The Enigma Machine

The Full Enigma (150 Points)

Substitution ciphers that encode a message by substituting one character for another go back at least as far as Julius Caesar, who used a rotating character scheme to encode military orders. This simple type of encryption is vulnerable to statistical attacks, however, as anyone who has solved CRYPTOGRAM puzzles can attest. In World War II, the Nazi military employed an encryption scheme that addressed this weakness of simple substitution ciphers. This scheme, implemented by typewriter-sized devices known as Enigma machines, gave the Nazis a tactical advantage that greatly contributed to their early success in the war. In fact, the eventual breaking of this coding scheme by researchers at Bletchley Park, England (including Alan Turing) is hailed as one of the turning points of the war.

Enigma machines used interchangeable rotors that could be placed in different orientations to obtain different substitution patterns. More significantly, the rotors rotated after each character was encoded, changing the substitution pattern and making the code very difficult to break. The behavior of the rotating rotors can be modeled, in a simplified form, by a device consisting of labeled, concentric rings. For example, the model below has three rings labeled with the letters of the alphabet and '#' (representing a space only for clarity on the ring).

For this assignment, you are to write a fully graphical program (Java FX) that simulates the workings of a **FULL Enigma machine**, as used by the German military.

The Encryption Technique

STEP 1 - PLUGBOARD – In the first step in the process, the Nazi's used Plug Board settings to transpose/map letters. This was a simple substation cipher, with one letter being mapped to a corresponding letter on the "day" chart. This was in the form of 10 pairs of letters (note that 20 letters get transposed, six that do not appear were unchanged). For example, using Day 1 of the sheet on our encoding sheet… a "S" would be changed to a "Z" (and vice versa, Z goes to S), a "G" would be changed to a "T" (T goes to G), etc.

To encode 'T' – go to plugboard to get 'A'

Example Plugboard DAY 3 (from sheet)
DJ $\boxed{\text{AT}}$ CV IO ER QS LW PZ FN BH

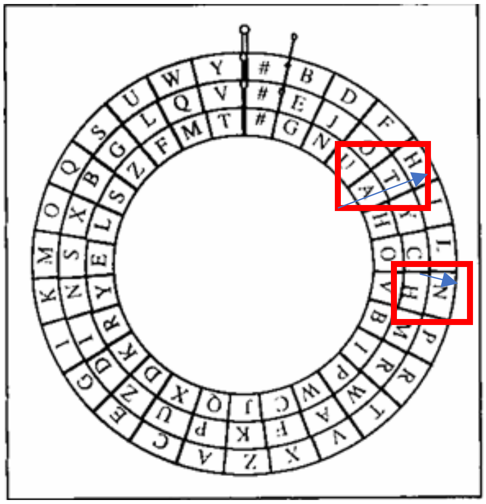


Figure 1 - SAMPLE ONLY –each wheel to map the A-Z and spaces (#=blank) 27 spaces per wheel.

STEP 2 - CIPHER WHEEL ENCRYPTION

To encrypt a character using this model, find the character on the **inner rotor** (i.e., the inside ring) and note the character aligned with it on the **outer rotor** (i.e., the outside ring), then find that character on the **middle rotor** (i.e., the middle ring) and output the one aligned with it on the **outer rotor.**

For example, in this configuration the character 'A' would be encrypted as 'N', since 'A' on the inner rotor is aligned with 'H' on the outer rotor, and 'H' on the middle rotor is aligned with 'N' on the outer rotor.

STEP 3 – REFLECTOR PANEL - The next step is to match the character with the Reflector Panel – a remapping of the current character, VERY SIMILAR TO THE PLUGBOARD remapping. These are represented as character pairs that map one character to another, much like a substitution cipher. For example, using the day one settings, "N" would map to "C"

Example- Reflector Panel (from sheet day 3)

KM AX PZ GO DI CN
BR PV LT EQ HS UW

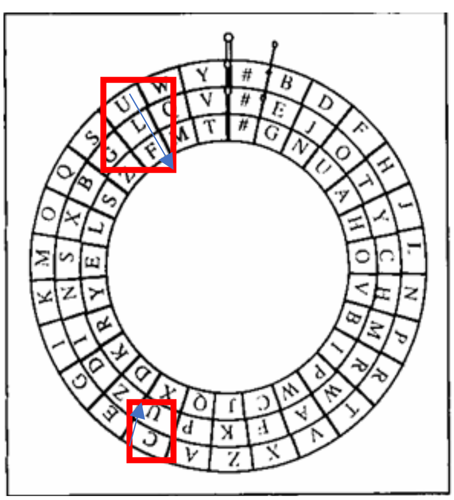


Figure 1 - SAMPLE ONLY –each wheel to map the A-Z and spaces (#=blank) 27 spaces per wheel.

STEP 4 – CIPHER WHEEL IN REVERSE

After a character is mapped using the reflector panel, it is sent back through the Reflector panel **in reverse**. Find the character on the **outer rotor** and note the character aligned with it on the **middle rotor**, then find that character on the **outer rotor** and output the one aligned with it on the **inner rotor.**

Taking the C we encrypted from the previous example, - C would map to U, and U would map to F. Therefore, our output would be "F", which goes to the final stage – the plugboard again.

