

Steganography and Cryptanalysis Project

Purpose

This project aims to gain experience with steganography, cryptanalysis, and random number generators. You will work at the byte level of files to create a bitmap image from scratch. You will programmatically modify such a file, hiding a message inside the image. In the second part, you will break an encryption by finding the key through a weakness in the random number generation.

Objectives

Students will be able to:

- Apply number theory concepts to solve real-world problems.
- Apply algorithms for random number generation, hash functions, and encryption.
- Analyze encryption and hash algorithms to find weaknesses and attacks.

Technology Requirements

This project requires the knowledge of the following tools and technologies:

- .NET Core 8.0
- Basic Understanding of C#
- [Zybooks IDE](#) for editing your code

Directions

Accessing ZyLabs

You will complete and submit your work through zyBooks's zyLabs. Follow the directions to correctly access the provided workspace:

1. Go to the Canvas project, "**Submission: Steganography and Cryptanalysis Project**"
2. Click the "**Load Submission...in new window**" button.

- When ready, review the provided code and develop your work where instructed.

Part 1 - Steganography

With a hex editor, you can manually create a bitmap (.bmp) file by typing in the bytes. Using either a downloaded hex editor or one you find online, create a bitmap using these bytes:

```
42 4D 4C 00 00 00 00 00 00 00 1A 00 00 00 0C 00 00 00 04 00 04 00 01 00 18 00 00 00 FF
FF FF FF 00 00 FF FF FF FF FF FF FF 00 00 00 FF FF FF 00 00 00 FF 00 00 FF FF FF FF
00 00 FF FF FF FF FF FF 00 00 00 FF FF FF 00 00 00
```

If you save your hex file as a .bmp file, you can view your image. It will only be 4x4 pixels large, so you will need to zoom in. Figure 1 shows the expected image:

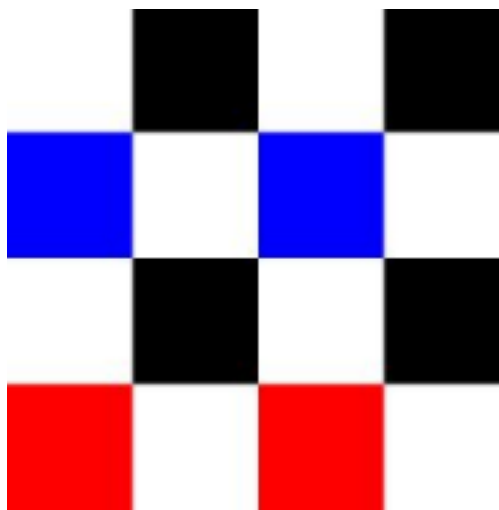


Figure 1: Manually created bitmap

In order to perform steganography, you must first understand the bmp file structure. The first 26 bytes are header bytes (i.e., the magic numbers). We cannot easily hide data inside a file header without potentially corrupting the file, especially with more complex file headers such as png.

First, there are some general header bytes: 42 4D 4C 00 00 00 00 00 00 00 1A 00 00 00 0C 00 00 00 04 00 04 00 01 00 18 00 00 00 00

The next two bytes specify the width (note that files are written in little endian order - each byte is in expected order, but the order of bytes is opposite what we would expect): 04 00

The next two bytes specify the height: 04 00

Finally there are four more header bytes: 01 00 18 00

Starting after the header bytes, every set of three bytes forms one pixel. Each of these sets contains the color representation in BGR (Blue Green Red) format. For example, the color blue is represented by FF 00 00. Also note that colors are defined from left to right and bottom to top.

Let us consider each of the bytes as being part of a Galois Field. In other words, we can treat each byte as a polynomial. Consider the byte 0xB4. This byte represents the magnitude of either the Blue, Green, or Red of a color. In binary, this byte is: 10110100. As part of GF(2⁷) (i.e., the Galois Field of 2⁷), we can treat this byte as a polynomial of the form:

$$1*x^7 + 0*x^6 + 1*x^5 + 1*x^4 + 0*x^3 + 1*x^2 + 0*x^1 + 0*x^0$$

Since $O(x^7) \gg O(x^1)$, we can modify the bits corresponding to x^1 and x^0 with a negligible effect on that color. Try this yourself. For example, FF = 11111111. We can change the last two bits 11111100 = FC. Change some of the bytes in this way, resave as a .bmp, and compare it to the original to see if you can tell the difference.

