROVIX-N20915 HikVision Camera:

- The PROVIX-N20915 HikVision Camera is a high-quality thermal imaging camera that is widely used in various applications, including security, surveillance, and industrial monitoring. Manufactured by HikVision, a leading company in the field of surveillance and security solutions, the PROVIX-N20915 camera features advanced thermal imaging technology that allows for the detection and capture of heat signatures from objects and subjects.
- With a resolution of 384x288 pixels, the PROVIX-N20915 camera provides detailed and accurate thermal images, making it suitable for a wide range of environmental conditions. It operates in the long-wave infrared (LWIR) spectrum, enabling it to capture thermal data even in complete darkness or through certain materials such as smoke, fog, and dust.
- The PROVIX-N20915 camera also comes with built-in features such as multiple color palettes, temperature measurement capabilities, and adjustable image settings, providing users with flexibility and versatility in image analysis. Its rugged design makes it durable and reliable for use in various challenging environments.
- As a valuable tool in the field of thermal imaging, the PROVIX-N20915 HikVision Camera is utilized in many applications where accurate and reliable thermal data is required. Its advanced features and high-quality imaging capabilities make it a popular choice for professionals and organizations seeking to leverage thermal imaging technology for various purposes.

Blackbody Radiation Source 97B1276:

- The Blackbody radiation box 97B1276 is a specialized piece of equipment used in thermal imaging and radiometric applications. It is designed to provide a known and stable source of thermal radiation with a uniform temperature across its surface, which is essential for calibrating and validating thermal imaging cameras and radiometric devices.
- The Blackbody radiation box is typically constructed using high-quality materials that have a high emissivity, which means they efficiently emit thermal radiation at a known temperature. The box is designed to enclose the thermal radiation source,

minimizing external influences and ensuring a stable and controlled environment for accurate calibration and validation of thermal imaging and radiometric devices.

- The 97B1276 Blackbody radiation box is typically used in laboratory or controlled environments where precise temperature control and calibration are required. It is commonly used in industries such as aerospace, automotive, electronics, and scientific research, where accurate and reliable thermal imaging and radiometric measurements are crucial.
- The Blackbody radiation box 97B1276 is an essential tool for ensuring the accuracy and reliability of thermal imaging and radiometric devices, making it a valuable asset in various applications that require precise temperature measurement and analysis.

Software: iVMS-4200

- iVMS-4200 is a widely used software application developed by Hikvision, a leading provider of video surveillance solutions. It is a comprehensive video management software (VMS) that is used for managing and analyzing video footage captured by Hikvision's network cameras, digital video recorders (DVRs), and network video recorders (NVRs).
- iVMS-4200 provides a user-friendly interface that allows users to view, manage, and analyze video footage from multiple cameras simultaneously. It offers a wide range of features, including live view, playback, video recording, event and alarm management, PTZ (pan-tilt-zoom) control, video analytics, and system configuration.
- With iVMS-4200, users can easily configure and manage their Hikvision surveillance devices, set up recording schedules, and customize video settings. It also allows users to remotely access and manage their surveillance system from anywhere using a computer, smartphone, or tablet, making it convenient for remote monitoring and management.
- iVMS-4200 is widely used in various industries and applications, including security and surveillance, retail, transportation, banking, education, healthcare, and more. It is known for its reliability, scalability, and ease of use, making it a popular choice for managing video surveillance systems of different sizes and complexities.

Software: VSCode

- VSCode, short for Visual Studio Code, is a free and open-source source code editor developed by Microsoft. It is a popular choice among developers for its extensive features, flexibility, and ease of use. VSCode supports a wide range of programming languages and provides a rich set of tools and extensions that enhance the coding experience. Some general features of VSCode include:
- **Cross-platform compatibility:** VSCode is available for Windows, macOS, and Linux, making it a versatile choice for developers using different operating systems.
- **Code editing and debugging:** VSCode provides advanced code editing capabilities with features such as syntax highlighting, code completion, and intelligent code

suggestions. It also includes built-in debugging tools for various programming languages.

- **Integrated terminal:** VSCode includes an integrated terminal that allows developers to run command-line tools and scripts without leaving the editor.
- **Extensions ecosystem:** VSCode has a vast collection of extensions developed by the community that adds additional functionalities such as language support, code snippets, and integrations with popular frameworks and tools.
- **Customization options:** VSCode allows users to customize the editor's appearance, keybindings, and settings to suit their preferences and workflow.
- **Git integration:** VSCode has built-in Git integration, making it easy for developers to manage version control and collaborate on projects.
- **Live Share:** VSCode provides a Live Share feature that allows developers to collaborate in real-time with others, making it convenient for remote pair programming and code reviews.

The language used: Python

- **Easy to Learn and Use:** Python is easy to learn and use. It is a developer-friendly and high-level programming language.
- **Expressive Language:** Python language is more expressive means that it is more understandable and readable.
- **Interpreted Language:** Python is an interpreted language, i.e., the interpreter executes the code line by line at a time. This makes debugging easy and thus suitable for beginners.
- **Cross-platform Language:** Python can run equally on different platforms such as Windows, Linux, Unix, Macintosh, etc. So, we can say that Python is a portable language.
- **Free and Open Source:** Python language is freely available at the address. The source code is also available. Therefore, it is open source.
- **Object-Oriented Language:** Python supports object-oriented language, and concepts of classes and objects come into existence.
- **Large Standard Library:** Python has a large and broad library and provides a rich set of modules and functions for rapid application development.