STEP 5 – PLUGBOARD AGAIN

In the last step in the process, the transposed character was sent back to the plugboard to match, before before getting the FINAL output. In our example, the "F" would match to "N" – so "N" would be the final output.

Example Plugboard DAY 3 (from sheet)
DJ AT CV IO ER QS LW PZ FN BH

STEP 6 – WHEEL ROTATION - After a character is encrypted, turn the **inner rotor** clockwise one-step. Whenever the inner rotor returns to its original orientation (27 ticks), the middle rotor turns once in lock-step, just like the odometer in a car. When the middle rotor turns 27 times, the outer rotor turns once in lock step.

For this assignment, you are to design a java program, and series of classes that simulate this enigma machine. Rotors consists of the 28 characters - 26 letters, plus a space, and '.' (period). The rotors are interchangeable, and are given in the Enigma Machine daily encoding sheet, included on the last page.

Specifics:

- There will be five Cipher Rings. These rings will each have a set "encryption" code (but which ones to use and what starting spot will vary based on day of encoding)
-
- **ROTOR_1 = AUNGHOVBIPWCJQXDKRY ELSZFMT. (note the space is 20th char, period is 28th)**
  ROTOR_2 = O J.ETYCHMRWAFKPUZDINSXBGLQV (note the space is 2nd char, period if 4th)
  ROTOR_3 = FBDHJLNPRTVXZ.ACEGI KMOQSUWY (note the space is 20th char, period is 14th)
  ROTOR_4 = .HKPDEAC WTVQMYNLXSURZOJFBGI (note the space is 9th char, period is first)
  ROTOR_5 = YDNGLCIQVEZRPTAOXWBMJSUH.K F (note the space is 27th char, period is 25th)

- You will implement all steps of the German encryption algorithm, as described above.
- All numbers are SPELLED out. For example, the message **Fahrenheit 451**, would be encoded as **Fahrenheit four five one.**

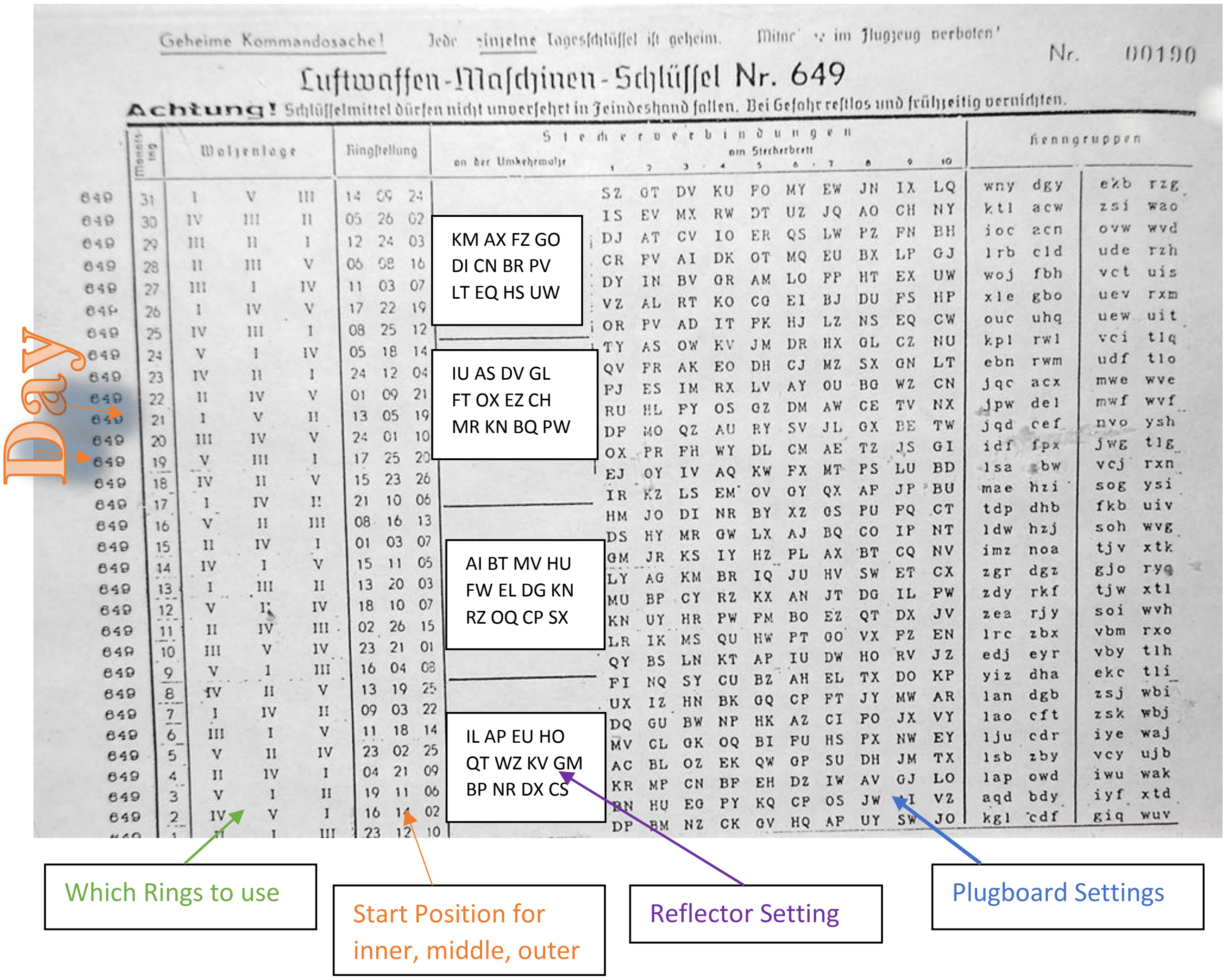
Use the following ACTUAL 31 Day encryption code settings sheet, on the next page, which indicates:

