

CrypTool

A free software program

- **for creating awareness of IT security issues**
- **for learning about and obtaining experience of cryptography**
- **for demonstrating encryption algorithms and analysis procedures**

www.cryptool.de
www.cryptool.com
www.cryptool.org

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DARMSTADT

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Introduction

1. What is CrypTool?

- a freeware Program with graphical user interface
- a tool for applying and analysing cryptographic algorithms
- with extensive online help, understandable without deep crypto knowledge
- contains nearly all state of the art crypto algorithms
- “playful” introduction to modern and classical cryptography
- not a “hacker tool”

2. Why CrypTool?

- origin in Deutsche Bank’s IT security awareness program
- developed in co-operation with universities
- improve IT security related courses in universities and companies

3. Audience

- target group: students of computer science, commercial IT and mathematics
- also aimed at: interested computer users and application developers
- prerequisites: secondary school mathematics or programming skills

CrypTool Overview

1. Features

Cryptography

Classical algorithms

- Caesar
- Vigenère
- Hill
- Monoalphabetic substitution
- Homophonic substitution
- Playfair
- Permutation
- Addition
- XOR
- Vernam

To facilitate performing text book examples with CrypTool

- alphabet can be configured
- treatment of white space etc. configurable

Cryptanalysis

Attacks on classical algorithms

- ciphertext only
 - Caesar
 - Vigenère
 - Addition
 - XOR
- known plaintext
 - Hill
 - Playfair
- manual
 - mono-alphabetic substitution

Supporting analysis procedures

- entropy, floating frequency
- histogram, n-gram analysis
- auto-correlation
- ZIP compression test

CrypTool Overview

1. Features

Cryptography

Modern symmetric algorithms

- IDEA, RC2, RC4, DES, 3DES
- last round AES candidates
- AES (=Rijndael)

Asymmetric algorithms

- RSA with X.509 certificates
- RSA demonstration
 - to facilitate performing text book examples with CrypTool
 - alphabet and block length configurable

Hybrid encryption

- RSA combined with AES encryption
- visualised by an interactive data flow diagram

Cryptanalysis

Brute-force attack on symmetric algorithms

- implemented for all algorithms
- assumption:
entropy of the plain text is small

Attack on RSA encryption

- factor RSA modulus
- workable for bit lengths ≤ 250

Attack on hybrid encryption

- attack on RSA (see below) or
- attack on AES (see above)

CrypTool Overview

1. Features

Cryptography

Digital Signature

- RSA with X.509 certificates
 - signature procedure visualised by an interactive data flow diagram
- DSA with X.509 certificates
- Elliptic curve DSA, Nyberg-Rueppel

Hash functions

- MD2, MD4, MD5
- SHA, SHA-1, RIPEMD-160

Random generators

- SECUDE
- X^2 modulo N
- Linear Congruence Generator (LCG)
- Inverse Congruence Generator (ICG)

Cryptanalysis

Attack on RSA Signature

- RSA modulus factorisation
- workable up to approx. 250 bit

Attack on hash function/digital signature

- Generation of hash collisions to ASCII texts

Random data analysis

- FIPS-PUB-140-1 test battery
- periodicity, Vitany, entropy
- histogram, n-gram analysis
- auto-correlation
- ZIP compression test

CrypTool Overview

2. Software package contents

CrypTool program

- all functions integrated in *one* program with uniform graphical user interface
- platforms: Win32 and Linux with WINE emulator
- cryptography based on Secude library (www.secude.com)
- arbitrary precision arithmetic: Miracl library (<http://indigo.ie/~mscott/>)

AES-Tool

- standalone program for AES encryption (self extracting)

Extensive online help (Winhelp)

- context sensitive online help for *all* program functions and all menu items
- detailed examples of usage for many program features

Script (PDF) with background information on

- encryption algorithms • prime numbers • digital signature
- elliptic curves • public key certification • elementary number theory

Short story “Dialogue of the Sisters” by Dr. C. Elsner



completely bilingual
English
German

CrypTool Overview

3. New in release 1.3.xx

Most important changes (details: see ReadMe-en.txt):

Release 1.3.00 published January 2002

- completely bilingual English/German
- improved dialog box consistency and comprehensibility
- Windows 9x file size limit removed
- homophonic and permutation encryption
- random generators, random data analysis (FIPS-140-1, periodicity, n-gram)
- AES-Tool: create self-decrypting files (AES)
- demonstration: number theory and RSA crypto system (further improved in 1.3.02)
- PKCS#12 export/import for PSEs

Release 1.3.02 published September 2002

- visualisation of hybrid encryption and decryption
- visualisation of signature creation and verification
- hash value calculation of large files (without loading them into memory)
- visualisation of the sensitivity of hash functions to changes in the hashed data
- short story “Dialogue of the Sisters” by Dr. C. Elsner included

CrypTool Overview

3. New in release 1.3.xx

Release 1.3.04 published August 2003

- visualisation of Diffie-Hellman key exchange
- attack on digital signature using hash-collisions (birthday paradox)
- brute-force attack on symmetric ciphers improved
- script updated (primes, factorization) and extended (hash functions, ECC, CrypTool menu tree)
- many small improvements (especially online help) and bug fixes

Examples of use

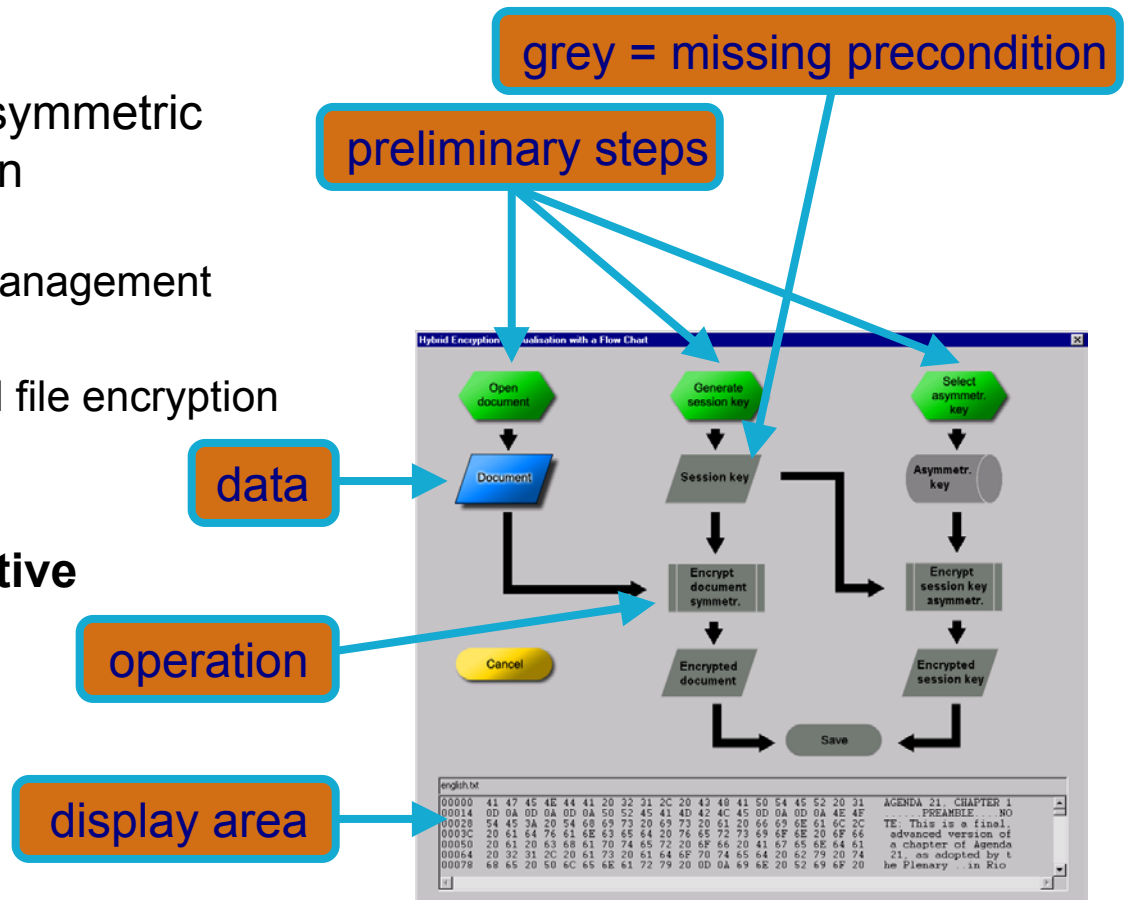
1. Hybrid encryption visualised

Hybrid encryption

- combines advantages of symmetric and asymmetric encryption
 - speed
 - simple and scalable key management
- widely used in practice
 - e-mail (S/MIME, PGP) and file encryption
 - SSL (https)

