CMU Project Report (Team6)

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# 0. Introduction

The system is an embedded face recognition system running on a Jetson Nano processor that utilizes CUDA and a windows C++ or Java control and display application.



|  |  |
| --- | --- |
| Name | Role |
| Jeonghwan.Ahn | Implement TLS, Crypto, Security Requirement, … |
| Jinmo.Kim | Requirement Analysis, Static Analysis, Threat Modeling, Schedule, … |
| Kyungnam.Bae | Implement Client, Test case, Contact Point, … |
| Seongju.Moon | Static Analysis, Threat Modeling, … |
| Byungchul.Park | Implement Server, Presentation |

# 1. Schedule

Note: This is our schedule that’s set-up during this course.



# 2. System Requirement

We’ve analyzed the requirement documents that was given by Professor Dan and Professor Jeff. The name of the first document is **LG May 2021 Lecture Secure Coding Project Intro V1.1.pptx.pdf** and the second is **LG Security Class Project Description.pdf.**

We’re struggling to find and extract our system requirement from these documents.

Here is our first artifact from the first, Project Description-1, 2, 3.



But, we needed to compare another document below because it (the second) was also describing system requirements of Jetson Nano system. The second document says requirements of Tartan Secure Camera Application.



Those made us confused. Therefore, we should clarify and draw the requirement for our system after discussing with Professor DAN.

|  |
| --- |
| Summary of meeting with Professor DAN |
| Mandatory requirements described in the "LG May 2021 Lecture Secure Coding Project Intro V1.1.pptx.pdf" document.  - no vulnerability in the system  - secure architecture  - implement 5 modes (run, test run, learning, secure, non-secure)  - Jetson Nano sends the Camera Image and Face Recognized information. It should be separated.  - Client receives the data above, and displays it after combining it |

We’ve extracted our requirements from the list above and attached the result.





# 3. Security Goals

Protecting the user privacy information in our system.

# 4. Assets

|  |  |  |  |
| --- | --- | --- | --- |
| # | Items | Items to manage | Comment |
| 1 | Images for transmission over camera cable | X | Out of S/W boundary |
| 2 | Images for transmission over network | O |  |
| 3 | Face Recognition Data | O |  |
| 4 | Client program itself | O |  |
| 5 | Client program hash code on server side | O |  |
| 6 | User info. data (ID, type, password) | O |  |
| 7 | Private key and certificate for TLS | O |  |

# 5. Threat Modeling

We used DFD and STRIDE as the basis because it is easy to derive many threats from system diagrams. We also used PnG and brainstorming techniques to uncover threats not derived from it.

In the case of attack trees, it is advantageous to derive threats from an expert's point of view using experience, but we excluded it because it was not suitable for beginners like us.

