CS 3110 Group Project Prototype Status (skip to page 9)

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Meeting Location: Carpenter Hall group rooms

Meeting Frequency/Schedule: MWF 4:30-6:00ish

Other methods of communication: Git, Email, GroupMe, ~~Facebook Messenger~~

Core vision for our system

We plan to create an OCaml implementation of the Advanced Encryption Standard (AES), a NIST specified symmetric encryption standard based on the Rijndael algorithm and approved for protection of classified information. We plan to create a GUI displaying the input, output, and user preferences that will be easy to navigate.

Key Features

- **Encryption algorithm**
- **Decryption algorithm**
- **GUI**
- **Key length choice**
- **Benchmark feature**

Functionality

We plan to create an OCaml implementation of the Advanced Encryption Standard using the NIST Standard. The program will have a GUI where the user can select a key length for encryption, generate a random key or input a key, input text to be encrypted or decrypted, and view or select (copy) the encrypted/decrypted output. The program will also have a feature to benchmark (check computation time) the implementation using different key lengths and compare against other software and hardware implementations.

Detailed spec here: https://nvlpubs.nist.gov/nistpubs/fips/nist.fips.197.pdf

System design (modules):

Our system will be built around four different modules -- one module will contain information about the current state of the encryption process and the encryption/decryption sub functions, two modules that contain the cipher and decipher functions. There will also be a GUI module to display the input and its resulting output. If time permits, we will also create an animated tutorial of the matrix operations that are being performed as the program runs for users to learn how the AES encryption algorithm works.

Below are the names of each module and their function in the overall system:

- **Main (5)**: contains the main function called at the start of execution, does NOT take input or display output (that is the GUI's job)
- **Cipher_AES (2) by 04/21:** a module containing a series of functions that must be executed in sequence to transform plaintext to ciphertext (both ASCII) using Cipher Key
- **Decipher_AES (3) by 04/21**: contains functions that are inverse of those in Cipher_AES and transforms ciphertext to plaintext using Cipher Key

- **GUI (4) 04/22 onwards**: the user interface that collects input and displays output
    - Drop-down list for key length choice
    - Option to generate random key
- **State (1) by 04/21**: data structure that stores data and keys
    - Functions implementing matrix operations
    - Functions implementing key expansion

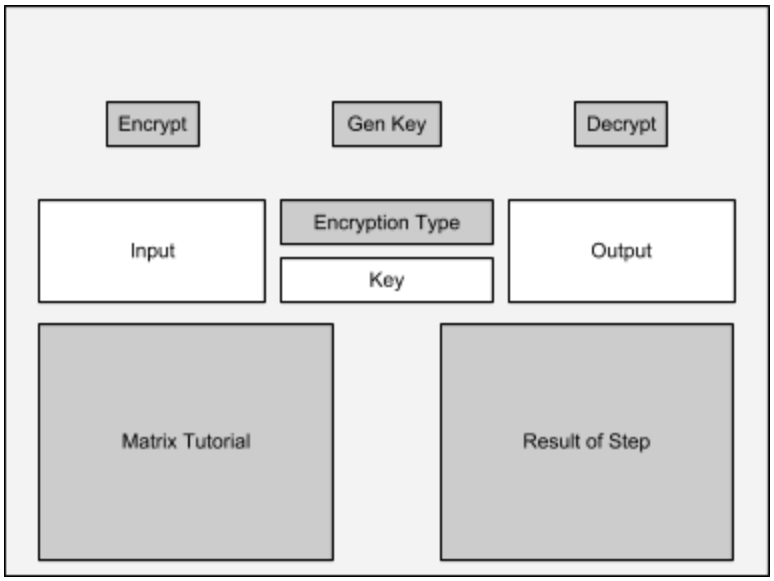
Module design (signatures):

Cipher and Decipher should only have the high-level cipher and decipher functions exposed in their signatures. The only functions exposed in State should be the encryption_type function that indicates the type of encryption (currently always AES, but we may implement other algorithms) and those necessary to update the data structure (including operations on data matrices and on keys). The only things the GUI should have exposed to the outside are functions to initialize and update it.

- See interfaces.zip
- State functions:
    - init_state() *ALTOGETHER*
    - get_data() *Alex* : returns the current data encoded as a string, needed for GUI output
    - Encryption_type () *Alex*
- Basic specifications for matrix and key cipher operations:
    - sub_bytes() *Alex*: performs substitution with SBox (substitution table storing a certain byte transformation encoded in hexadecimal)
    - shift_rows() *Jane*: performs permutation of the rows by shifting the last three rows of state by differing offsets

    - mix_columns() *Jane*: mixes the data in columns in order to make new columns
    - add_round_key() *Karol*: performs XOR operation with the round key
- Decipher operations
    - Inverse of each of the 4 above cipher functions
- GUI operations *ALTOGETHER*
    - init() : initializes and opens the GUI
    - update() : takes in a state and updates the GUI accordingly
    - run_tutorial() : runs the “matrix tutorial” animation showing the steps of encryption