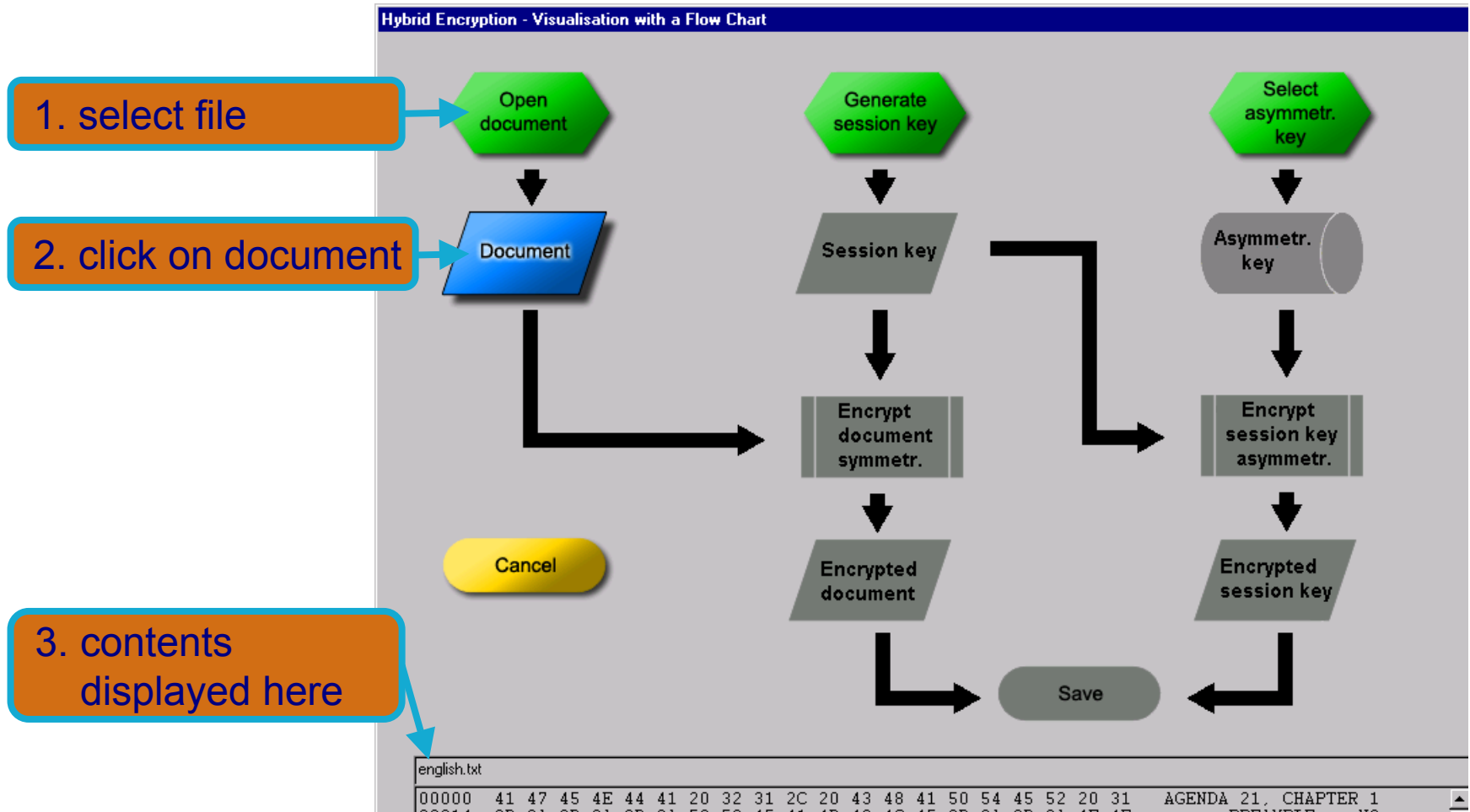
Visualisation by an interactive data flow diagram