## 5.1. DFD



## 5.2. STRIDE

Threats that could not arise as a result of the review or are outside the scope of this project were ***grayed*** out.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ID | Category | Interaction | Description | Justification |
| TR-01 | Information Disclosure | DF4.2 Load Login Credential / Learning Data ... | Improper data protection of S1. User Credential Data File System can allow an attacker to read information not intended for disclosure. Review authorization settings. | [Threat] If the user credential data is stored as plain text, it can be disclosed.  [Review] Use data encryption |
| TR-02 | Tampering | DF4.2 Load Login Credential / Learning Data ... | Log readers can come under attack via log files. Consider ways to canonicalize data in all logs. Implement a single reader for the logs, if possible, in order to reduce attack surface area. Be sure to understand and document log file elements which come from untrusted sources. | [Threat] An attacker modify user credential data. [Review] Use hashing |
| TR-03 | Spoofing | DF4.2 Load Login Credential / Learning Data ... | S1. User Credential Data File System may be spoofed by an attacker and this may lead to incorrect data delivered to 2.1 Server (Jetson). Consider using a standard authentication mechanism to identify the source data store. | [Threat] An attacker modify user credential data and then server can use it without checking. [Review] Use hashing |
| TR-04 | Spoofing | DF2.1 Request (Login / Mode Ctrl..) | 2.1 Server (Jetson) may be spoofed by an attacker and this may lead to information disclosure by 1.1 Client (PC). Consider using a standard authentication mechanism to identify the destination process. | [Threat] An attacker spoof the user (Client) [Review] use 2FA |
| TR-05 | Tampering | DF2.1 Request (Login / Mode Ctrl..) | Data flowing across DF2.1 Request (Login / Mode Ctrl..) may be tampered with by an attacker. This may lead to a denial of service attack against 2.1 Server (Jetson) or an elevation of privilege attack against 2.1 Server (Jetson) or an information disclosure by 2.1 Server (Jetson). Failure to verify that input is as expected is a root cause of a very large number of exploitable issues. Consider all paths and the way they handle data. Verify that all input is verified for correctness using an approved list input validation approach. | [Threat] An attacker tampers data to server in order to get information. [Review] use TLS |
| TR-06 | Repudiation | DF2.1 Request (Login / Mode Ctrl..) | 2.1 Server (Jetson) claims that it did not receive data from a source outside the trust boundary. Consider using logging or auditing to record the source, time, and summary of the received data. | [Threat] Clients can repudiate the actions they have performed. [Review] Use mutual authentication |
| TR-07 | Information Disclosure | DF2.1 Request (Login / Mode Ctrl..) | Data flowing across DF2.1 Request (Login / Mode Ctrl..) may be sniffed by an attacker. Depending on what type of data an attacker can read, it may be used to attack other parts of the system or simply be a disclosure of information leading to compliance violations. Consider encrypting the data flow. | [Threat] An attack can sniff the data on the connection. [Review] Use TLS Encrypted Communication channel, mTLS (mutual Auth) may be implemented. |
| TR-08 | Information Disclosure | DF2.1 Request (Login / Mode Ctrl..) | Custom authentication schemes are susceptible to common weaknesses such as weak credential change management, credential equivalence, easily guessable credentials, null credentials, downgrade authentication or a weak credential change management system. Consider the impact and potential mitigations for your custom authentication scheme. | [Threat] Weak Authentication may lead to disclose information [Review] Need to more stronger authentication process. Use 2FA |
| TR-09 | Denial Of Service | DF2.1 Request (Login / Mode Ctrl..) | 2.1 Server (Jetson) crashes, halts, stops or runs slowly; in all cases violating an availability metric. | [Review] Server is simple then there is no way to detect that symptoms. |
| TR-10 | Denial Of Service | DF2.1 Request (Login / Mode Ctrl..) | An external agent interrupts data flowing across a trust boundary in either direction. | [Threat] the information of the communication between client and server is interrupted by attackers. [Review] using TLS |
| TR-11 | Elevation Of Privilege | DF2.1 Request (Login / Mode Ctrl..) | 2.1 Server (Jetson) may be able to impersonate the context of 1.1 Client (PC) in order to gain additional privilege. | [Review] Server doesn't need to impersonate in order to gain additional privilege. |
| TR-12 | Elevation Of Privilege | DF2.1 Request (Login / Mode Ctrl..) | 1.1 Client (PC) may be able to remotely execute code for 2.1 Server (Jetson). | [Review] Client cannot execute code in Server remotely. |
| TR-13 | Elevation Of Privilege | DF2.1 Request (Login / Mode Ctrl..) | An attacker may pass data into 2.1 Server (Jetson) in order to change the flow of program execution within 2.1 Server (Jetson) to the attacker's choosing. | [Threat] An attacker sends a malicious data to server in order to change the flow of program execution. [Review] need input sanitization |
| TR-14 | Spoofing | DF3.2 Sensor Data | 3.1 Camera Unit may be spoofed by an attacker and this may lead to unauthorized access to 2.1 Server (Jetson). Consider using a standard authentication mechanism to identify the source process. | [Review] Camera unit can get information only about Camera control signal, cable is dedicated for that. |
| TR-15 | Spoofing | DF3.2 Sensor Data | 2.1 Server (Jetson) may be spoofed by an attacker and this may lead to information disclosure by 3.1 Camera Unit. Consider using a standard authentication mechanism to identify the destination process. | [Review] Camera is just simple unit, so no threat is expected to arise. |
| TR-16 | Tampering | DF3.2 Sensor Data | Data flowing across DF3.2 Sensor Data may be tampered with by an attacker. This may lead to a denial of service attack against 2.1 Server (Jetson) or an elevation of privilege attack against 2.1 Server (Jetson) or an information disclosure by 2.1 Server (Jetson). Failure to verify that input is as expected is a root cause of a very large number of exploitable issues. Consider all paths and the way they handle data. Verify that all input is verified for correctness using an approved list input validation approach. | [Review] Since it is connected with a physical dedicated cable, it is difficult to interrupts and tamper data from the outside. |
| TR-17 | Repudiation | DF3.2 Sensor Data | 2.1 Server (Jetson) claims that it did not receive data from a source outside the trust boundary. Consider using logging or auditing to record the source, time, and summary of the received data. | [Review] Camera Unit cannot claims the receive data from a source outside. |
| TR-18 | Information Disclosure | DF3.2 Sensor Data | Data flowing across DF3.2 Sensor Data may be sniffed by an attacker. Depending on what type of data an attacker can read, it may be used to attack other parts of the system or simply be a disclosure of information leading to compliance violations. Consider encrypting the data flow. | [Review] The camera unit can only do very simple things, and that threat is unlikely to arise. |
| TR-19 | Denial Of Service | DF3.2 Sensor Data | 2.1 Server (Jetson) crashes, halts, stops or runs slowly; in all cases violating an availability metric. | [Review] Server is simple then there is no way to detect that symptoms. |
| TR-20 | Denial Of Service | DF3.2 Sensor Data | An external agent interrupts data flowing across a trust boundary in either direction. | [Review] Since they are connected by physical cables, it is difficult to interrupt with data. |
| TR-21 | Elevation Of Privilege | DF3.2 Sensor Data | 2.1 Server (Jetson) may be able to impersonate the context of 3.1 Camera Unit in order to gain additional privilege. | [Review] Even if the camera unit acquires additional privileges, It just send Sensor Data, so no threat is expected to arise. |
| TR-22 | Elevation Of Privilege | DF3.2 Sensor Data | 3.1 Camera Unit may be able to remotely execute code for 2.1 Server (Jetson). | [Review] Camera is just simple unit, so no threat is expected to arise. |
| TR-23 | Elevation Of Privilege | DF3.2 Sensor Data | An attacker may pass data into 2.1 Server (Jetson) in order to change the flow of program execution within 2.1 Server (Jetson) to the attacker's choosing. | [Review] Camera is just simple unit, so no threat is expected to arise. |
| TR-24 | Spoofing | DF3.1 Camera Ctrl | 2.1 Server (Jetson) may be spoofed by an attacker and this may lead to unauthorized access to 3.1 Camera Unit. Consider using a standard authentication mechanism to identify the source process. | [Review] Server can control Camera Unit via Device driver, and authorized access is taken care of by the OS. |
| TR-25 | Spoofing | DF3.1 Camera Ctrl | 3.1 Camera Unit may be spoofed by an attacker and this may lead to information disclosure by 2.1 Server (Jetson). Consider using a standard authentication mechanism to identify the destination process. | [Review] Camera unit can get information only about Camera control signal, cable is dedicated for that. |
| TR-26 | Tampering | DF3.1 Camera Ctrl | Data flowing across DF3.1 Camera Ctrl may be tampered with by an attacker. This may lead to a denial of service attack against 3.1 Camera Unit or an elevation of privilege attack against 3.1 Camera Unit or an information disclosure by 3.1 Camera Unit. Failure to verify that input is as expected is a root cause of a very large number of exploitable issues. Consider all paths and the way they handle data. Verify that all input is verified for correctness using an approved list input validation approach. | [Review] Since it is connected with a physical dedicated cable, it is difficult to interrupts and tamper data outside. |
| TR-27 | Repudiation | DF3.1 Camera Ctrl | 3.1 Camera Unit claims that it did not receive data from a source outside the trust boundary. Consider using logging or auditing to record the source, time, and summary of the received data. | [Review] Camera Unit cannot claims the receive data from a source outside. |