GUI Diagram



Input

- Text field for user to type in plain text

Output

- Cipher text output

Encrypt

- Button that encrypts the input

Decrypt

- Button that decrypts the input

Gen Key

- Button to generate cryptographically secure random key for encryption

Encryption Type

- Dropdown list for possible encryption types to select from

Key

- Text field to input key if user supplies one or output field for Gen Key

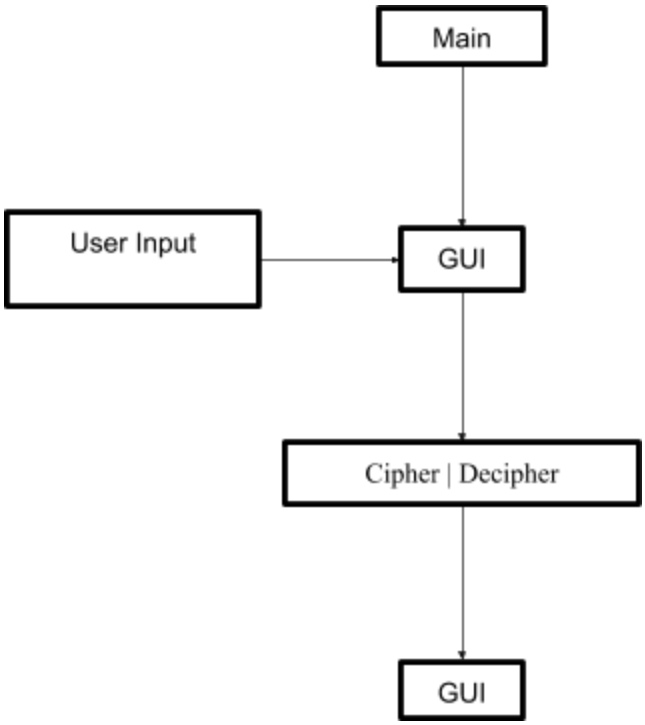
Matrix Tutorial

- Displays a step-by-step animation of how the AES algorithm works (e.g. matrix operations), possibly include “run/pause/step” like debugger

Results of Step

- Stores history of the results of previous encrypt / decrypt computations

Control Flow (simplified, technically Main is intermediate in every step)



Data Management

What data will your system maintain?

- The system will maintain a copy of the inputted data as it goes through the encryption process
- The system will also maintain a structure containing the keys created from the inputted/generated key using key expansion.

What formats will be used for storage or communication?

- All data will be stored in the state structure accessed through the State module
- The GUI will collect user input and display encrypted/decrypted output
- Users can communicate their inputs (as strings) to the system through the GUI

What data structures do you expect to use as part of your implementation?

- An array of 2D arrays for data (represented as strings or bytes)
- A 2D array for the byte substitution table

- An array of keys (from key expansion)

External dependencies: What third-party libraries (if any) will you use?

- **LablGtk2** - (GUI library) is the OCaml interface for Gtk2, a toolkit for graphical applications. Will be used to create a user interface (GWindow.window) displays an input and output, a drop-down list for key length choice (GMenu.menu_bar), and an option to generate a random key (GButton.button).
- **CryptoKit** - existing library in OCaml that contains a wide range of cryptographic primitives (e.g. random number generation); will be used to test against (both correctness and benchmarks)

Testing Plan

- **utop** - quick tests while implementing, immediately after finishing each function
- **OUnit**
    - Black box testing:
        - Each member will create test cases for the functions that he or she is responsible for, and
        - Other group members will write additional test cases based on the specifications (preconditions) of his or her functions.
    - Glass box testing

        - Each member will be responsible for extensively testing his or her functions before moving onto a different part of the program.
    - Randomized testing
        - Check that we get original strings back when we encrypt and decrypt some large number of random strings
    - AES Known Answer Test (KAT) Vectors: The NIST documentation of the AES algorithm provides a set of known ciphers with their keys and inputs that we will use to test our program.
- **Code review**
    - Each piece of code will be checked by at least 2 members and we will help each other on writing difficult functions.

Prototype

- **System description:** Include your system proposal and design document from Milestones 0 and 1, updated to account for any changes you have since made.
    - See above, no changes to make (though signatures in .mli files have changed to be more imperative)
- **Changes:** Highlight any major changes you have made to the project since the design review meeting and briefly discuss your reasons for making these changes.
    - We have not made any major changes to the project since the design review meeting, but we are unsure of the feasibility of the original plan for the animation that we will attach to our GUI.
    - Slight control flow change (init_state taking and get_data returning hexadecimal instead of text) means that some helper functions already complete in State will be transferred to Main (so that we can preprocess user

text input into hexadecimal before calling init_state) and GUI (so that we can process get_data hexadecimal output into text)
        - This change was made to better accommodate NIST standard example test vectors
- **Status:** Describe what pieces of your project you have implemented so far.
    - Code written for all state functions (and helper functions), cipher, decipher
    - Working on understanding lablgtk, got sample/tutorial GUI working (not included in prototype.zip)
    - Tests for all our functions and their inverses
- **Roadmap:** Describe what functionality remains to be implemented and how you plan to complete it.
    - Fix bugs in State functions
        - Deadline- May 5
    - Main module (most functions already complete in State but need to create GUI to interface with)
        - Deadline- May 5
    - GUI- lablgtk downloaded and sample/tutorial GUI working
        - Deadline- May 15 (hopefully earlier)
    - Animation- after/potentially concurrently with main GUI once a base is created
        - Deadline- May 15 (probably last thing)
    - Benchmarks- work on it in parallel with GUI and animation
        - Deadline- May 5
- **Testing:** Describe what tests you have been able to successfully run. Submit a file `prototype.zip` containing your current prototype and tests.
    - Black-box boundary case tests for all state functions except encryption_type (which is unimplemented)
    - Example test vector cases from NIST standard documentation for sub_bytes and shift_rows and their inverses (also indirectly test init_state and get_data)
    - Tests for add_round_key are failing for unknown reasons
    - The mix_cols function and its inverse are known to be incorrect, as we remembered too late that the specification re-defines multiplication