- The rings to use (inner, middle, outer), and
- Starting spot for each ring (1 is the first character, 28 is the last)
- Reflector Setting
- PLUGBOARD settings for the day (which pairs of letters to transpose)

For this assignment, you are given an encoded message that has the day the message was encoded, which will define the mappings for that day.

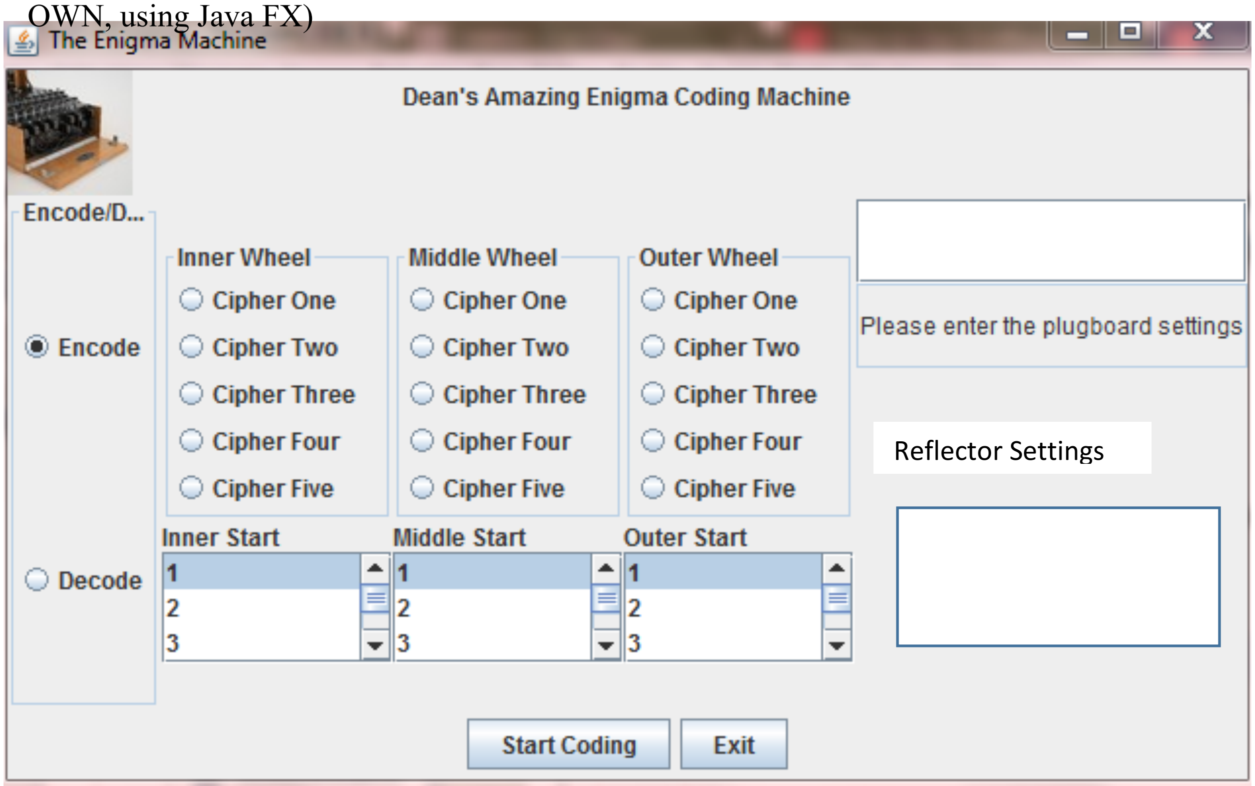
You will also encode one of your messages, provide me the day that you encode this message and include the encrypted text in your solution zip file.

German Enigma Machine setting daily sheet:



In designing your solution, you should strive to follow good object-oriented design principles. That is, define highly cohesive classes that correspond to real-world objects, and make sure those classes are loosely coupled so that the implementation details of one are independent of the others. The interface for your Enigma program is entirely up to you. It need not be fancy, but it must *at least* allow the user to select the order and settings of the rotors and subsequently encode/decode messages.

You should implement a Fully Graphical Version, as described in class… Please design your own solution, but an example screen shot (PLEASE BE CREATIVE AND DESIGN YOUR OWN, using Java FX)



Grading Matrix: TBD

-