- playful learning leads to deeper understanding



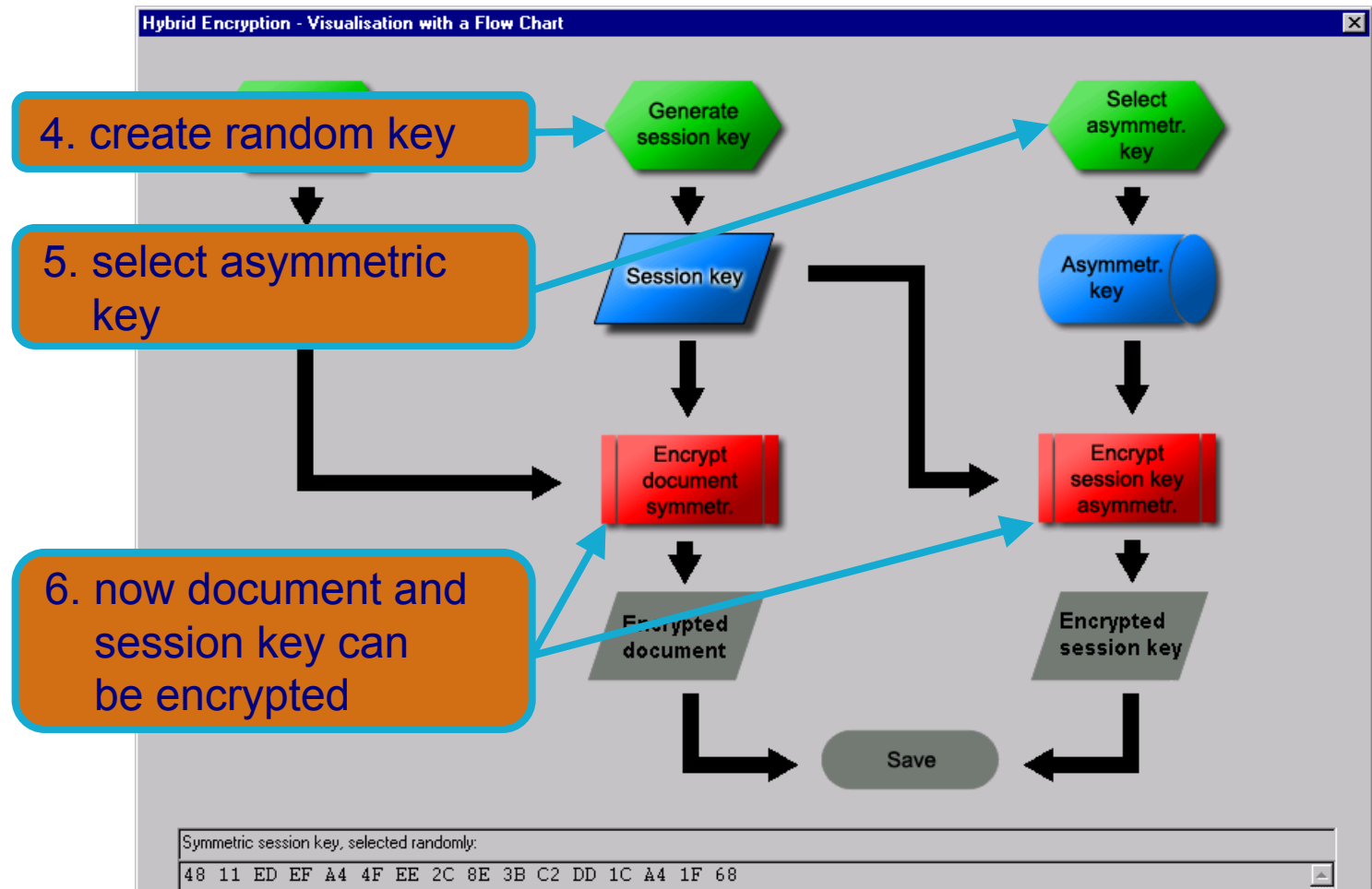
Examples of use

1. Hybrid encryption visualised: Preparation



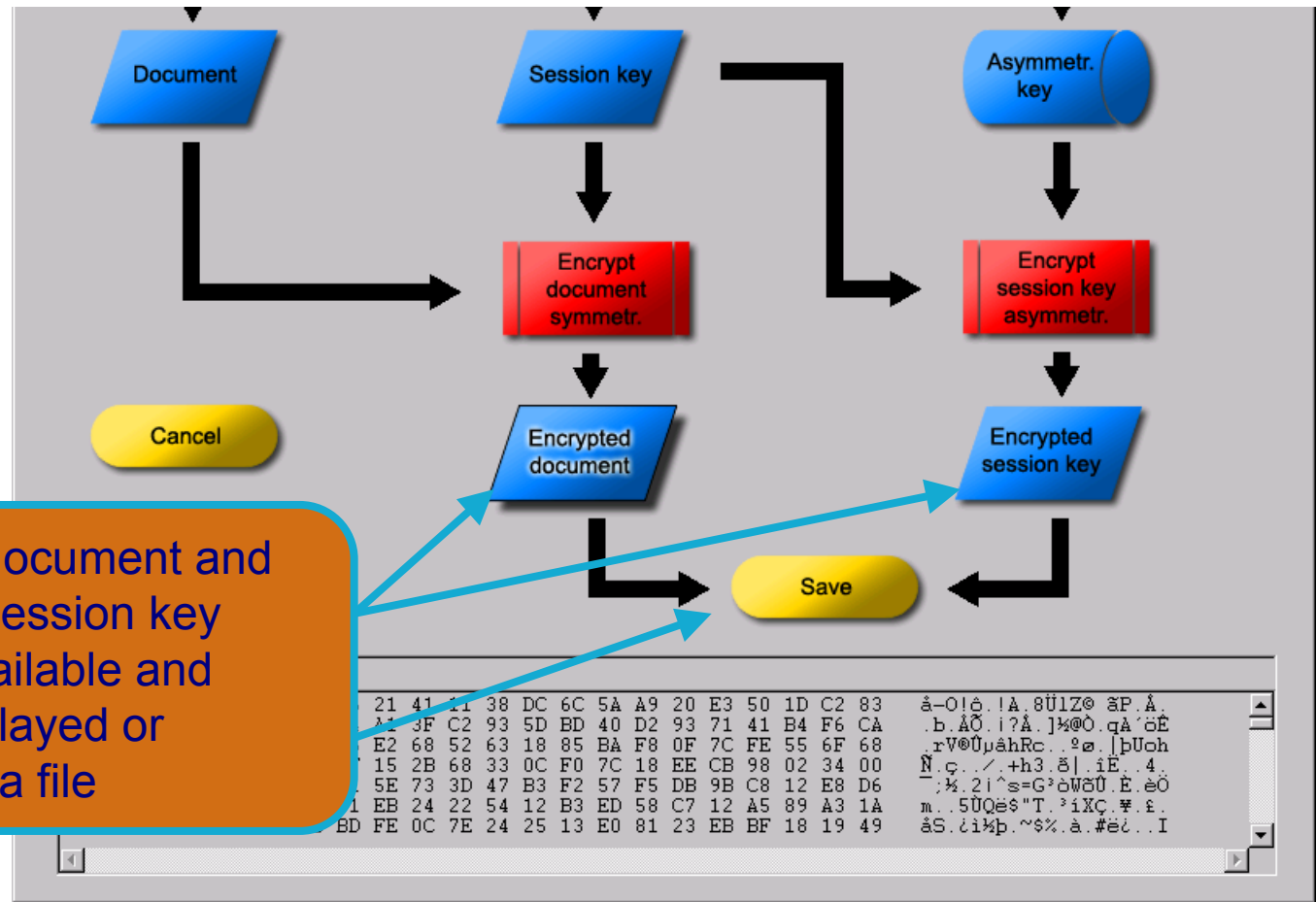
Examples of use

1. Hybrid encryption visualised: Cryptography



Examples of use

1. Hybrid encryption visualised: Result



7. encrypted document and encrypted session key are now available and can be displayed or written into a file

Examples of use

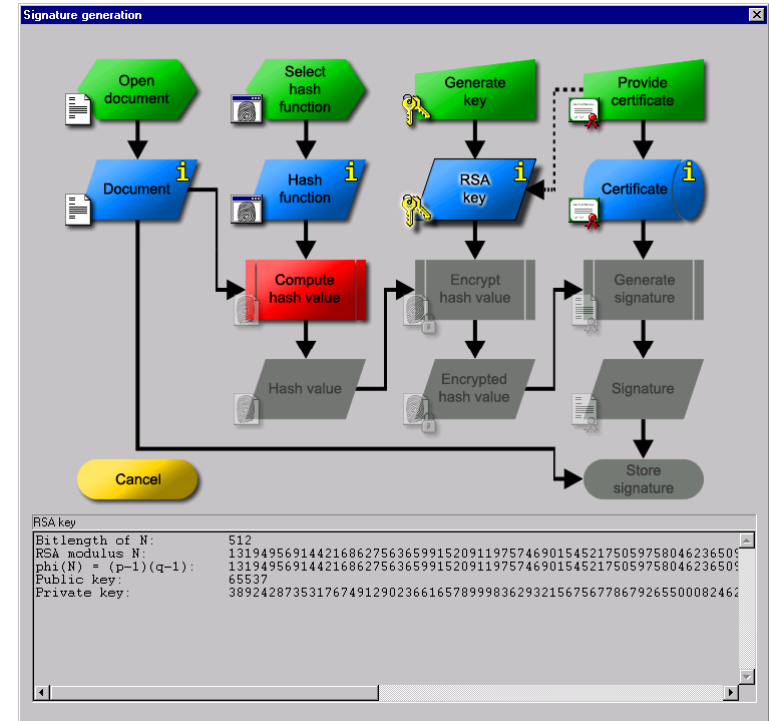
2. Digital signature visualised

Digital signature

- increasingly important
 - equivalence with manual signature (digital signature law)
 - increasingly used by industry, government and consumers
- few people know how it works

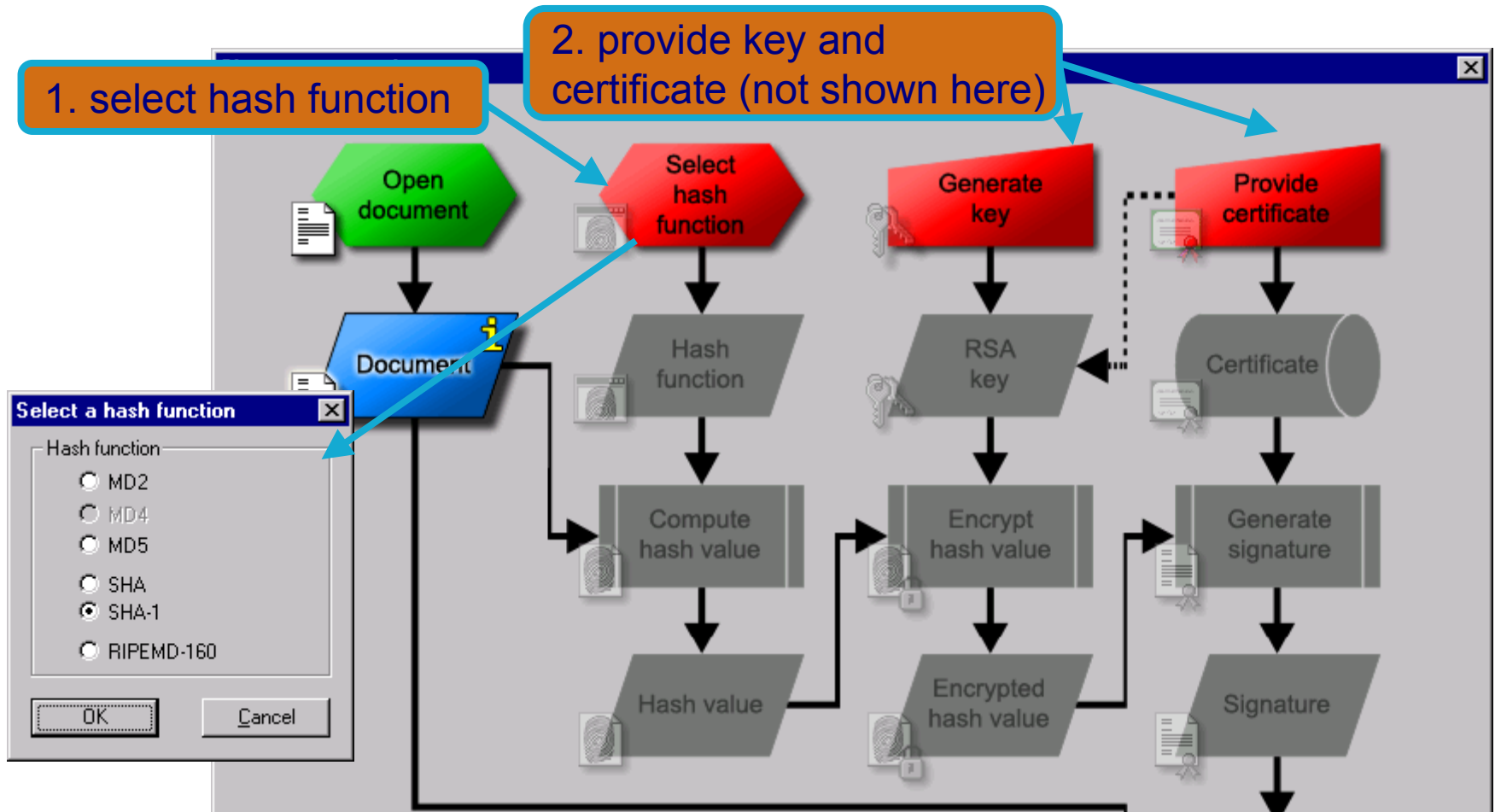
Visualisation in CrypTool

- interactive data flow diagram
- similar to the visualisation of hybrid encryption



