Basic Cryptanalysis Techniques

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November 17th, 2001

Introduction

Cryptography is a complex and mathematically challenging field of study. It involves taking some data or message and obfuscating it so that it is unreadable by parties that the message was not intended. Before the message becomes encrypted it is referred to as the *plain text* . Once a message becomes encrypted it is then referred to as the *cipher text* .

The study of cipher text in an attempt to restore the message to plaintext is known as cryptanalysis. Cryptanalysis is equally mathematically challenging and complex as cryptography. Because of the complexity involved with cryptanalysis work this document is only focused on the basic techniques needed to decipher monoalphabetic encryption ciphers and cryptograms.

The only application referenced in this document is the CRyptoANalysis ToolKit (CRANK). This program can be found at http://crank.sourceforge.net/. A basic understanding of cryptanalysis is essential to appreciating the complexities of a good cryptographic algorithm. For example a manager of a software company or someone who is involved with code auditing would find it is essential that good well tested algorithms are used instead of a weak in house cipher. This paper will give you the basic tools necessary to begin a rudimentary examination of a cipher.

Definition of terminology

This section will define several terms as well as give a brief introduction into cryptography. A term used specifically for cryptanalysis is called *known text*. Known text is when there is an encrypted message and a known corresponding plaintext. This may not be the whole message but perhaps a section of the message, e.g. every message sent ends with the plaintext letters "EOT". By using cipher text with known text you can attempt to deduce the complete key used to encrypt all messages, which will greatly facilitate future deciphering.

Their are several basic methods that can be used to encrypt a message. One method is called a *transpotional cipher*. This cipher only changes the order of the plaintext within the message, e.g. "LEAVE AT NOON" might become "EVAELTANOON". Another method is known as a *substitional cipher* . This method exchanges the characters in the plaintext with other characters defined by a *key*. The key is the mapping of characters from the plain text to the cipher text as in the following:

```
ABCDEFGHIJKLMNOPQRSTUVWXYZ
zyxwvutsrqponmlkjihgfedcba
```

Using the same message from the above example this key would produce the following message: "OVZEVZGMLLM". This method of substitution is known as a *Monoalphabetic Unilateral Substitution cipher*. This term implies that for each letter in a plaintext message there is only one equivalent cipher character. (Note: The majority of this document will focus on these types of cipher systems. Monoalphabetic Unilateral Substitution systems will simply be referred to as a substitution cipher for the sake of clarity and brevity.)

Basic cryptanalysis techniques
One good method for solving basic substitution ciphers is with frequency counts. A frequency count can be conducted on a cipher to learn what the most and least common characters are in the cipher. The most common letters in the English language are E,T,N,R,O,A,I and S. These eight characters make up around 67% of the words in the English language. Vowels, A,E,I,O, and U make up around 40% of English text. The frequency may vary depending on what the plaintext is. For example, if the message is source code it will use many more symbols than a message that is just written in English. If you conduct a frequency count of this paragraph your results would be: E, T, A, O, and S.

As you can see the results are not exactly the same. This is because the there are approximately 500 characters in the above paragraph. If you use a sample of 1000 characters or more your results will become more accurate. The frequency count of a single character is referred to as a *Unigraph* . If the frequency of cipher text is actually the same as plaintext then the encoded method is actually a transpositional cipher instead of a substitution cipher. Consider the following example:

Pltaintext: IF WE DO NOT PROPERLY PROTECT THE USERS DATA WE CAN SIMPLY HIDE BEHIND THE DMCA IF SOMEONE NOTICES!!
Transpositional: I OOYFDTP O EPW PRRENRLOTTSDWEHEAECERT T SAC U ANPIE LDHTSYEIHI NEMHBD DIM CMFENEC OOSASNT! OEI!
Substitution: RU DV WL MLG KILKVIOB KILGVXG GSV FHVIH WZGZ DV XZM HRNKOB SRWV YVSRMW GSV WNXZ RU HLNVLMV MLGRXVH!!