Here is a piece of a program that will print out the bytes of the bitmap discussed earlier (you can start with this code for this part of the assignment):

```
byte[] bmpBytes = new byte[] {
    0x42,0x4D,0x4C,0x00,0x00,0x00,0x00,0x00,
    0x00,0x00,0x1A,0x00,0x00,0x00,0x0C,0x00,
    0x00,0x00,0x04,0x00,0x04,0x00,0x01,0x00,
    0x18,0x00,0x00,0x00,0xFF,0xFF,0xFF,0xFF,
    0x00,0x00,0xFF,0xFF,0xFF,0xFF,0xFF,0xFF,
    0xFF,0x00,0x00,0x00,0xFF,0xFF,0xFF,0x00,
    0x00,0x00,0xFF,0x00,0x00,0xFF,0xFF,0xFF,
    0xFF,0x00,0x00,0xFF,0xFF,0xFF,0xFF,0xFF,
    0xFF,0x00,0x00,0x00,0xFF,0xFF,0xFF,0x00,
    0x00,0x00
};

Console.WriteLine(BitConverter.ToString(bmpBytes).Replace("-", " "));
```

From the command line (not from keyboard input), you will receive a string of 12 hexadecimal digits (e.g., B1 FF FF CC 98 80 09 EA 04 48 7E C9). Since our image has 16 pixels, there are $3*16 = 48$ color bytes. Hiding 2 bits per byte allows us to hide $48 * 2 = 96$ bits / 8 bits/byte = 12 bytes of data.

Modify your image to hide those 12 bytes in the color bytes and print out the result in the same format as the sample code does. For example, suppose the first byte is B1. In binary, this is 10110001. We hide the values using the XOR operator. The first 4 color bytes in the above image are 00 00 FF FF (you must start after the header ends — note that the header ends at 0x00, not 0x18). In binary, these bytes are 00000000 00000000 11111111 11111111. Taking two bits at a time, we XOR with each byte. We start with bits 10, then 11, 00, and finally 01. Thus, our 4 bytes become 00000010 00000011 11111111 11111110.

Hint: You can convert a string such as “F8” to a byte using `Convert.ToByte(“F8”, 16)`. 16 represents the base you are converting from.

Example: Using the sample input from above, here is the command to run the program and the

expected output:

Command: dotnet run "B1 FF FF CC 98 80 09 EA 04 48 7E C9"

Expected output: 42 4D 4C 00 00 00 00 00 00 00 1A 00 00 00 0C 00 00 00 04 00 04 00 01
00 18 00 02 03 FF FE FC FC 03 03 FC FC FC FC FF FC 00 02 01 FD FF FD 00 00 00 FF
00 02 FE FC FD FD 02 00 FF FE FF FE FF FD 00 01 03 FC FD FC 00 02 01

Figure 2 shows what this bitmap looks like. Despite hiding a secret message in it, the change is impossible to see:



Figure 2: Bitmap with secret message

Part 2 - Cryptanalysis

There are two general types of random number generators. The first is the type that ships with most programming languages, a pseudo-random number generator (PRNG). The second is a more secure type, the cryptographically secure pseudo-random number generator (CSPRNG).

Typically, a PRNG is a function that generates a series of seemingly random numbers. The starting point for this calculation is given by the seed. Most languages do not require a seed to be passed into a call for a random number. Some languages will use a default seed in this case (e.g., C uses 1 as the default seed: [rand\(3\): pseudo-random number generator - Linux man page](#)). Other languages will seed the PRNG with a non-static seed (e.g., C#: [Random Class \(System\)](#)).

Experiment with the C# Random class. Given the same seed, note that the same series of numbers will be generated regardless of how many times you run your program.

For this exercise, you will break an encryption by finding the key through a weakness in the random number generation.

Scenario: Suppose you are able to access your friend's computer and find that they created an encryption program. Their key is generated randomly, but they chose to use the current time as the seed. By looking at the file properties, you find that the program was run at some point between

7/3/2020 (July 3) 11:00:00.000 and 7/4/2020 (July 4) 11:00:00.000 (1 day later).

Here is the code your friend used to perform the conversion and encryption:

```
DateTime dt = DateTime.Now;
TimeSpan ts = dt.Subtract(new DateTime(1970, 1, 1));

string secretString;
Random rng = new Random((int)ts.TotalMinutes);
byte[] key = BitConverter.GetBytes(rng.NextDouble());

Console.WriteLine(Encrypt(key, secretString));

private static string Encrypt(byte[] key, string secretString)
{
    DESCryptoServiceProvider csp = new DESCryptoServiceProvider();
    MemoryStream ms = new MemoryStream();
    CryptoStream cs = new CryptoStream(ms,
        csp.CreateEncryptor(key, key), CryptoStreamMode.Write);
    StreamWriter sw = new StreamWriter(cs);
    sw.Write(secretString);
    sw.Flush();
    cs.FlushFinalBlock();
    sw.Flush();
    return Convert.ToBase64String(ms.GetBuffer(), 0, (int)ms.Length);
}
```

Hint: Casting TotalMinutes to an int truncates the value. Thus, 7/3/2020 11:03:04.123 produces the same seed as 7/3/2020 11:03:00.000.