The library used: OpenCV

- OpenCV is a free and open-source computer vision and machine learning library developed by Intel. It provides a rich set of tools and functions for processing and analyzing images, videos, and other visual data. Some key features of OpenCV include image processing, video processing, camera calibration, machine learning, GUI and display, multi-platform support, and extensive community and documentation. It is widely used for computer vision tasks in various applications and platforms.

The library used: Pandas

- Pandas is a powerful open-source data analysis and manipulation library for Python. It provides easy-to-use data structures such as DataFrame and Series for handling and analyzing data in a flexible and efficient manner. With Pandas, you can perform various data operations such as data cleaning, data aggregation, data transformation, and data visualization. It also integrates well with other popular libraries in the Python ecosystem, such as NumPy, matplotlib, and Scikit-learn, making it a popular choice for data analysis tasks in various domains such as finance, marketing, healthcare, and more. Pandas is widely used by data scientists, analysts, and developers for data processing and analysis in Python projects.

The library used: NumPy

- NumPy is a popular open-source library for numerical computing in Python. It provides support for working with large, multi-dimensional arrays and matrices, along with mathematical functions for efficient array operations. NumPy is widely used in scientific computing, data analysis, machine learning, and AI due to its advanced indexing, slicing, and broadcasting capabilities. It also serves as a foundation for many other Python libraries, making it essential for numerical computations.

Library used: Tkinter

- Tkinter is a standard Python library for creating graphical user interfaces (GUIs). It provides a set of tools and widgets for creating windows, dialogs, buttons, labels, text boxes, and other graphical components in Python applications. Tkinter is simple to use and widely used for developing desktop applications with a GUI in Python. It is cross-platform, meaning that GUI applications created with Tkinter can run on various operating systems, including Windows, macOS, and Linux. Tkinter is often chosen for its ease of use, flexibility, and compatibility with other Python libraries, making it a popular choice for developing GUI applications in Python.

GANTT Chart

We have used a Gantt chart to document our process throughout the project execution. Initially, we had different plans for the project tasks, but as we moved further and faced different constraints, our progress has been changed a bit, and we made the changes in the Gantt chart accordingly.

Unfortunately, we had to shrink down the original plan to accommodate the limitations we faced during the project. We faced a latency issue while performing the final testing of the project. Due to time constraints, we could only identify the reasons behind it and could not troubleshoot the problem.

Literature Review

1. **Szeliski, R. (2010). Computer vision: Algorithms and applications. Springer Science & Business Media**: This comprehensive textbook provides an in-depth overview of various computer vision techniques, including image processing, feature extraction, and machine learning algorithms. It covers both fundamental concepts and practical applications, making it a valuable reference for understanding the basics of computer vision.
2. **Gonzalez, R.C., & Woods, R.E. (2018). Digital image processing. Pearson:** This classic textbook covers a wide range of image processing techniques, including image enhancement, filtering, and restoration. It also provides a solid foundation in digital image processing theory and applications, making it a relevant reference for understanding the underlying concepts in image processing.
3. **LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. Nature, 521(7553), 436-444:** This influential paper introduces the concept of deep learning and convolutional neural networks (CNNs), which are widely used in computer vision tasks such as image recognition and object detection. It provides insights into the principles and advancements of deep learning techniques, which could be relevant for discussing machine learning approaches in the literature review.
4. **OpenCV Documentation: https://docs.opencv.org/ (Official documentation of OpenCV)** OpenCV is a popular open-source computer vision library that provides a vast collection of functions and tools for image processing, computer vision, and

machine learning. Referring to the official documentation of OpenCV can provide detailed information about its features, functionalities, and usage, which could support the findings related to the use of OpenCV in the project.

Deliverables with Code

I. **Index.py:** This is a file for a face registration system that captures live video from a camera and detects faces in real time using a pre-trained deep neural network. The detected faces are then processed to generate thermal images that are saved as part of a dataset for future use.

II. **UI.py:** This is a Python script that uses the Tkinter module to create a graphical user interface (GUI) for a thermal face recognition system. The GUI has four buttons: "New Registration", "Recognize", "History", and "Exit". When the "New Registration" button is clicked, it executes the "index.py" script. When the "Recognize" button is clicked, it executes the "recognition.py" script. When the "History" button is clicked, it calls the "getHistory()" function from the "helper" module to display the contents of a text file named "History.txt" (if it exists). When the "Exit" button is clicked, it closes the GUI.

III. **Recognition.py:** This file is a face recognition script that detects faces in a camera stream, applies a thermal map, fuses the thermal and RGB images, and uses a trained LBPH face recognizer to recognize the face in the image. It also displays the recognized name and a green bounding box around the detected face. The script also saves the face data in a CSV file for future recognition.

IV. **Splash_Screen.py:** This code creates a splash screen using an image file and displays it on the screen without any frame or border. It sets the size of the screen and the image using the Tkinter library in Python. The screen is shown for 2000 milliseconds before being closed automatically.

References

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