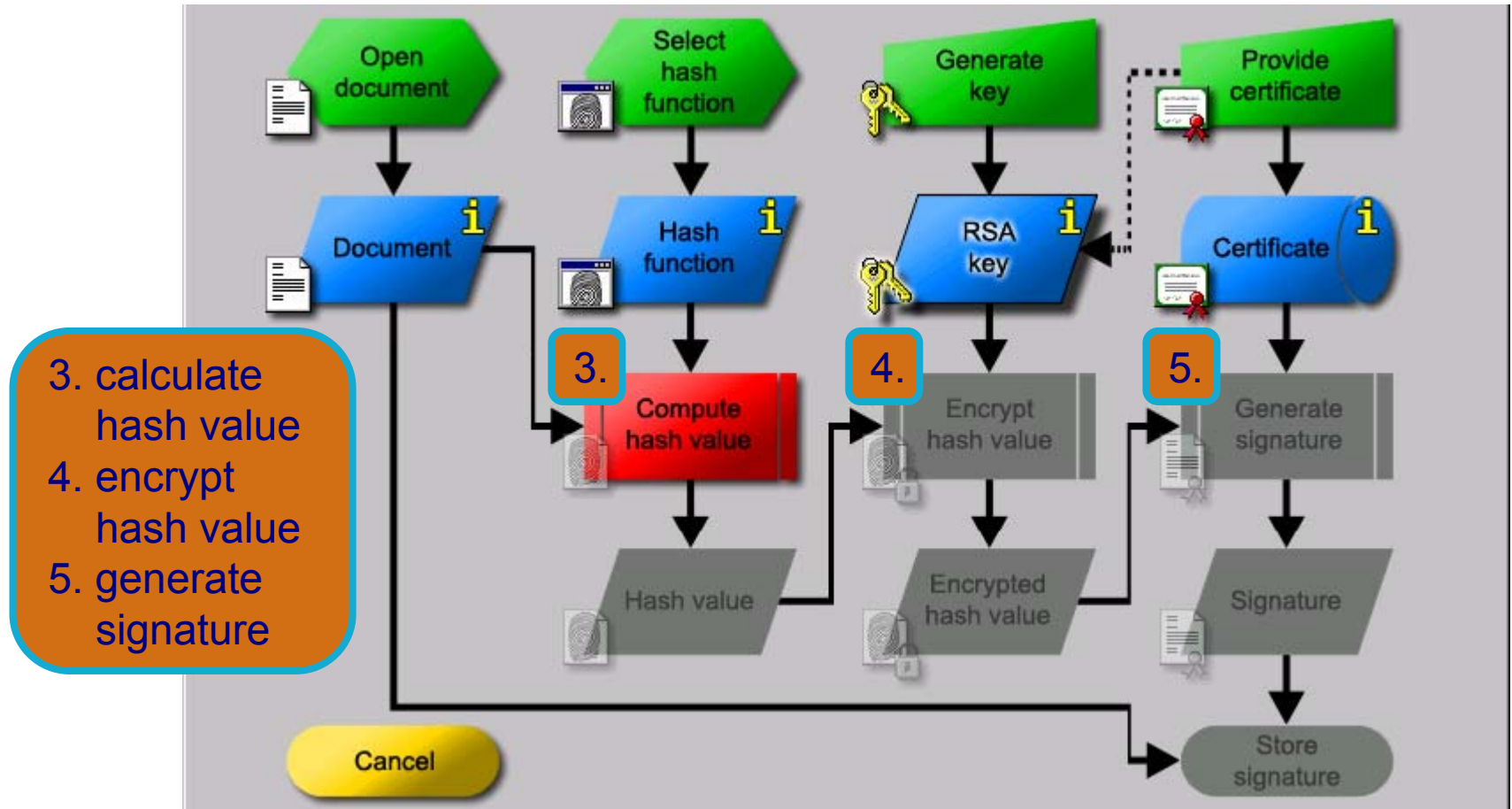
Examples of use

2. Digital signature visualised: Preparation

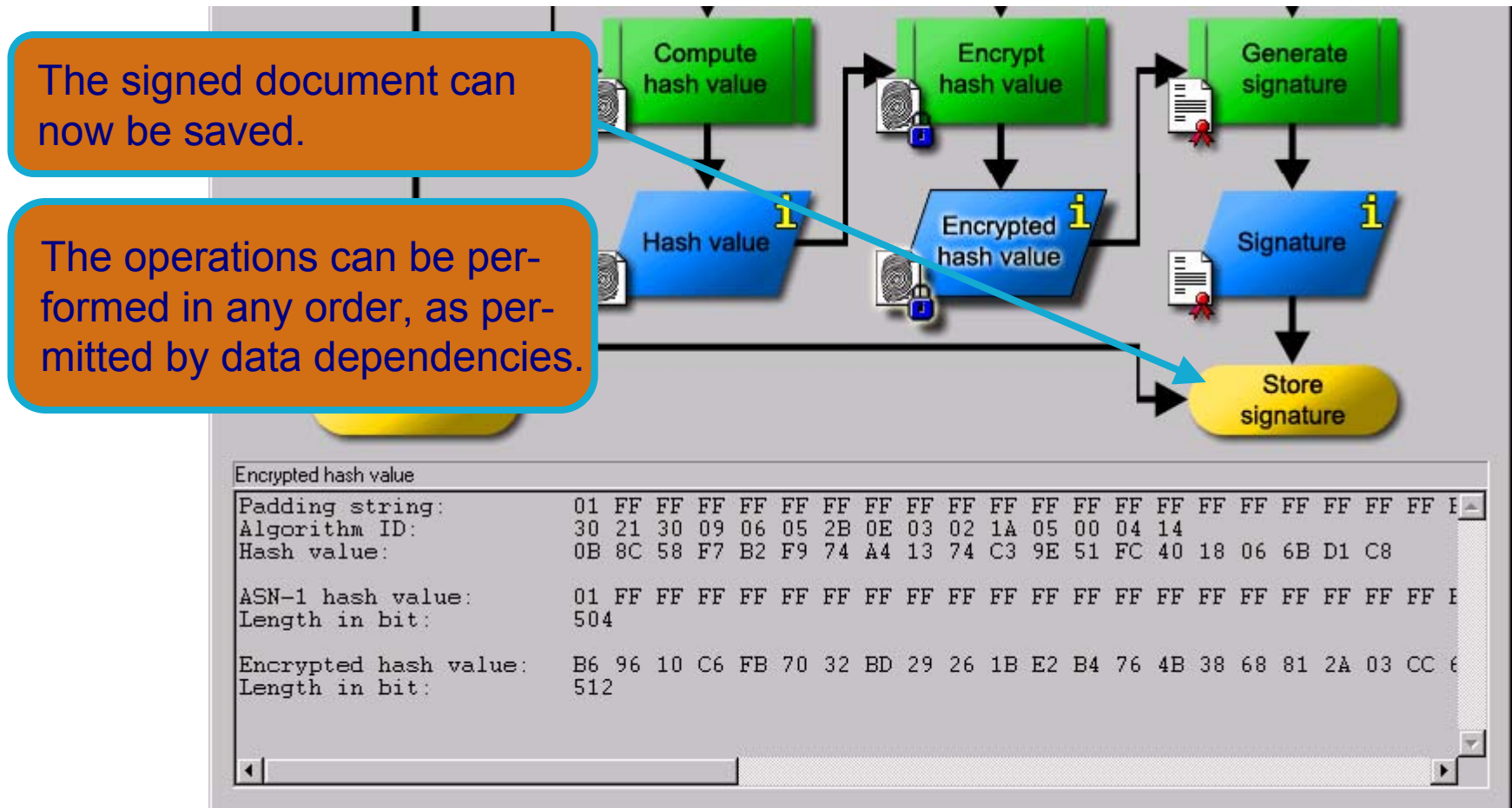


Examples of use

2. Digital signature visualised: Cryptography



2. Digital signature visualised: Result



Examples of use

3. Attack on RSA encryption with short RSA modulus

Example from Song Y. Yan, Number Theory for Computing, Springer, 2000

- public key
 - RSA modulus $N = 63978486879527143858831415041$ (95 bit, 29 decimal digits)
 - public exponent $e = 17579$
- cipher text (block length = 14):
 - $C_1 = 45411667895024938209259253423,$
 - $C_2 = 16597091621432020076311552201,$
 - $C_3 = 46468979279750354732637631044,$
 - $C_4 = 32870167545903741339819671379$
- the text shall be deciphered!