| TR-28 | Information Disclosure | DF3.1 Camera Ctrl | Data flowing across DF3.1 Camera Ctrl may be sniffed by an attacker. Depending on what type of data an attacker can read, it may be used to attack other parts of the system or simply be a disclosure of information leading to compliance violations. Consider encrypting the data flow. | [Review] The camera unit can only do very simple things, and that threat is unlikely to arise. |
| TR-29 | Denial Of Service | DF3.1 Camera Ctrl | 3.1 Camera Unit crashes, halts, stops or runs slowly; in all cases violating an availability metric. | [Threat] It may be physically damaged and you may not be able to get Data from Camera [Review] Protect Camera from physical damage |
| TR-30 | Denial Of Service | DF3.1 Camera Ctrl | An external agent interrupts data flowing across a trust boundary in either direction. | [Review] Since they are connected by physical cables, it is difficult to interrupt with data. |
| TR-31 | Elevation Of Privilege | DF3.1 Camera Ctrl | 3.1 Camera Unit may be able to impersonate the context of 2.1 Server (Jetson) in order to gain additional privilege. | [Review] Even if the camera unit acquires additional privileges, It just send Sensor Data, so no threat is expected to arise. |
| TR-32 | Elevation Of Privilege | DF3.1 Camera Ctrl | 2.1 Server (Jetson) may be able to remotely execute code for 3.1 Camera Unit. | [Review] Camera is just simple unit, so no threat is expected to arise. |
| TR-33 | Elevation Of Privilege | DF3.1 Camera Ctrl | An attacker may pass data into 3.1 Camera Unit in order to change the flow of program execution within 3.1 Camera Unit to the attacker's choosing. | [Review] Camera is just simple unit, so no threat is expected to arise. |
| TR-34 | Denial Of Service | DF4.1 Store Login Credential / Learning Data ... | Does 2.1 Server (Jetson) or S1. User Credential Data File System take explicit steps to control resource consumption? Resource consumption attacks can be hard to deal with, and there are times that it makes sense to let the OS do the job. Be careful that your resource requests don't deadlock, and that they do timeout. | [Threat] It is possible to add a lot of Images in the storage. [Review] The limitation of number of image is need. |
| TR-35 | Information Disclosure | DF4.1 Store Login Credential / Learning Data ... | Credentials held at the server are often disclosed or tampered with and credentials stored on the client are often stolen. For server side, consider storing a salted hash of the credentials instead of storing the credentials themselves. If this is not possible due to business requirements, be sure to encrypt the credentials before storage, using an SDL-approved mechanism. For client side, if storing credentials is required, encrypt them and protect the data store in which they're stored | [Threat] User credential may be disclosed. [Review] User credential should be encrypted before being stored. |
| TR-36 | Repudiation | DF4.1 Store Login Credential / Learning Data ... | Consider what happens when the audit mechanism comes under attack, including attempts to destroy the logs, or attack log analysis programs. Ensure access to the log is through a reference monitor, which controls read and write separately. Document what filters, if any, readers can rely on, or writers should expect | [Review] This case will not happen in the system. |
| TR-37 | Repudiation | DF4.1 Store Login Credential / Learning Data ... | Does the log capture enough data to understand what happened in the past? Do your logs capture enough data to understand an incident after the fact? Is such capture lightweight enough to be left on all the time? Do you have enough data to deal with repudiation claims? Make sure you log sufficient and appropriate data to handle a repudiation claims. You might want to talk to an audit expert as well as a privacy expert about your choice of data. | [Review] This case will not happen in the system. |
| TR-38 | Repudiation | DF4.1 Store Login Credential / Learning Data ... | Do you accept logs from unknown or weakly authenticated users or systems? Identify and authenticate the source of the logs before accepting them. | [Review] This case will not happen in the system. |
| TR-39 | Repudiation | DF4.1 Store Login Credential / Learning Data ... | If you have trust levels, is anyone other outside of the highest trust level allowed to log? Letting everyone write to your logs can lead to repudiation problems. Only allow trusted code to log. | [Review] This case will not happen in the system. |
| TR-40 | Tampering | DF4.1 Store Login Credential / Learning Data ... | Log readers can come under attack via log files. Consider ways to canonicalize data in all logs. Implement a single reader for the logs, if possible, in order to reduce attack surface area. Be sure to understand and document log file elements which come from untrusted sources. | [Review] This case will not happen in the system. |
| TR-41 | Spoofing | DF4.1 Store Login Credential / Learning Data ... | S1. User Credential Data File System may be spoofed by an attacker and this may lead to data being written to the attacker's target instead of S1. User Credential Data File System. Consider using a standard authentication mechanism to identify the destination data store. | [Threat] User Credential Data can be exposed to attackers. [Review] User Credential Data should be kept securely. |
| TR-42 | Spoofing | DF1.1 User Input (Login Credential & Mode Control Input) | E1. Human User may be spoofed by an attacker and this may lead to unauthorized access to 1.1 Client (PC). Consider using a standard authentication mechanism to identify the external entity. | [Review] Client cannot distinguish Human Users. |
| TR-43 | Elevation Of Privilege | DF1.1 User Input (Login Credential & Mode Control Input) | 1.1 Client (PC) may be able to impersonate the context of E1. Human User in order to gain additional privilege. | [Review] Client cannot distinguish Human Users. |
| TR-44 | Spoofing | DF2.5 Result (Video Stream...) | 2.1 Server (Jetson) may be spoofed by an attacker and this may lead to unauthorized access to 1.1 Client (PC). Consider using a standard authentication mechanism to identify the source process. | [Threat] Server (Jetson) may be spoofed by an attacker  [Review] use mutual authentication |
| TR-45 | Spoofing | DF2.5 Result (Video Stream...) | 1.1 Client (PC) may be spoofed by an attacker and this may lead to information disclosure by 2.1 Server (Jetson). Consider using a standard authentication mechanism to identify the destination process. | [Threat] Client (PC) may be spoofed by an attacker  [Review] use mutual authentication |
| TR-46 | Tampering | DF2.5 Result (Video Stream...) | Data flowing across DF2.5 Result (Video Stream...) may be tampered with by an attacker. This may lead to a denial of service attack against 1.1 Client (PC) or an elevation of privilege attack against 1.1 Client (PC) or an information disclosure by 1.1 Client (PC). Failure to verify that input is as expected is a root cause of a very large number of exploitable issues. Consider all paths and the way they handle data. Verify that all input is verified for correctness using an approved list input validation approach. | [Threat] Video Stream may be tampered with by an attacker. [Review] Video Stream over the connection should be protected. |
| TR-47 | Repudiation | DF2.5 Result (Video Stream...) | 1.1 Client (PC) claims that it did not receive data from a source outside the trust boundary. Consider using logging or auditing to record the source, time, and summary of the received data. | [Review] even though This case will happen, this case does not affect. |
| TR-48 | Information Disclosure | DF2.5 Result (Video Stream...) | Data flowing across DF2.5 Result (Video Stream...) may be sniffed by an attacker. Depending on what type of data an attacker can read, it may be used to attack other parts of the system or simply be a disclosure of information leading to compliance violations. Consider encrypting the data flow. | [Threat] Video Stream may be sniffed with by an attacker. [Review] Video Stream over the connection should be protected. |
| TR-49 | Denial Of Service | DF2.5 Result (Video Stream...) | 1.1 Client (PC) crashes, halts, stops or runs slowly; in all cases violating an availability metric. | [Threat] Client (PC) crashes, halts, stops or runs slowly. [Review] Server is working properly. |
| TR-50 | Denial Of Service | DF2.5 Result (Video Stream...) | An external agent interrupts data flowing across a trust boundary in either direction. | [Review] This case won't be handled. |
| TR-51 | Elevation Of Privilege | DF2.5 Result (Video Stream...) | 1.1 Client (PC) may be able to impersonate the context of 2.1 Server (Jetson) in order to gain additional privilege. | [Review] support only single user |
| TR-52 | Elevation Of Privilege | DF2.5 Result (Video Stream...) | 2.1 Server (Jetson) may be able to remotely execute code for 1.1 Client (PC). | [Threat] Server (Jetson) may be able to remotely execute code [Review] need input sanitization |
| TR-53 | Elevation Of Privilege | DF2.5 Result (Video Stream...) | An attacker may pass data into 1.1 Client (PC) in order to change the flow of program execution within 1.1 Client (PC) to the attacker's choosing. | [Threat] An attacker may pass data into 1.1 Client (PC) [Review] need input sanitization |
| TR-54 | Information Disclosure | DF3.1 Camera Ctrl | Credentials on the wire are often subject to sniffing by an attacker. Are the credentials re-usable/re-playable? Are credentials included in a message? For example, sending a zip file with the password in the email. Use strong cryptography for the transmission of credentials. Use the OS libraries if at all possible, and consider cryptographic algorithm agility, rather than hardcoding a choice. | [Review] Since they are connected by physical cables, it is difficult to interrupt with data. |
| TR-55 | Information Disclosure | DF3.2 Sensor Data | Credentials on the wire are often subject to sniffing by an attacker. Are the credentials re-usable/re-playable? Are credentials included in a message? For example, sending a zip file with the password in the email. Use strong cryptography for the transmission of credentials. Use the OS libraries if at all possible, and consider cryptographic algorithm agility, rather than hardcoding a choice. | [Review] Since they are connected by physical cables, it is difficult to interrupt with data. |