Top 5 Unigraph Frequency counts:
Plaintext: E, O, T, I and D
Transpositional: E, O, T, I and D
Substitution: V, G, L, R and H

Even though the transpositional cipher is a small sample, it has the top 4 letters used in plaintext with E being the highest.

When dealing with a substitution cipher you should check the frequency of letters and their adjacent letters as well. A pair of letters together is referred to as a *Digraph*. The common digraphs in the English language are, TH, HE, EN, RE and ER. There are also *Trigraphs* that consist of frequency of three letters next to each other THE, ING, CON, ENT and ERE.

Roughness of the cipher
If some characters are significantly more frequent than others then the cipher is considered "rough". Rough ciphers are a sign that a monoalphabetic unilateral cipher is

being used. A more complex cipher will distribute the frequency, making the cipher appear flat.

```
                     X
                     X
                     X
                     X
                     X
                     X
      X    X         X
      X    X     X   X
      XX   XX     X   XX
      XXX XXX    XX  XXX X
      XXX XXXX   XX  XXX X
 X X  XXX XXXXX  XX XXXX X
 X X XXXX XXXXX  XX XXXXXX
ABCDEFGHIJKLMNOPQRSTUVWXYZ
```

If the cipher was more complex than it would maintain a flat look even with a greater sample. Here's is an example of what a flat layout might look like.

```
 XXX  XXX X XX X XXX XXXX
XXXX XXXX XXXXXX XXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXX
XXXXXXXXXXXXXXXXXXXXXXXXXX
ABCDEFGHIJKLMNOPQRSTUVWXYZ
```

Determining a ciphers roughness helps in determining it's complexity and how much work might be involved in deciphering it.

Format and patterns of a cipher
Every outside piece of information can help in deciphering a message. What language, underlying content, word sizes, can all greatly assist in determining the plain text. Many ciphers will not show spaces and punctuation with their cipher. For instance they may group all the words in chunks of five with a set character if padding is needed. If the message is "DO NOT TRANSMIT", then the cipher may be broken up to look like this: WLMLG GIZMH NRGXX, "X" is padding; with simple Sunday paper cryptograms you get spaces and sometimes punctuation. Special tricks can be used to decipher these ciphers very quickly. One very fast trick is to find a word that is greater than six characters and determine it's pattern. For each unique letter in the word assign it a sequential number. We will decipher the following cryptogram as an example.

UEY WKHH YOA OAXABSH PKNNABAFZ KFOZBYGAFZO ZE PAQKDLAB S GAOOSMA

Here the cipher is small and our frequency count may be off by a significant amount but the benefit of knowing the size of the words (assuming that the spaces are correct) exists. First we'll select a large word, "KFOZBYGAFZO" and determine it's pattern.

```
KFOZBYGAFZO
12345678243
```

The first 8 letters are unique and the last three are repeats from the beginning of a word. Using this pattern and comparing it to 11 letter words in the dictionary, the possibilities are reduced provided "KFOZBYGAFZO" translates into an English word. Below is a simple perl script used to simplify this task.

----[Snip]----

```
#!/usr/bin/perl
# Searches a dictionary for a word pattern
# 2001 Craig Smith
#
die "Usage: $0 <word>\n" if $#ARGV != 0;

my $DICT_FILE="/usr/share/dict/american-english"; # English text
my $my_pattern=get_pattern(uc($ARGV[0]));         # Retrieve our
pattern

open DICT, $DICT_FILE || die "Couldn't open $DICT_FILE!\n";
while(<DICT>) {
        chomp($dict_word=$_);                     # Remove Carriage
Return from word
        next if length($dict_word) ne length($ARGV[0]);    # Only
compare same length
        print "Try $dict_word.\n" if $my_pattern eq
get_pattern(uc($dict_word));
}
close DICT;
exit(0);

# Usage: get_pattern(TEXT) retuns numeric pattern
sub get_pattern {
  my $word=shift;
  my $letter;
  my $pat_count=0;
  my %letter_pat;
  my $pattern;

  for(my $cnt=0; $cnt<length($word); $cnt++) {
        $letter=substr($word,$cnt,1);
        $letter_pat{$letter}=++$pat_count if !$letter_pat{$letter};
        $pattern.=$letter_pat{$letter};
  }
  return $pattern;
}
```