Solution using CrypTool (more detailed in online help examples section):

- enter public parameters into “RSA cryptosystem” (menu indiv. procedures)
- button “factorise the RSA modulus” yields prime factors $p, q = N$
- based on that information private exponent $d = e^{-1} \bmod (p-1)(q-1)$ is determined
- decrypt the cipher text with d : $M_i = C_i^d \bmod N$

The attack with CrypTool is workable for RSA moduli up to 250 bit

Examples of use:

3. Short RSA modulus: enter public RSA parameters

The RSA Cryptosystem

RSA using the private and public key -- or using only the public key

- ☐ Choose two prime numbers p and q . The number $N = pq$ is the public RSA modulus and $\phi(N) = (p-1)(q-1)$ is the Euler number. Public key e is coprime to $\phi(N)$. The private key $d = e^{-1} \pmod{\phi(N)}$ is calculated from this.
- ☒ For the purpose of data encryption or certificate checking it is sufficient to enter the public RSA parameters: the RSA modulus N and the public key e .

Factorisation attack

You may try to factorise the public RSA modulus N into its primes p and q .

Factorise RSA modulus...

RSA parameters

RSA modulus N (public)

$\phi(N) = (p-1)(q-1)$ (secret)

Public key e (public)

Private key d

Update parameters

☐ RSA encryption using e / decryption using d

2. factorise

1. enter RSA parameters N and e



Examples of use:

3. Short RSA modulus: factorise RSA modulus

Factorisation of a Number

Algorithms for factorisation:

- ☒ Brute-force method
- ☒ Brent algorithm
- ☒ Pollard method
- ☒ Williams method
- ☒ Lenstra algorithm
- ☒ Quadratic sieve method

Input:

Enter the number to be factorised:

63978486879527143858831415041

Factorisation:

The factorisation is represented in the format $\langle z_1^{a_1} * z_2^{a_2} * \dots * z_n^{a_n} \rangle$. Composite numbers are appearing in red color.

Last factorisation through: Pollard

Time required: 0,981 seconds.

Factorisation result:

145295143558111 * 440334654777631

Details

Close

CrypTool

The RSA modulus N has been successfully factorised into the primes p and q!
You can now perform the RSA operation with the secret key d.
For this purpose just click the button Decrypt.

OK

3. factorisation yields p and q

Examples of use:

3. Short RSA modulus: determine private key d

The RSA Cryptosystem

RSA using the private and public key -- or using only the public key

- ☒ Choose two prime numbers p and q. The number $N = pq$ is the public RSA modulus and $\phi(N) = (p-1)(q-1)$ is the Euler number. Public key e is coprime to $\phi(N)$. The private key $d = e^{-1} \pmod{\phi(N)}$ is calculated from this.
- ☐ For the purpose of data encryption or certificate checking it will do with the published RSA parameter: the RSA modulus N and the public key e.

Prime number entry

Prime number p: 145295143558111

Prime number q: 440334654777631

Generate prime numbers

RSA parameters

RSA modulus N: 63978486879527143858831415041 (public)

$\phi(N) = (p-1)(q-1)$: 63978486879526558229033079300 (secret)

Public key e: 17579

Private key d: 10663687727232084624328285019

Update parameters

RSA encryption using e / decryption using d

Input as ☒ text ☐ numbers

Options for alphabet and number system...

Enter either as text or as numbers in the format number[1] # ... # number[n] (numbers of base 1240752)

4. p and q have been entered automatically and secret key d has been calculated

5. adjust options

Examples of use:

3. Short RSA modulus: adjust options

Options for RSA Encryption

Text options

☐ All 256 ASCII characters

☒ Specify alphabet: Number of characters: 27

ABCDEFGHIJKLMNOPQRSTUVWXYZ

Block length

The number of characters that are encrypted with each RSA operation. The maximum size is subject to the length of the RSA modul N in bit, the number of characters in the alphabet and the method used for the coding.

Block length in characters: (Maximum block length 2 characters)

Number system

The numbers for RSA encryption and decryption will be represented in the following number system

☒ Decimal ☐ Binary ☐ Octal ☐ Hexadecimal

OK Cancel

6. select alphabet

7. select coding method

8. select block length



Examples of use:

3. Short RSA modulus: decrypt cipher text

RSA parameters

RSA modulus N	63978486879527143858831415041	(public)
$\phi(N) = (p-1)(q-1)$	63978486879526558229033079300	(secret)
Public key e	17579	
Private key d	10663687727232084624328285019	

[Update parameters](#)

RSA encryption using e / decryption using d

Input as ☐ text ☒ numbers [Options for alphabet and number system...](#)

Ciphertext coded in numbers of base 10

7091621432020076311552201 # 46468979279750354732637631044 # 32870167545903741339819671279

Decryption into plaintext $m[i] = c[i]^d \pmod{N}$

00000000000001401202118011200 # 00000000000001421130205181900 # 0000000000000011805001301

Output text from the decryption (into segments of size 8; the symbol '#' is used as separator).

NATURAL # NUMBERS # ARE MADE # BY GOD

Plaintext

NATURAL NUMBERS ARE MADE BY GOD

[Encrypt](#) [Decrypt](#) [Close](#)

9. enter cipher text

10. decrypt

Examples of use

4. Analysis of encryption used in the PSION 5 PDA

Attack on the encryption option in the PSION 5 PDA word processing application



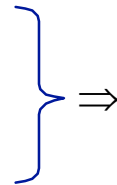
Starting point: an encrypted file on the PSION

Requirements

- encrypted English or German text
- depending on method and key length, 100 bytes up to several kB of text

Procedure

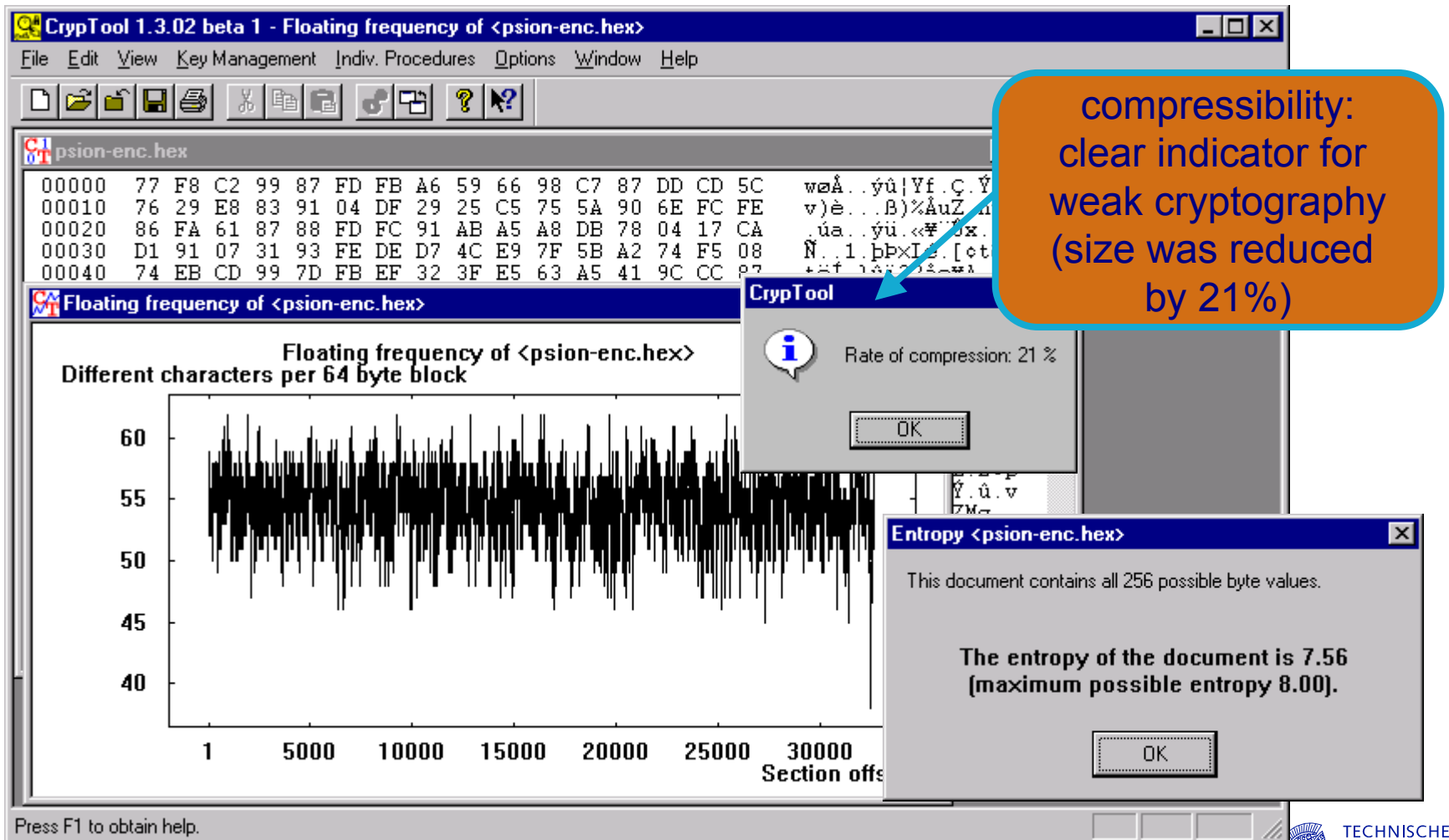
- pre-analysis
 - entropy
 - floating entropy
 - compression test
- auto-correlation
- try out automatic analysis with classical methods