In a real-world example, you may not have access to the plaintext directly. In a file example, you could use knowledge about the file headers to find the key. In World War II, the Germans made use of their Enigma Cipher to encrypt radio traffic, such as reports and other military intelligence. In some of these reports, part of the plaintext was known; simple common phrases such as “nothing to report” could be inferred as part of the radio traffic according to message length and similarity to other messages. This small part of the plaintext enabled the Allied forces to decrypt the messages through a key-finding algorithm. Similarly, you will assume that you have a phrase of the plaintext and will use it to find the key.

In this project, the plaintext and ciphertext will be passed to you as command-line arguments. Your program should output the integer value used to seed the random number generator that your friend used for that plaintext and ciphertext.

Note: You will be outputting the seed, not the key. The seed will be shorter and will simplify testing and debugging. You can always get the key using the seed.

Example: Below is a sample command and expected output:

Command: `dotnet run "Hello World" "RgdIKNgHn2Wg7jXwAykTIA=="`

Expected output: 26564295

In this example, the correct seed corresponded to 7/4/2020 10:15:00.000.

Submission Directions for Project Deliverables

Part 1 - Steganography

You are given an unlimited attempts to submit your best work. The number of attempts is given to anticipate any submission errors you may have in regards to properly submitting your best work within the deadline (e.g., accidentally submitting the wrong paper). It is not meant for you to receive multiple rounds of feedback and then one (1) final submission. Only your most recent submission will be assessed.

You must submit your Steganography and Cryptanalysis Project deliverables through zyBooks. Carefully review the submission directions outlined in this overview document to correctly earn credit for your work. Learners may not email or use other means to submit any assignment or project for review, including feedback, and grading.

You must complete and submit your work through zyBooks's zyLabs to receive credit for the project:

1. Please use the **program.cs** file provided in your zyBooks workspace to complete your 'Part 1 - Steganography' program, ensuring that you do not change the class name.
 - a. Execute your code by running the below command in the terminal located at the bottom of the IDE.
 - i. `dotnet run "B1 FF FF CC 98 80 09 EA 04 48 7E C9"`
2. When you are ready to submit your completed work, click on "**Submit for grading**" located on the bottom left.
3. When feedback appears below the workspace, you will know you have completed the project.
4. If needed: to resubmit the project in zyLabs
 - a. Edit your work in the provided workspace.
 - b. Click "**Submit for grading**" again at the bottom of the screen.

Your submission will be reviewed by the course team and then, after the due date has passed, your score will be populated from zyBooks into your course grade.

Part 2 - Cryptanalysis

You must complete and submit your work through zyBooks's zyLabs to receive credit for the project:

5. Please use the **program.cs** file provided in your zyBooks workspace to complete your 'Part 2 - Cryptanalysis' program, ensuring that you do not change the class name.
 - a. Execute your code by running the below command in the terminal located at the bottom of the IDE.
 - i. `dotnet run "Hello World" "RgdIKNgHn2Wg7jXwAykTIA=="`
6. When you are ready to submit your completed work, click on "**Submit for grading**" located on the bottom left.
7. You will know you have completed the project when feedback appears below the workspace.
8. If needed: to resubmit the project in zyLabs
 - a. Edit your work in the provided workspace.
 - b. Click "**Submit for grading**" again at the bottom of the screen.

Your submission will be reviewed by the course team and then, after the due date has passed, your score will be populated from zyBooks into your course grade.

The Steganography and Cryptanalysis Project includes two (2) deliverables:

- **Bit-map Image:** Use the zyBooks workspace to complete and submit your project using the program.cs workbook file.
- **Code Submission:** Use the zyBooks workspace to complete and submit your project using the program.cs workbook file.

Evaluation

Part 1 and Part 2 are worth 50 points each for a total of 100 points in the project.

Part 1 Steganography:

The autograder will execute your code by passing the bytes through the command line. The grader will compare the results produced by your code with the expected results. If the results match, you will receive **50 points**. Otherwise, you will receive **0 points** with corresponding error messages.

Part 2 Cryptanalysis:

The autograder will execute your code by passing the plain and cipher text through the command line. The grader will compare the seed value produced by your code with the expected seed value. If these match, you will receive **50 points**. Otherwise, you will receive **0 points** with corresponding error messages.