## 5.3. PnG

We found 3 PnGs from our project.

|  |  |  |
| --- | --- | --- |
| PnG 1 | Type | Internal Engineer |
| Goal | Ruin the administrator's reputation |
| Motivation | Revenge to the administrator |
| Skill | manipulate the user credential data, find out the administrator’s password from the previous one that is used to other system |
| Misuse case | (TR-56) Change the image data not to recognize registered users.  (TR-57) Disclose administrator’s ID/Password to the employees in the company. |

|  |  |  |
| --- | --- | --- |
| PnG 2 | Type | Spy |
| Goal | Steal all components of the system |
| Motivation | Competitors request |
| Skill | Physical power and ability to use various equipment |
| Misuse case | (TR-58) Steal the client and server => Out of S/W boundary |

|  |  |  |
| --- | --- | --- |
| PnG 3 | Type | Hacker |
| Goal | Post the achievements of hacking on the internet |
| Motivation | Strives for recognition |
| Skill | Extensive knowledge of network protocols and hacking program. |
| Misuse case | (TR-59) Sniff the communication channel between server and client to get user credential data. |

## 5.4. Brainstorming

Many threats have already been detected by the previous tools, but several threats have emerged.

|  |  |  |
| --- | --- | --- |
| ID | Threat | Review |
| TR-60 | Compromise the connection of network physically by an attacker |  |
| - | Sniffing in the middle of communication between camera and Jetson | Same as TR-18 |
| - | Sniffing in the middle of communication between client and server | Same as TR-07 |
| - | Leak pictures from the directory to unauthorized users | Same as TR-35 |
| - | Anyone can view video stream from Jetson | Same as TR-48 |
| TR-61 | By changing the server/client's certificate or key, an attacker may attempt to connect to an unauthorized client.  And attacker can try to steal the information of the encryption channel. |  |
| TR-62 | By modifying the face recognition data, an attacker may cause an error or abnormal operation in the face recognition result.  By stealing facial recognition data, an attacker can steal information from the system. |  |
| TR-63 | An attacker can find out the ROOT KEY used for encryption through reverse binary analysis, decrypt the encrypted file, and steal information.  An attacker can infer the key used for encryption through statistical analysis of the encrypted file. |  |