probably classical
encryption algorithm

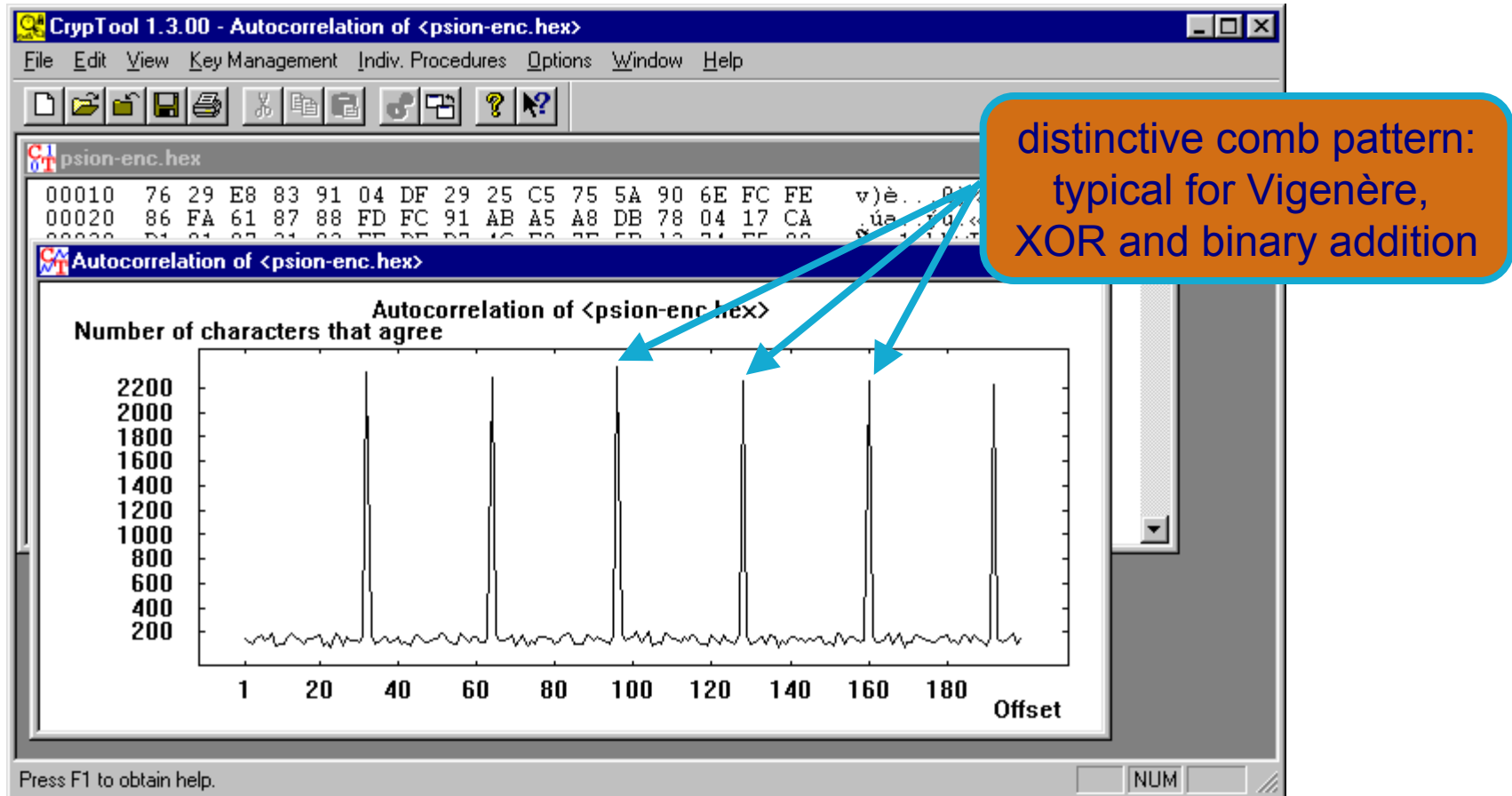
Examples of use

4. PSION PDA: determine entropy, compression test



Examples of use

4. PSION PDA: determine auto-correlation



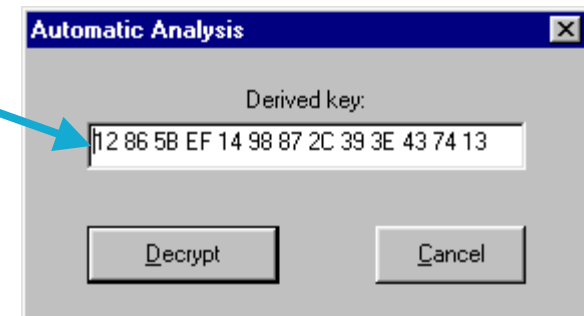
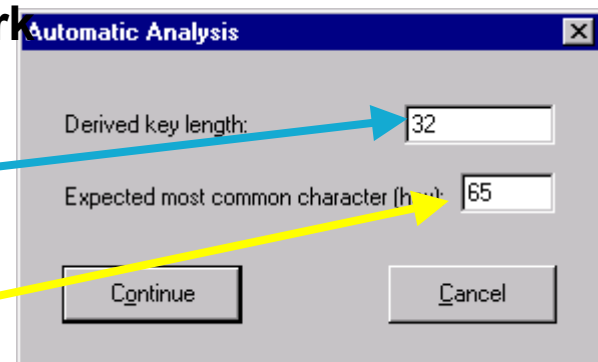
Examples of use

4. PSION PDA: automatic analysis

Automatic analysis using XOR: does not work

Automatic analysis using Binary Addition:

- CrypTool calculates the key length using auto-correlation: 32 bytes
- The user can choose which character is expected to occur most frequently: “e” = 0x65 (ASCII code)
- Analysis calculates the most likely key (based on the assumptions about distribution)
- Results: good, but not perfect

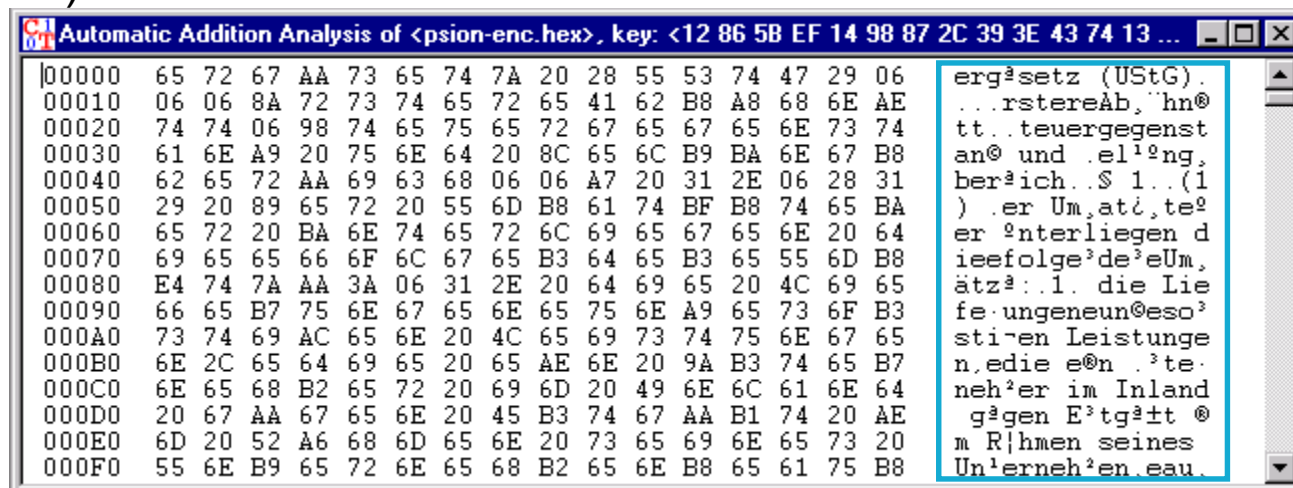


Examples of use

4. PSION PDA: results of automatic analysis

Results of automatic analysis with assumption “binary addition”:

- results good, but not perfect: 24 out of 32 key bytes correct.
- the key length was correctly determined.
- the password entered was not 32 bytes long.
⇒ PSION Word derives the actual key from the password.
- manual post-processing produces the encrypted text
(not shown)



Automatic Addition Analysis of <psion-enc.hex>, key: <12 86 5B EF 14 98 87 2C 39 3E 43 74 13 ...