----[End Snip]----

Using this program the encrypted word "`KFOZBYGAFZO`" yields:

```
Try instruments.
```

If this word works then there will be 8 letters to the cipher. After replacing KFOZBYGAFZO with the word "instruments" the results look rather promising. The capital letters are the original cipher text and the lower case letters are what is believed to be the plain text.

Message: UEu WiHH use seXerSH PiNNerent instruments tE PeQiDLer S messSMe

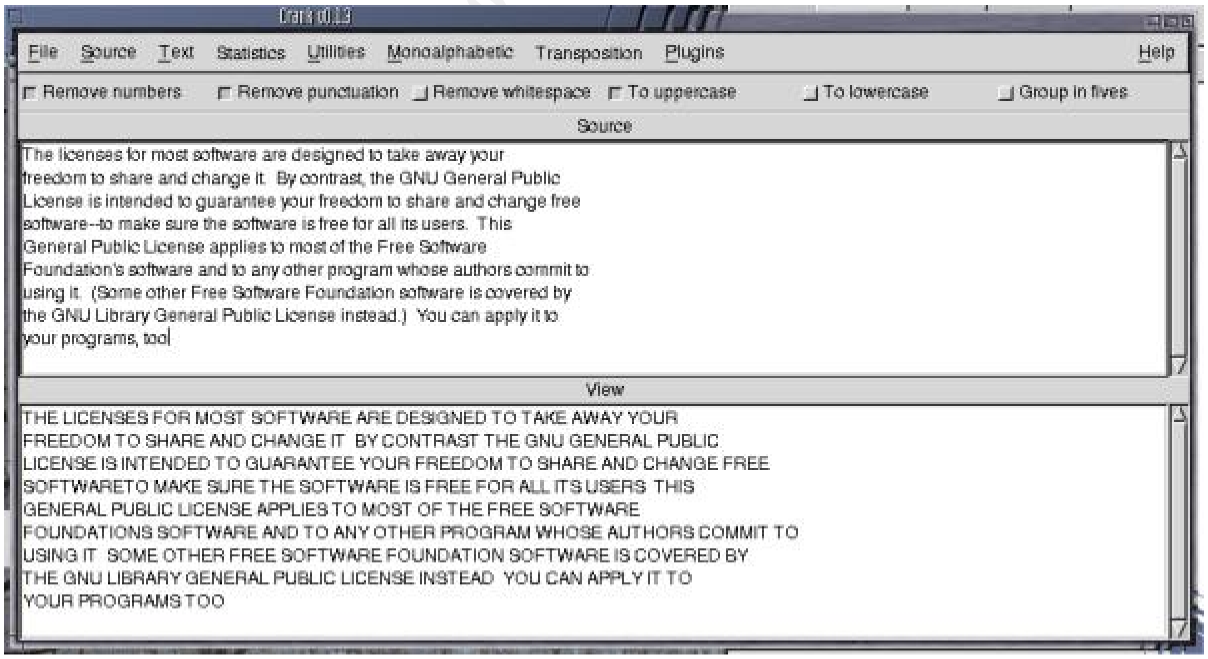
Taking the word before "instruments" and using the program to see if any of the results end with 'erent'. With the assistance of the UNIX "grep" command the program yeilds:

```
./find_pattern.pl PKNNABAFZ | grep erent
Try different.
```

As evident these type of ciphers are extremely trivial and can be decoded quickly. This technique is only effective when there are spaces between the words in a cipher. There are many other different tricks that can used depending on the circumstances and any *knowns* about the cipher or the underlying plain text.