## 5.5. Result of Threat Modeling

We found 25 threats below by using STRIDE, PnG, Brainstorming.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ID | Tool | Category | Interaction | Threat | Review |
| TR-01 | STRIDE | Information Disclosure | DF4.2 Load Login Credential / Learning Data ... | If the user credential data is stored as plain text, it can be disclosed. | User credential should be kept securely |
| TR-02 | STRIDE | Tampering | DF4.2 Load Login Credential / Learning Data ... | An attacker modify user credential data. | User credential should be kept securely |
| TR-03 | STRIDE | Spoofing | DF4.2 Load Login Credential / Learning Data ... | An attacker modify user credential data and then server can use it without checking. | User credential should be kept securely |
| TR-04 | STRIDE | Spoofing | DF2.1 Request (Login / Mode Ctrl..) | An attacker spoof the user (Client) | Need to more stronger authentication process |
| TR-05 | STRIDE | Tampering | DF2.1 Request (Login / Mode Ctrl..) | An attacker tampers Login or Mode control data to server in order to get information. | Need to encrypt communication channel |
| TR-06 | STRIDE | Repudiation | DF2.1 Request (Login / Mode Ctrl..) | Clients can repudiate the actions they have performed. | Need to apply mutual authentication |
| TR-07 | STRIDE | Information Disclosure | DF2.1 Request (Login / Mode Ctrl..) | An attack can sniff the data on the connection. | Need to consider encrypting the data flow. |
| TR-08 | STRIDE | Information Disclosure | DF2.1 Request (Login / Mode Ctrl..) | Weak authentication may lead to disclose information | Need to more stronger authentication process |
| TR-10 | STRIDE | Denial Of Service | DF2.1 Request (Login / Mode Ctrl..) | the information of the communication between client and server is interrupted by attackers. | Need to use TLS |
| TR-13 | STRIDE | Elevation Of Privilege | DF2.1 Request (Login / Mode Ctrl..) | An attacker sends a malicious data to server in order to change the flow of program execution. | Need to apply input sanitization |
| TR-29 | STRIDE | Denial Of Service | DF3.1 Camera Ctrl | It may be physically damaged and you may not be able to get Data from Camera | Need to protect camera unit from physical damage |
| TR-34 | STRIDE | Denial Of Service | DF4.1 Store Login Credential / Learning Data ... | It is possible to add a lot of Images in the storage. | Need to limit the number of images |
| TR-35 | STRIDE | Information Disclosure | DF4.1 Store Login Credential / Learning Data ... | User credential may be disclosed. | Need to encrypt user credential data |
| TR-41 | STRIDE | Spoofing | DF4.1 Store Login Credential / Learning Data ... | User Credential Data can be exposed to attackers. | Need to encrypt user credential data |
| TR-44 | STRIDE | Spoofing | DF2.5 Result (Video Stream...) | Server (Jetson) may be spoofed by an attacker | Need to apply mutual authentication |
| TR-45 | STRIDE | Spoofing | DF2.5 Result (Video Stream...) | Client (PC) may be spoofed by an attacker | Need to apply mutual authentication |
| TR-46 | STRIDE | Tampering | DF2.5 Result (Video Stream...) | Video Stream may be tampered with by an attacker. | Need to protect the video stream over the connection |
| TR-48 | STRIDE | Information Disclosure | DF2.5 Result (Video Stream...) | Video Stream may be sniffed with by an attacker. | Need to protect the video stream over the connection |
| TR-49 | STRIDE | Denial Of Service | DF2.5 Result (Video Stream...) | Client (PC) crashes, halts, stops or runs slowly. | Need to remain stable in abnormal cases |
| TR-52 | STRIDE | Elevation Of Privilege | DF2.5 Result (Video Stream...) | Server (Jetson) may be able to remotely execute code | Need input sanitization |
| TR-53 | STRIDE | Elevation Of Privilege | DF2.5 Result (Video Stream...) | An attacker may pass data into 1.1 Client (PC) | Need input sanitization |
| TR-56 | PnG | Tampering | User credential data | Change the image data not to recognize registered users. | Need to protect user credential data |
| TR-57 | PnG | Information Disclosure | Client => Server | Disclose administrator’s ID/Password to the employees in the company. | Need to more stronger process for authentication |
| TR-59 | PnG | Information Disclosure | Server <=> Client | Sniff the communication channel between server and client to get user credential data. | Need to protect the data over the connection |
| TR-60 | Brainstorming | N/A | Network | Compromise the connection of network physically by an attacker | Server need to be robust in abnormal case. |
| TR-61 | Brainstorming | Tampering/ Information Disclosure/ Spoofing | Server <=> Client | By changing the server/client's certificate or key, an attacker may attempt to connect to an unauthorized client.  And attacker can try to steal the information of the encryption channel. | Need to protect or verify the certificates and keys used by the server and client for TLS communication |
| TR-62 | Brainstorming | Tampering/ Information Disclosure | Face Recognition data | By modifying the face recognition data, an attacker may cause an error or abnormal operation in the face recognition result.  By stealing facial recognition data, an attacker can steal information from the system. | Need to protect face recognition data |
| TR-63 | Brainstorming | N/A | Cryptographically robust | An attacker can find out the ROOT KEY used for encryption through reverse binary analysis, decrypt the encrypted file, and steal information.  An attacker can infer the key used for encryption through statistical analysis of the encrypted file. | Need to preventing reverse analysis of encrypted information  Need to protect ROOT encrypt key |

# 6. Security Risk Assessment

OWASP Tools is known for well-formed sub-categories to weight to threat level and impact level comparing to the heavens.

And we've learned this tool from our lecture and used to it.



















# 7. Security Requirements

We’ve derived the security requirements through the STRIDE methodology. And we found out some of security requirements are linked to system requirements, section 2 above.

|  |  |  |  |
| --- | --- | --- | --- |
| SR-ID | Security Requirement | Mapping with system requirement | Mitigation ID |
| SR-01 | A strong authentication method should be used. | CMU-REQ-D-09 | MI-10 |
| SR-02 | Cryptographically strong password should be used. |  | MI-01 |
| SR-03 | Errors, exceptions, and abnormal conditions that may occur in the software must be handled robustly. | CMU-REQ-D-15 | MI-04 |
| SR-04 | Input validation check is required in Client side. |  | MI-05 |
| SR-05 | Only the verified server and client should be connected and communicated. |  | MI-11 |
| SR-06 | Protect Camera from physical damage |  | MI-08 |
| SR-07 | Restrictions related to files are necessary to avoid system problems. |  | MI-12 |
| SR-08 | Save contents of the communication as a log and use as proof of non-repudiation. |  | MI-09 |
| SR-09 | Server and client must communicate using an encrypted channel. | CMU-REQ-D-02 | MI-02 |
| SR-10 | The system must perform an integrity check before using user credentials. |  | MI-07 |
| SR-11 | The system shall know the change of the user credential data. |  | MI-07 |
| SR-12 | Use well-known cryptographic libraries and robust algorithms. |  | MI-03, MI-07 |
| SR-13 | User Credential Data should be encrypted in the storage. | CMU-REQ-D-10 | MI-03 |
| SR-14 | Video Stream over the connection should be protected. |  | MI-02 |
| SR-15 | A server and client program must perform an integrity check before using a certificate or key. |  | MI-13 |
| SR-16 | Face recognition data should be encrypted in the storage. |  | MI-06 |
| SR-17 | Every encryption time, newly generated random key is used for encryption to make reverse analysis difficult |  | MI-14 |
| SR-18 | ROOT encrypt key must be protected from binary analysis |  | MI-15 |