00000	65	72	67	AA	73	65	74	7A	20	28	55	53	74	47	29	06	erg³setz (UStG).
00010	06	06	8A	72	73	74	65	72	65	41	62	B8	A8	68	6E	AE	...rstereAb,`hn®
00020	74	74	06	98	74	65	75	65	72	67	65	67	65	6E	73	74	tt...teuergegenst
00030	61	6E	A9	20	75	6E	64	20	8C	65	6C	B9	BA	6E	67	B8	an® und .el¹²ng,
00040	62	65	72	AA	69	63	68	06	06	A7	20	31	2E	06	28	31	ber³ich...\$ 1..(1
00050	29	20	89	65	72	20	55	6D	B8	61	74	BF	B8	74	65	BA) .er Um,at¿,te²
00060	65	72	20	BA	6E	74	65	72	6C	69	65	67	65	6E	20	64	er ²nterliegen d
00070	69	65	65	66	6F	6C	67	65	B3	64	65	B3	65	55	6D	B8	ieefolge³de³eUm,
00080	E4	74	7A	AA	3A	06	31	2E	20	64	69	65	20	4C	69	65	ätz³:..1. die Lie
00090	66	65	B7	75	6E	67	65	6E	65	75	6E	A9	65	73	6F	B3	fe·ungeneun@eso³
000A0	73	74	69	AC	65	6E	20	4C	65	69	73	74	75	6E	67	65	stiren Leistunge
000B0	6E	2C	65	64	69	65	20	65	AE	6E	20	9A	B3	74	65	B7	n,edie e®n .³te
000C0	6E	65	68	B2	65	72	20	69	6D	20	49	6E	6C	61	6E	64	neh²er im Inland
000D0	20	67	AA	67	65	6E	20	45	B3	74	67	AA	B1	74	20	AE	g³gen E³tg³tt ®
000E0	6D	20	52	A6	68	6D	65	6E	20	73	65	69	6E	65	73	20	m R³hmen seines
000F0	55	6E	B9	65	72	6E	65	68	B2	65	6E	B8	65	61	75	B8	Un¹erneh²en.eau.

Examples of use

4. PSION PDA: determining the remaining key bytes

Copy key to clipboard during automatic analysis

In automatic analysis hexdump,

- determine incorrect byte positions, e.g. 0xAA at position 3
- guess and write down corresponding correct bytes: „e“ = 0x65

In encrypted initial file hexdump,

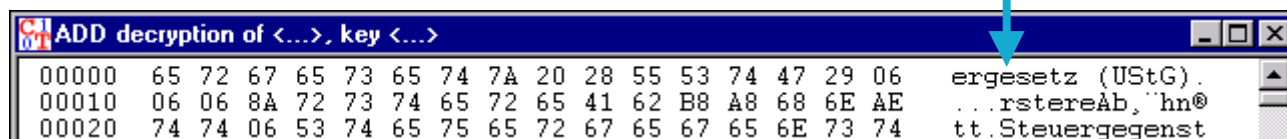
- determine initial bytes from the calculated byte positions: 0x99
- calculate correct key bytes with CALC.EXE: $0x99 - 0x65 = 0x34$

Correct key from the clipboard

- 12865B341498872C393E43741396A45670235E111E907AB7C0841...

Decrypt encrypted initial document using binary addition

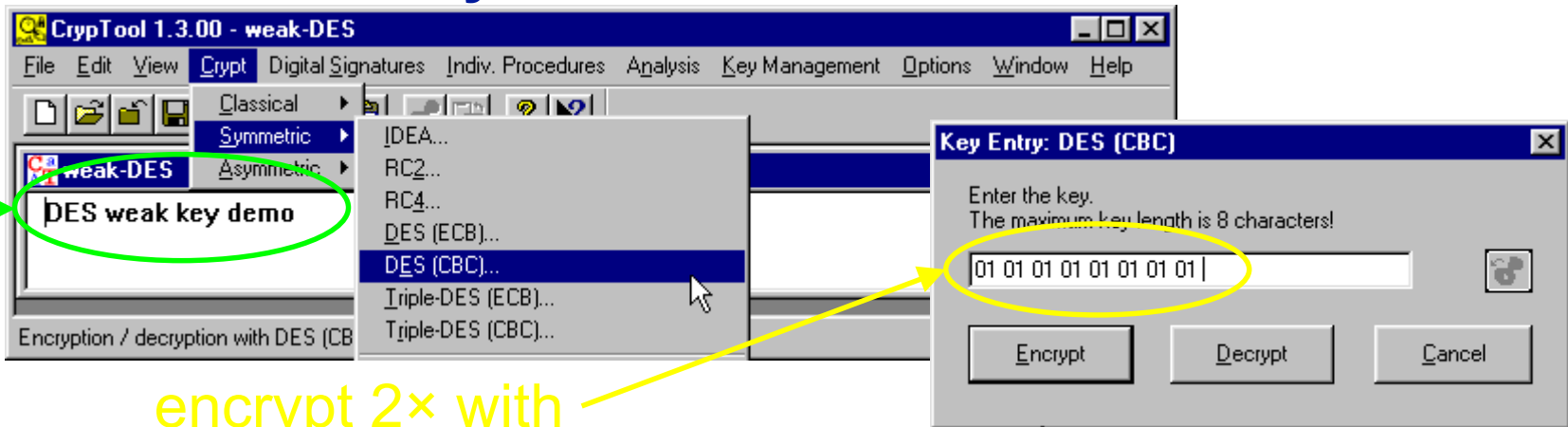
- bytes at position 3, 3+32, 3+2*32, ... are now correct



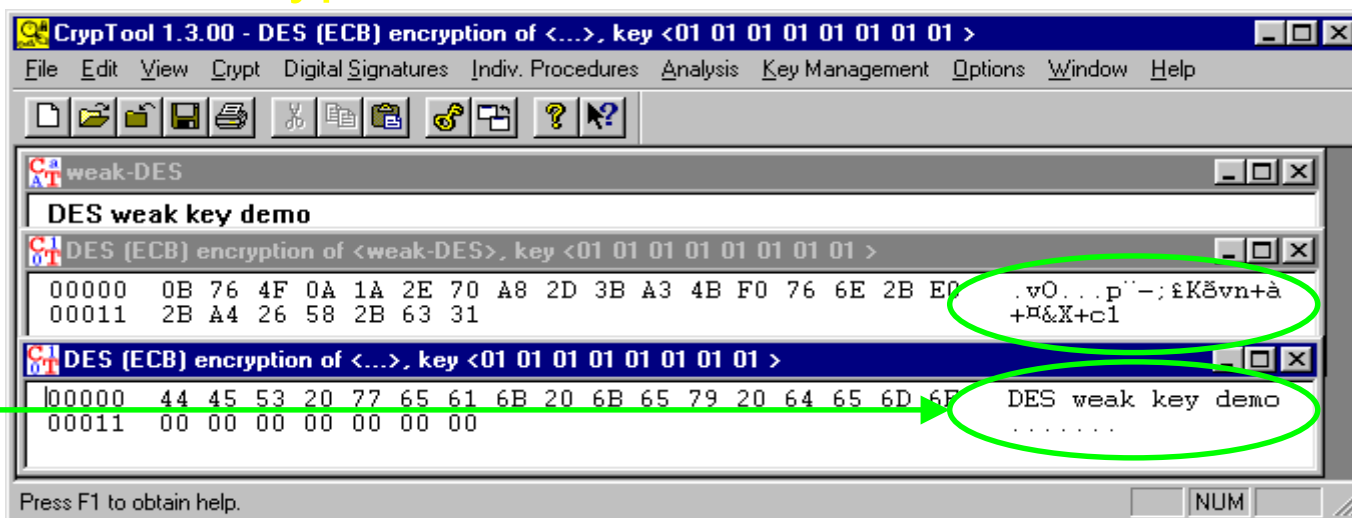
```
ADD decryption of <...>, key <...>
00000 65 72 67 65 73 65 74 7A 20 28 55 53 74 47 29 06  ergesetz (UStG).
00010 06 06 8A 72 73 74 65 72 65 41 62 B8 A8 68 6E AE  ...rstereAb,`hn@
00020 74 74 06 53 74 65 75 65 72 67 65 67 65 6E 73 74  tt.Steuerggegenst
```