Using CRANK to assist in deciphering messages
CRANK is the CRyptANalysis toolKit created by Matthew Russell. The program and source code can be obtained at http://crank.sourceforge.net/. This program focuses on Monoalphabetic substitution ciphers as well as transpositional ciphers. At the time of this writing there are two versions of CRANK, v1.4 and v2.1, though v2.1 is still in beta. Version 1.4 can help with much of the math and statistics when dealing with a substitution cipher.

There are two main windows that will do most of your work in, source and view. The source window is for the original cipher text and the view is the current guess on the plain text. The first thing is to load some text into the source window and prepare it to be encrypted. After pasting the text into the Souce window choose Text->Simple Filters.



Remove numbers [✓] Remove punctuation [✓] Remove whitespace [ ] To uppercase [✓] To lowercase [ ] Group in fives [ ]

Source

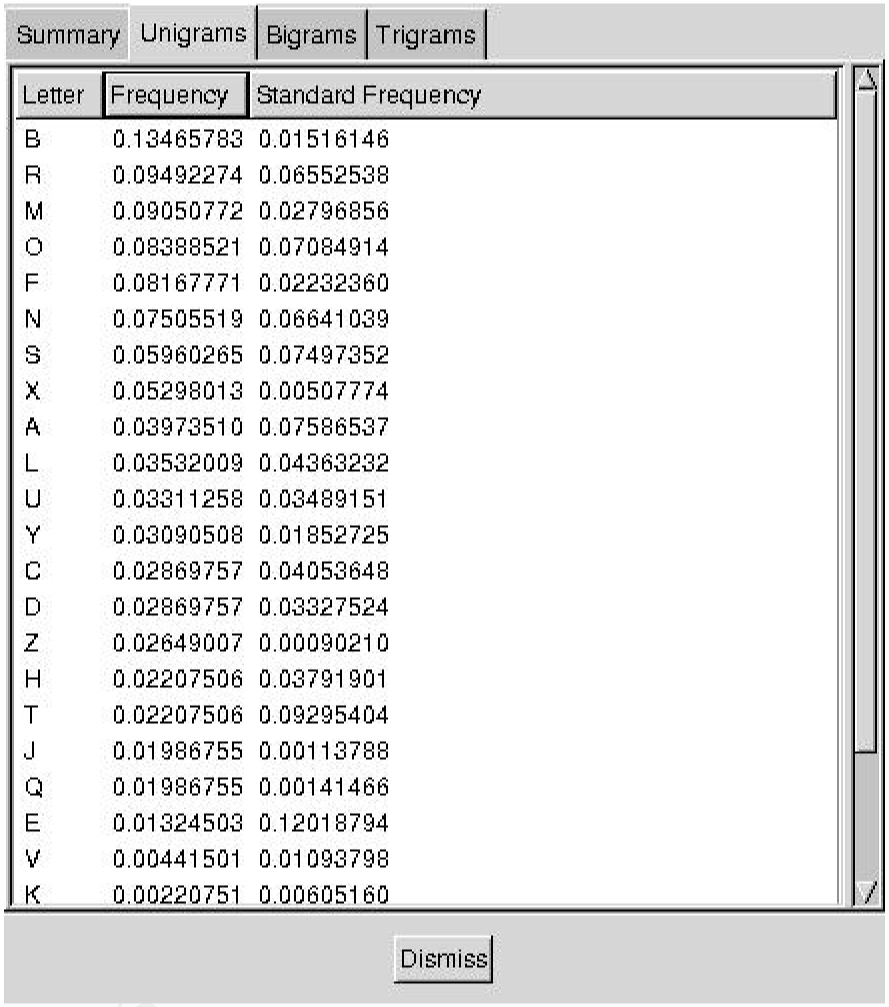
The licenses for most software are designed to take away your
freedom to share and change it. By contrast, the GNU General Public
License is intended to guarantee your freedom to share and change free
software--to make sure the software is free for all its users. This
General Public License applies to most of the Free Software
Foundation's software and to any other program whose authors commit to
using it. (Some other Free Software Foundation software is covered by
the GNU Library General Public License instead.) You can apply it to
your programs, too