# 8. Mitigation

We were trying to mitigate the threat and mentioned in the Security Requirements, section 7. And we’ve derived the result below.

|  |  |
| --- | --- |
| MI-ID | Mitigation |
| MI-01 | Apply setting policy of cryptographically strong password - Enforce passwords longer than 7 characters. - Forces the use of mixed the letters of the alphabet and numbers. |
| MI-02 | Communicate using Encrypted channel - using protocol TLS1.2 or higher - Consider mutual authentication between server and client |
| MI-03 | Encrypt user credential data in storage - Use OpenSSL library of latest version (1.1.1k) - Use an algorithm that are stronger than AES256 - Use CBC or GCM mode |
| MI-04 | Implement robust system - Error handling - Exception handling - Finding countermeasures for predictable abnormal conditions |
| MI-05 | Input validation check - Input sanitization |
| MI-06 | Encrypt face recognition data in storage  - Use OpenSSL library of latest version (1.1.1k)  - Use an algorithm that are stronger than AES256  - Use CBC or GCM mode |
| MI-07 | Integrity Check with hash function - Use OpenSSL library of latest version (1.1.1k) - Use an algorithm that are stronger than sha256 |
| MI-08 | Protect from physical damage - Wrap the camera module out of sight, or glue the cable to the camera. |
| MI-09 | Save contents of communication as a log - Save log of the request and response between the server and the client |
| MI-10 | Strong authentication method - Consider 2-Factor-Authentication method |
| MI-11 | Use mutual authentication - Using protocol TLS1.2 or higher - Use mutual authentication between server and client |
| MI-12 | Validation of image when file saving - Limit on number of files - File name verification when image save - File size validation when image save |
| MI-13 | Certificate & Key file existence check  Integrity Check with hash function  - Use OpenSSL library of latest version (1.1.1k)  - Use an algorithm that are stronger than sha256 |
| MI-14 | Use random encrypt key  - use TRNG (True Random Number Generator) is best  - Cryptographically secure pseudorandom number generator can be used alternatively |
| MI-15 | Protect ROOT encryption key  - HSM (Hardware Secure Module) is best  - alternatively White-box Cryptography or Code obfuscation method can be used |

# 9. Architecture

## 9.1. Overall Architecture



## 9.2. Terminology and Definitions

|  |  |
| --- | --- |
| **Terminology** | **Definitions** |
| CA CRT | Self-signed Root Certificate |
| CRT | CA signed Certificate |
| Key | Private Key |
| Login info | Client id/password to connect server |
| Face Image | The face image registered with name by client |
| faceNet model | Face recognition model |
| Machine learning model | TensorRT machine learning model |
| Secure Mode | The photo is being transferred securely through TLS |
| Non Secure Mode | The photo is being transferred through non TLS TCP |
| Test Mode | The photo is generated from the Friends video file |
| Learn Mode | Request saving the current face image |
| Secure channel for control data | TLS TCP connection.  The request and response message is transmitted. |
| Secure channel for photo | TLS TCP connection.  The photo data is transmitted from the server to the client |
| Non-secure channel for photo | TCP connection.  The photo data is transmitted from the server to the client |
| Secure channel for face recognition info | TLS TCP connection.  The coordination of the recognized face on the photo and the recognized name is transmitted from the server to the client |

## 9.3. Source Directory



## 9.4. Setup Guide

### 9.4.1. Server

|  |
| --- |
| # cd source/server/  # python3 step01\_pb\_to\_uff.py  # rm -rf MTCNN\_FaceDetection\_TensorRT/  # git clone https://github.com/PKUZHOU/MTCNN\_FaceDetection\_TensorRT  # mv MTCNN\_FaceDetection\_TensorRT/det\* ./mtCNNModels  # mkdir build; cd build  # cmake -DCMAKE\_BUILD\_TYPE=Release ..  # make -j  # ./LgFaceRecDemoTCP\_Jetson\_NanoV2 5000 9.2.2. Client |

### 9.4.2. Client

|  |
| --- |
| # apt install cmake libssl-dev libgtkmm-3.0-dev libopencv-dev  # cd source/client/ && mkdir build; cd build  # cmake ..  # make  # ./client |

## 9.5. Crypto Algorithms

### 9.5.1. Primitives and Algorithms

1. Crypto Library : OpenSSL
2. Version : 1.1.1
3. OpenSSL has known vulnerabilities, but Jetson Nano Development Environment has dependencies to OpenSSL 1.1.1 (ex: curl, cmake ...), so we use this version as is.
4. Followings are known vulnerabilities on OpenSSL 1.1.1
   1. CVE-2021-3449
   2. CVE-2021-23841
   3. CVE-2021-23840
   4. CVE-2020-1971
   5. CVE-2019-1563
   6. CVE-2019-1552
   7. CVE-2019-1551
   8. CVE-2019-1549
   9. CVE-2019-1547
   10. CVE-2019-1543
   11. CVE-2019-0190
   12. CVE-2018-0735
   13. CVE-2018-0734
   14. CVE-2007-5502

### 9.5.2. Symmetric cipher algorithm

1. Algorithm : AES
2. Key Size : 256 bits
3. Mode of Operation : CBC
4. Key derivation function : PBKDF2

### 9.5.3. Methods of Secret Hiding

1. Code obfuscation: Hardware security module will provide the strong security strength. However, the system in this project has no support of hardware security anchor (e.g. TPM, HSM, PUF, TE etc.), So Code obfuscation is practical alternative choice (unless Whitebox crypto is not considered). Code obfuscation is less secure than Whitebox crypto, however, it provides the reliable security strength against real-world attacks.

