CODE BREAKING
(An Application of Computers to Text)

- A Quick Overview of Cryptography
- The German Enigma Machine
- Breaking the Code of Enigma during World War II.

Overview of Cryptography - 1

- The oldest codes are *substitution codes* where each letter is replaced by another, for example:

  THE DOG ATE MY HOMEWORK
  ZRP OTQ LZP GD RTGPJTXU

- Such codes are easy to break by looking at how often letters appear.
  ("P" may correspond to "E").

Overview of Cryptography - 2

- The correspondence between letters and their encrypted form is called an *encoding table*.
- We can make a code harder to break by using several tables and selecting a different table for each position in the text.

  THE DOG ATE MY HOMEWORK
  YNL MYR NHT NA LTSLEXBV

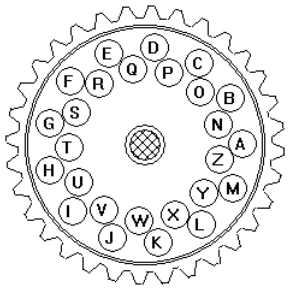
Overview of Cryptography - 3

- **THE DOG ATE MY HOMEWORK**
  YNL MYR NHT NA LTSLEXBV
- The first letter T is mapped to Y, that is 5 places later in the alphabet. The second letter H is mapped to N, 6 places later in the alphabet, and the third E to L, 7 places later.
- Each time we code a letter, it is mapped one more place later. Now D is mapped to M, that is 9 places later. Obviously the space caused an increment. This way we predict that the A in ATE would be mapped 13 places later or into N and that is indeed the case.

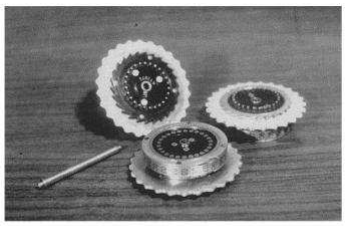
The Enigma Machine - 1

- Having multiple tables makes a code much harder to break but it presents no problem in communications as long as both parties have similar devices.
- The German Enigma machine used a multiple table encoding scheme (far more sophisticated than the scheme of our example).

The Enigma Machine - 2



Schematic



Rotors of the German Encryption Machine ENIGMA
Courtesy of Wikipedia

The Real Thing

The Enigma Machine - 3

Enigma machine in use (Left) and with printer attached to it (Right).

Source: Wikipedia (http://en.wikipedia.org/wiki/Enigma_machine)

Breaking the Enigma Code - 1

- One way to break an encryption with multiple tables is to find (or guess) a plaintext corresponding to the encrypted message (slide 4).
- Another way is to try all possible combinations of words and see which one of them suggests a plausible encoding scheme.
- Or use combination of the two methods.

Breaking the Enigma Code - 2

- How many combinations do we need to try?
- A natural language has over 100,000 words but we may wish to consider only those likely to appear in a message, so let us say we will try 1,000 words. If we need a sentence of ten words to try to infer the encoding scheme we need to consider 1000^{10} possible sentences.
- Not all sequences will make sense so let us say that on each position we need consider only 10 possible words, so that the number of sentences is 10^{10} or 1 followed by 10 zeros, that is 10 billion.

Combinatorial explosion

- The term refers to the fact that can get a huge number out of multiplying a relatively small number by itself a few times.
- **A Number to Remember:** There are 3600 seconds in an hour or 86,400 seconds in a day or 31,536,000 seconds in a year. We can write the last number approximately as $\mathbf{3X10^7}$ and we will use it several times in these lectures as a humanly meaningful yardstick.

Breaking the Enigma Code - 3

- A human looking at one possible sequence of words per second would need 10^{10} divided by $3X10^{7}$or about 300 years (without stopping to eat or sleep). Allowing for some sleep the time would be closer to 500 years. Assembling a team of 500 people for the task would still require a full year.
- Therefore the Germans may have been justified in thinking that the Enigma code could not be broken (they changed the settings of the machine every few months).

Breaking the Enigma Code - 4

- But suppose we have a device that can look at a 1,000 strings a second rather than only one. Then we would need only 10^{7} seconds or about four months! By using a few such devices we could reduce the time to days. Suddenly, the "unbreakable" code can be broken.
- This is, **roughly**, what happened during World War II when Alan Turing supervised the building of a computer that was used to break the Enigma code.
- The effort was known as the *Ultra* project.

The *Ultra* Project - 1

- It took a few months to break the code the first time and, because the Germans changed periodically their settings, the process had to be repeated.
- The British were able to decipher the orders that the German command gave to its U-boats in the Atlantic. As a result convoys bringing supplies to Britain from the United States would be re-routed away from the areas patrolled by the U-boats. This had a significant effect on the war effort.
- Supposedly Churchill said that *Ultra* shortened the war by two years.

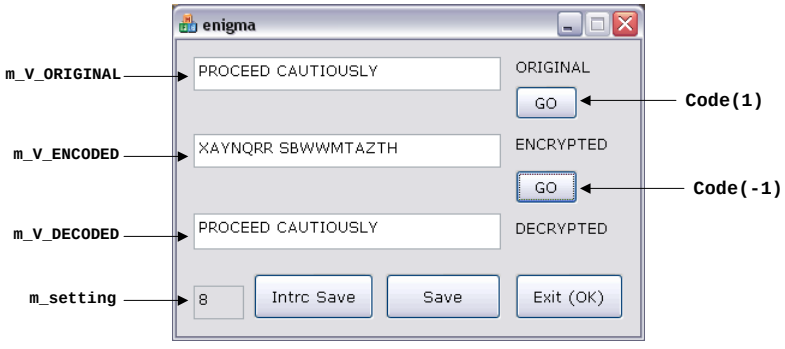
The *Ultra* Project -2

- There was one unexpected gift to the British. The Germans often started their messages with the phrase "I have the honor to inform your excellency", and that helped the initial search.
- The Germans knew that the British had found the location of the U-boats because the U-boats could find no convoys to attack. But because they were convinced that the Enigma code was unbreakable, they thought that spies around the U-boat ports were finding the information from the crews.

Bibliography

- Andrew Hodges, *Alan Turing: the enigma*, Touchtone, 1983

Coding with Multiple Tables
An Example



```
void CenigmaDlg::Code(int kind)        {
          int DS = 'Z'-'A'+1;  // more declarations ...
          if(kind > 0) {      // encoding
                    z = m_setting_used = m_setting; // picked at random
                    INsp = &(m_V_ORIGINAL);       OUTsp = &(m_V_ENCODED);
          }
          else {    // decoding
                    z = m_setting_used;
                    INsp = &(m_V_ENCODED);        OUTsp = &(m_V_DECODED);
          }
          int N = INsp->GetLength();    (*OUTsp) = "";
          for(int i=0; i<N; i++) {
                    a = (*INsp)[i];     // ith char of input string
                    if(a != ' ') {
                              if( kind>0) a = a+z ; else a = a-z;
                              if(a > 'Z') a -= DS; if(a < 'A') a += DS;
                    }
                    OUTsp->Insert(i, a);
                    z = z+1; if(z>m_CYCLE) z = 1; //m_CYCLE tables
          }
}
```