View

THE LICENSES FOR MOST SOFTWARE ARE DESIGNED TO TAKE AWAY YOUR
FREEDOM TO SHARE AND CHANGE IT BY CONTRAST THE GNU GENERAL PUBLIC
LICENSE IS INTENDED TO GUARANTEE YOUR FREEDOM TO SHARE AND CHANGE FREE
SOFTWARETO MAKE SURE THE SOFTWARE IS FREE FOR ALL ITS USERS THIS
GENERAL PUBLIC LICENSE APPLIES TO MOST OF THE FREE SOFTWARE
FOUNDATIONS SOFTWARE AND TO ANY OTHER PROGRAM WHOSE AUTHORS COMMIT TO
USING IT SOME OTHER FREE SOFTWARE FOUNDATION SOFTWARE IS COVERED BY
THE GNU LIBRARY GENERAL PUBLIC LICENSE INSTEAD YOU CAN APPLY IT TO
YOUR PROGRAMS TOO

There exists some convenient formating tools that can strip out punctuation, spaces and even group the text into five characters a piece. This tool bar can be used for creating and formating plaintext messages to encrypt.

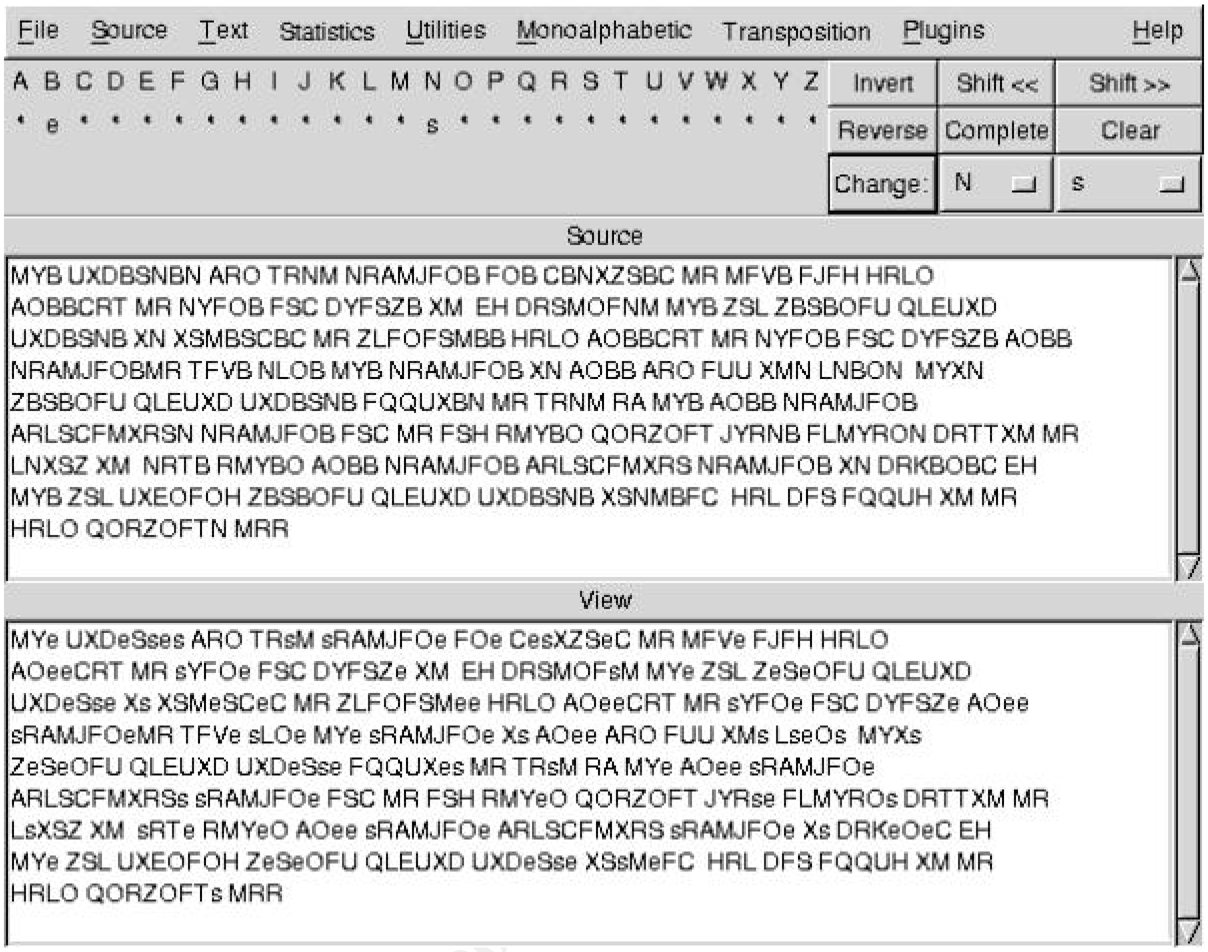
CRANK can calculate the frequency of the unigraphs, bigraphs, and trigraphs by selecting Statistics->n-grams, then choose either unigrams, bigrans or trigrams respectively.