### 9.5.4. User Data Encryption/ Decryption

1. Server encrypt user data. Examples of user data includes followings
   1. AI classified photo
   2. Video
   3. User credentials
   4. Key and CRT for TLS
2. Overall flows on user data encryptions are shown in the figure below



* 1. AES key for ROOT is obfuscated and distributed in code
  2. Use PBKDF2 function for derive ROOT key
  3. Create hash and attach for Integrity verification
  4. Generate Random Number and use it for AES encrypt key in every time at encrypt User Data

1. Overall flows on user data decryptions are shown in the figure below



## 9.6. Compile Options

Defenses at the compiler, check the mitigation technologies in use by processes on a Linux system.

1. checksec.sh ( https://www.trapkit.de/tools/checksec/ )
   1. Modern Linux distributions offer some mitigation techniques to make it harder to exploit software vulnerabilities reliably. Mitigations such as RELRO, NoExecute (NX), Stack Canaries, Address Space Layout Randomization (ASLR) and Position Independent Executables (PIE) have made reliably exploiting any vulnerabilities that do exist far more challenging. The checksec.sh script is designed to test what standard Linux OS and PaX security features are being used.
   2. Result of running checksec.sh (before)
      1. Symbols is not striped
      2. RW-RUNPATH



* 1. Result of running checksec.sh (after apply options for defenses)
     1. Add Symbol stripped option
     2. Apply option for “No RUNPATH”



* 1. Corresponding cmake options are as follows.



## 9.7. Client Program Guide

 

* **ID Input**: Input ID (Alphabet and number are accepted only)
* **Pass Input**: Input Password (Minimum eight characters, at least one alphabet, one number and one special character)
* **Login Button**: Login with ID/PASS. For 2FA, the admin face should be recognized by server
* **Logout Button**: Logout. disconnect with server
* **Secure Mode Checkbox**: Represented whether the photo is being transferred securely through TLS or not.
* **Test Mode Checkbox**: Represented the point where is generated of photo. checked – camera, unchecked – file
* **Pause Button**: The photo is stopped to register new person into the server.

Name Input would be enabled only when it’s pushed and the person exists

with valid recognized face. If you cannot get the face recognized photo,

resume and pause again.

* **Name Input**: The name of the person
* **Learn Mode – Save Button**: Request the saving of photo to the server

## 9.8. Test Cases

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **TC Name** | | **Step** | | **Expected** | **Execution Result** |
| 1 | id validation | 1 | type id more than 10 len | cannot type character more than 10 | OK |
| 2 | pass validation | 1 | type pass more than 20 len | cannot type character more than 20 | OK |
| 3 | login | 1 | type id something | check login button is not activated | OK |
| 2 | make id to empty string | check login button is not activated | OK |
| 3 | type pass something | check login button is not activated | OK |
| 4 | type id,pass something | check login button is activated | OK |
| 5 | disconnect client and server in the local network |  | OK |
| 6 | push login button | check alert 'Connection Fail' | OK |
| 7 | connect client and server in the local network |  | OK |
| 8 | Do not meet the condition below  - type alphabet and number in id  - Minimum eight characters, at least one letter, one number and one special character on password | check login button is activated | OK |
| 9 | push login button and show admin user face on camera | check alert 'Show your face on camera'  after 5 sec, check alert 'Connection Fail' | OK |
| 10 | type valid id,pass |  | OK |
| 11 | push login button and show admin user face on camera within 5sec | check id, pass, login button component are deactivated secure mode check button activated and checked check running secure run mode (camera is on and I can see the camera) | OK |
| 4 | logout | pre | login is needed |  | OK |
| 1 | push logout button | check id,pass components are activated other componens are deactivated all connection with server are disconnected | OK |
| 5 | secure & run mode | pre | login is needed |  | OK |
| 1 | enable checkbox of Secure Mode disable checkout of Test Mode | securely receive the image data generated from server camera | OK |
| 6 | secure & test mode | pre | login is needed |  | OK |
| 1 | enable checkbox of Secure Mode enable checkout of Test Mode | securely receive the image data generated from server media file | OK |
| 7 | non secure & run mode | pre | login is needed |  | OK |
| 1 | disable checkbox of Secure Mode disable checkout of Test Mode | receive the image data generated from server camera | OK |
| 8 | non secure & test mode | pre | login is needed |  | OK |
| 1 | disable checkbox of Secure Mode enable checkout of Test Mode | receive the image data generated from server media file | OK |
| 9 | Learn Mode | pre | login is needed select test mode |  | OK |
| 1 | push Pause button when no face recognition | photo is stopped. no face recognition Pause button is changed to "Resume need to pause again to Save Picture" button | OK |
| 2 | push Resume... button | photo is played | OK |
| 3 | push Pause button when face recognition | photo is stopped. one face recognition is represented Pause button is changed to "Resume" button. Name input is enabled | OK |
| 4 | type name more than 20 len on Name input | "Learn Mode - Save" button is enabled | OK |
| 5 | remove and empty name on Name input | "Learn Mode - Save" button is disabled | OK |
| 6 | type name again on Name input | "Learn Mode - Save" button is enabled | OK |
| 7 | push "Resume" button | confirm "save done" dialog | OK |