Letter	Frequency	Standard Frequency
B	0.13465783	0.01516146
R	0.09492274	0.06552538
M	0.09050772	0.02796856
O	0.08388521	0.07084914
F	0.08167771	0.02232360
N	0.07505519	0.06641039
S	0.05960265	0.07497352
X	0.05298013	0.00507774
A	0.03973510	0.07586537
L	0.03532009	0.04363232
U	0.03311258	0.03489151
Y	0.03090508	0.01852725
C	0.02869757	0.04053648
D	0.02869757	0.03327524
Z	0.02649007	0.00090210
H	0.02207506	0.03791901
T	0.02207506	0.09295404
J	0.01986755	0.00113788
Q	0.01986755	0.00141466
E	0.01324503	0.12018794
V	0.00441501	0.01093798
K	0.00220751	0.00605160

Within Frequency, are the letters ordered by highest to lowest frequency. These number are actually the overall percentage frequency that the character show up in the text. "B" is the most frequent character at 13.4% followed by "R", "M", "O" and "F". The standard frequency column is the frequency that is normally expected. Sorting by standard frequency will show the top five characters as E,T,N,R and O. CRANK can recalculate the standard frequencies of many different types of plain text files. This can be useful for analyzing something that may not be written in complete sentences such as military communications.

CRANK also has a nice key control feature for use with basic substitution ciphers. The following toolbar is displayed when Monoalphabetic->key controls is selected.


File Source Text Statistics Utilities Monoalphabetic Transposition Plugins Help
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
* e * * * * * * * * * * * s * * * * * * * * * * * *
Invert
Shift <<
Shift >>
Reverse
Complete
Clear
Change:
N
s
Source
View

```
MYB UXDBSNBN ARO TRNM NRAMJFOB FOB CBNXZSBC MR MFVB FJFH HRLO
AOBBCRT MR NYFOB FSC DYFSZB XM  EH DRSMOFNM MYB ZSL ZBSBOFU QLEUXD
UXDBSNB XN XSMBSCBC MR ZLFOFSMBB HRLO AOBBCRT MR NYFOB FSC DYFSZB AOBB
NRAMJFOBMR TFVB NLOB MYB NRAMJFOB XN AOBB ARO FUU XMN LNBON  MYXN
ZBSBOFU QLEUXD UXDBSNB FQQUXBN MR TRNM RA MYB AOBB NRAMJFOB
ARLSCFMXRSN NRAMJFOB FSC MR FSH RMYBO QORZOFT JYRNB FLMYRON DRTTXM MR
LNXSZ XM  NRTB RMYBO AOBB NRAMJFOB ARLSCFMXRS NRAMJFOB XN DRKBOBC EH
MYB ZSL UXEOFOH ZBSBOFU QLEUXD UXDBSNB XSNMBFC  HRL DFS FQQUH XM MR
HRLO QORZOFTN MRR
```

```
MYe UXDeSses ARO TRsM sRAMJFOe FOe CesXZSeC MR MFVe FJFH HRLO
AOeeCRT MR sYFOe FSC DYFSZe XM  EH DRSMOFsM MYe ZSL ZeSeOFU QLEUXD
UXDeSse Xs XSMeSCeC MR ZLFOFSMee HRLO AOeeCRT MR sYFOe FSC DYFSZe AOee
sRAMJFOeMR TFVe sLOe MYe sRAMJFOe Xs AOee ARO FUU XMs LseOs  MYXs
ZeSeOFU QLEUXD UXDeSse FQQUXes MR TRsM RA MYe AOee sRAMJFOe
ARLSCFMXRSs sRAMJFOe FSC MR FSH RMYeO QORZOFT JYRse FLMYROs DRTTXM MR
LsXSZ XM  sRTe RMYeO AOee sRAMJFOe ARLSCFMXRS sRAMJFOe Xs DRKeOeC EH
MYe ZSL UXEOFOH ZeSeOFU QLEUXD UXDeSse XSsMeFC  HRL DFS FQQUH XM MR
HRLO QORZOFTs MRR
```

First, the screen should have the alphabet in capital letters as well as lowercase. The capital letters represent the cipher text and the lowercase will be the key. If no key is present then press the "complete" button to fill in a default key. The key can be shifted by using "Shift<<" or "Shift>>". Press the "Reverse" button to re-arrange the key in reverse order.

Use "Clear" to wipe out the key and the display will show '*'s for unkown key entries. By using the change key you can enter the letters you wish to substitute, e.g. since B was the most frequent it can be changed to an E. The key will be updated as well as the View window. Uppercase letters show up as entries that have not been decoded yet while the lower case letters are from the key. It should be noted that CRANK does not differentiate between Uppercase and Lowercase in the cipher itself.

CRANK has many more features and several tools such as an auto-cracker for monoalphabetic ciphers. It also has an extensive amount of tools for dealing with transpositional ciphers as well.

Exercise for the reader

Now that you should be very comfortable in solving monoalphabetic unilateral ciphers, I leave you with a small exercise. Time yourself and decode the following cipher text.

```
HEWFNUXEYHC XS AHNOLFOB WYH ZURNFU XSAROTFWXRS FEELOFSDH DHOWXAXDFWXRS
ZXFD QORZOFT XE F OXZRORLE QORZOFT CHEXZSHC WR HSELOH WYFW EHDLOXWB
QORAHEEXRSFUE THHW F TXSXTLT EWFSCFOC RA HIDHUUHSDH XS WYH VSRJUHCZH
FSC EVXUUE WYHB QREEHEE WYHOH XE F DOXWXDFU EYROWFZH RA XSAROTFWXRS
EHDLOXWB QORAHEEXRSFUE XS WYH XSCLEWOB WRCFB TFSB RA WYREH HSWOLEWHC
JXWY EHDLOXWB OHEQRSEXNXUXWXHE YFKH SRW OHDHXKHC WYH WOFXSXSZ SHDHEEFOB
WR CR WYHXO MRNE ZXFD DHOWXAXDFWXRS HSFNUHE WYREH XS WYH EHDLOXWB
XSCLEWOB WR CHTRSEWOFWH WYH CHQWY RA WYHXO FNXUXWB FSC FEELOH DLOOHSW
RO QOREQHDWXKH HTQURBHOE WYFW WYH DHOWXAXHC XSCXKXCLFU YFE WYH FNXUXWB
WR ELDDHHC
```

Enjoy!

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