9.9. Implementation of mitigation

|  |  |  |
| --- | --- | --- |
| **MI-ID** | **Mitigation** | **Implementation** |
| MI-01 | Apply setting policy of cryptographically strong password - Enforce passwords longer than 7 characters. - Forces the use of mixed the letters of the alphabet and numbers. | Validating the condition below for password  - Minimum eight characters, at least one letter, one number and one special character |
| MI-02 | Communicate using Encrypted channel - using protocol TLS1.2 or higher - Consider mutual authentication between server and client | Apply TLS1.3  Apply Mutual Authentication (it's included in TLS handshake) |
| MI-03 | Encrypt user credential data in storage - Use OpenSSL library of latest version (1.1.1k) - Use an algorithm that are stronger than AES256 - Use CBC of GCM mode | Couldn’t use 1.1.1k library because of the dependency issues. client(1.1.1f), server(1.1.1) are used.  AES256-CBC is used. |
| MI-04 | Implement robust system - Error handling - Exception handling - Finding countermeasures for predictable abnormal conditions | Error and exception handling is applied properly in server & client program.  If client and server are not connected in the local network, the timeout is applied in order to prevent program hang. Also if the client and server are disconnected abnormally, restore the program state to the initial state. |
| MI-05 | Input validation check - Input sanitization | All user input (id, password, name, ipaddr, etc) are checked correctly. |
| MI-06 | Encrypt face recognition data in storage  - Use OpenSSL library of latest version (1.1.1k)  - Use an algorithm that are stronger than AES256  - Use CBC or GCM mode | Couldn’t use 1.1.1k library because of the dependency issues. client(1.1.1f), server(1.1.1) are used.  AES256-CBC is used. |
| MI-07 | Integrity Check with hash function - Use OpenSSL library of latest version (1.1.1k) - Use an algorithm that are stronger than sha256 | Couldn’t use 1.1.1k library because of the dependency issues. client(1.1.1f), server(1.1.1) are used.  SHA256 is used for checking integrity TLS key and CRT. |
| MI-08 | Protect from physical damage - Wrap the camera module out of sight, or glue the cable to the camera. | It’s out of SW boundary. |
| MI-09 | Save contents of communication as a log - Save log of the request and response between the server and the client | Print the message send and receive log at client and server side |
| MI-10 | Strong authentication method - Consider 2-Factor-Authentication method | To use the system, the admin id and password is needed. Also the admin face should be recognized. If server doesn’t have admin face, it should be registered by server command. |
| MI-11 | Use mutual authentication - Using protocol TLS1.2 or higher - Use mutual authentication between server and client | Couldn’t use 1.1.1k library because of the dependency issues. client(1.1.1f), server(1.1.1) are used.  AES256-CBC is used. |
| MI-12 | Validation of image when file saving - Limit on number of files - File name verification when image save - File size validation when image save | Limit on number and size of files is not implemented yet.  Validating the condition below for file name  - The alphabet, numbers, and the special character (,.\_’`-) can be accepted. |
| MI-13 | Certificate & Key file existence check  Integrity Check with hash function  - Use OpenSSL library of latest version (1.1.1k)  - Use an algorithm that are stronger than sha256 | Couldn’t use 1.1.1k library because of the dependency issues. client(1.1.1f), server(1.1.1) are used.  SHA256 is used for checking integrity TLS key and CRT. |
| MI-14 | Use random encrypt key  - use TRNG (True Random Number Generator) is best  - Cryptographically secure pseudorandom number generator can be used alternatively | Pseudorandom number is used in openSSL library. |
| MI-15 | Protect ROOT encryption key  - HSM (Hardware Secure Module) is best  - alternatively White-box Cryptography or Code obfuscation method can be used | Code obfuscation method is applied. |

# 10. Static Analysis

In this Static Analysis, it is very helpful for us to check the initial vulnerabilities of our code.

We’re actually thinking of how to check vulnerabilities of the code and we wanted to detect them using any kind of static tools. Firstly, we used two tools in syllabus– flawfinder. The reason why is this tool is introduced in our syllabus and easy to use so that we can adapt it.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Tools | Support C/C++ | Free software | Latest release | Comment |
| Flawfinder | O | O | O (2021-06-03) |  |
| RATS | O | O | X (2014-01-01) |  |
| SpotBugs | X (Java) | O | O (2021-04-16) |  |
| SonarQube | O | X | O (2021-05-04) |  |
| PMD | X (Java, JS, …) | O | O (2021-05-29) |  |
| Klocwork | O | X | O (2021-01) |  |
| Cppcheck | O | O | O (2021-03-23) |  |
| Coverity | O | X | O | Need build environment |

\* Note: Although our mentor(Professor Jeff)’s suggested to use the SonaCube as a tool with a comment that it’s utilized with the github system we’re using, actually Cppcheck was one of candidates at that time. We were considering many tools we were going to use for cross-check.

When we reviewed the result from Flawfinder, we found out it’s working as a code scanner and detecting vulnerabilities according to its DB. So we searched the tool detecting more specific vulnerabilities. Finally we’ve known the Cppcheck is more suitable for the C++ language so that we can decide to use the Cppcheck.

\* Cppcheck: <http://cppcheck.sourceforge.net/>

\* Flawfinder: <https://dwheeler.com/flawfinder/>

## 10.1. v0.0.1 (original code)

Here are vulnerabilities that we had in the initial status of our source code by the tool of Flawfinder.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Stats from Flawfinder | Total | Open | Closed | False Positive |
| # of vulnerabilities | 31 | 12 | 5 | 14 |

And we’re using the bug system on github to manage these issues. Once an issue is closed in development cycle, we will know the change of the status immediately.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Stats from Cppcheck | Total | Open | closed | False Positive |
| # of vulnerabilities | 154 | 110 | 44 | 0 |

Here are another vulnerabilities found by the tool of the Cppcheck. It’s also the initial status of our source code.

It is interesting that both tools show us a different result. The Flawfinder gives us general information about somethings vulnerable and considerable but the Cppcheck tells us what is incorrect usages and what should be updated to be eliminated with more specific.

Therefore we’ve thought Cppcheck more specific and suitable for us during this short iteration like this CMU’s course so that we are going to select this Cppcheck as a main tool.

## 10.2. v0.5.0

The Version of v0.5.0 is our base version that we have re-factored from the original version, v0.0.1.

The table below shows vulnerabilities at the version of v0.5.0.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Stats from Flawfinder | Total | Open | Closed | False Positive |
| # of vulnerabilities | 36 | 13 | 6 | 17 |

The Flawfinder detected the vulnerability that the usage of g\_sprintf() is vulnerable. Interestingly, the tool recommends that we should replace g\_sprintf() with g\_snprintf().

Here is another result from the Cppcheck. The Cppcheck detected 100 vulnerabilities in the version of v 0.5.0. We’re going to resolve vulnerabilities from now on.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Stats from Cppcheck | Total | Open | closed | False Positive |
| # of vulnerabilities | 100 | 100 | 0 | 0 |

## 10.3. v1.0.0

# 11. Fuzz & Penetration Test

# 12. Conclusion