Examples of use

5. Weak DES keys



encrypt 2× with



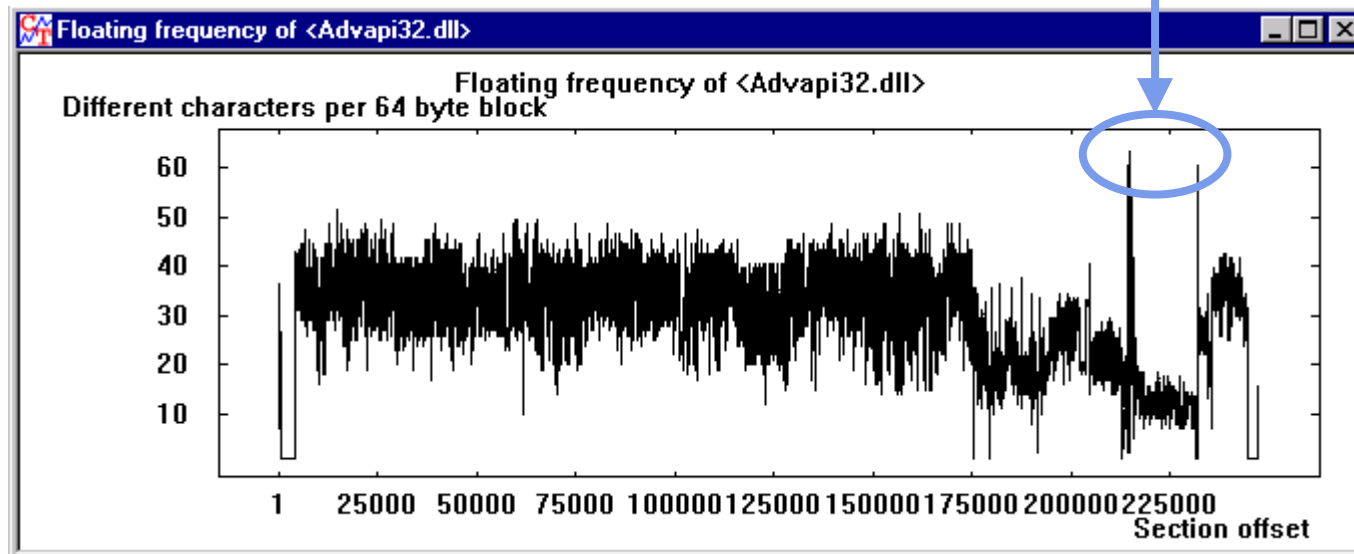
Examples of use

6. Locate key material

The function “Floating frequency” is suitable for locating key material and encrypted areas in files.

Background:

- key data is “more random” than text or program code
- can be recognised as peaks in the “floating frequency”
- example: the “NSAKEY” in advapi32.dll



Examples of use

7. Attack on digital signature: idea

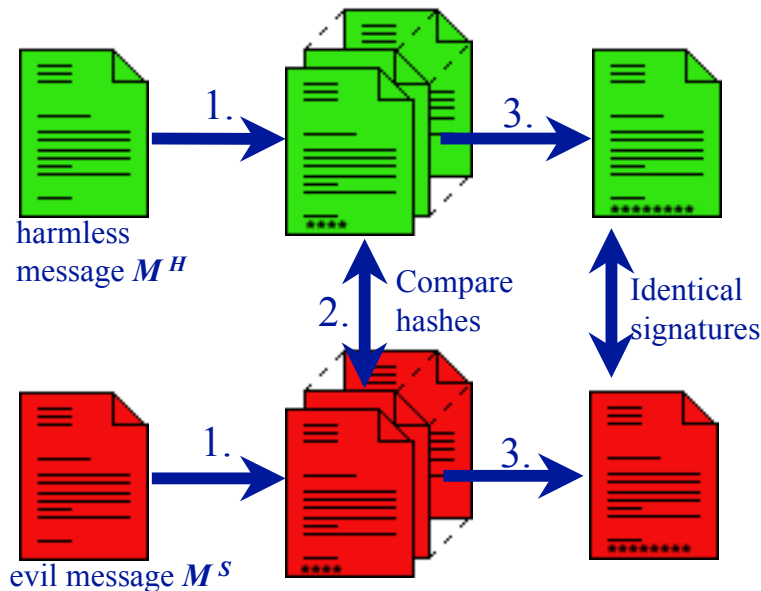
Attack on the digital signature of an ASCII text based on hash collision search

Idea:

- ASCII-Texts can be modified by changing/inserting ***non-printable*** characters, without changing the visible content
- modify two texts in parallel until a hash collision is found
- exploit the birthday paradox (birthday attack)
- generic attack applicable to all hash functions
- can be run in parallel on many machines (not implemented)
- implemented in CrypTool by Jan Blumenstein as part of his bachelor thesis "*Methods and tools for attacks on digital signatures*" (German), 2003.

Examples of use

7. Attack on digital signature: idea (2)



1. **Modification:** starting from a message M create N different messages M_1, \dots, M_N with the same "content" as M .
2. **Search:** find modified messages M_i^H and M_j^S with the same hash value.
3. **Attack:** the signatures of those two documents M_i^H and M_j^S are the same.

We know from the birthday paradox that for hash values of bit length n :

- search collision between M^H and M_1^S, \dots, M_N^S : $N \approx 2^n$
- search collision between M_1^H, \dots, M_N^H and M_1^S, \dots, M_N^S : $N \approx 2^{n/2}$

Examples of use

7. Attack on digital signature: attack

The image displays four screenshots from the Cryptool 1.3.04 application, illustrating the steps for an attack on a digital signature. A red arrow points from the 'Options...' button in the main window to the 'Options for the attack on the hash value of the digital signature' dialog.

Attack on the Hash Value of the Digital Signature

In this implemented attack at hand the attacker tries to find two different messages which translate to the same hash value.

1. Choose "harmless" file

The attacker assumes that his victim will digitally sign the "harmless" message due to its non vicious content.

C:\Programme\CrypTool-1-3-04-beta-8-en\original.txt Browse ...

2. Choose "dangerous" file

In case of a successful attack the attacker can argue that his victim has digitally signed the "dangerous" instead of the "harmless" message.

C:\Programme\CrypTool-1-3-04-beta-8-en\fake.txt Browse ...

Start search / Set options

By clicking "Start search" you initiate the attack which searches for two modifications of the messages above which translate to the same hash value.

The semantics of the messages do not vary throughout the attack as only unprintable or formatting characters are used to modify them.

In the "Options" you can set the hash function, the number of bits of the hash values that have to match and the method of modifying the messages.

4. Start search Options ... Cancel

Options for the attack on the hash value of the digital signature

Hash function

Choose one of the six hash functions and set the number of bits that have to match between two hash values so that the attack is considered successful.

☐ MD2 ☐ MD4 ☒ MD5

☐ SHA ☐ SHA-1 ☐ RIPEMD-160

Significant bit length 32 Co-domain: 1 - 128

Options for the modification of messages

Determine the way messages are modified

☐ Insert blanks ☒

☒ Attach characters ☐

Apply Reset to standard

Searching for a pair of messages ...

Run 1
Cycle search
Progress: 36% remaining time: 00:00:29

Searching for a pair of messages ...

Run 1
Collision search
Progress: 53% remaining time: 00:00:21

Cancel

Examples of use

7. Attack on digital signature: results

The diagram shows two windows representing email messages. The top window is titled 'Harmless message: MD5, <A9 76 34 AB>' and contains the text: 'Dear Mr Shopaholic, please order a typewriter. Regards Honest John ABBDBCBCDBAAAADABB'. The bottom window is titled 'Dangerous message: MD5, <A9 76 34 AB>' and contains the text: 'Dear Mr Shopaholic, please order a Porsche and a prepaid insurance scheme for Mr. Dodgy. Regards Honest John ABBBCCDDAABADCDDDC'. A blue arrow points from the signature 'ABBDBCBCDBAAAADABB' in the harmless message to the signature 'ABBBCCDDAABADCDDDC' in the dangerous message. To the right of each message, its MD5 hash is displayed in a box. For the harmless message, the hash is: MD5: A9 76 34 AB, 65 53 37 21 6F 70, 1F 6C 6C 3F 2F 6D. For the dangerous message, the hash is: MD5: A9 76 34 AB, AC 10 96 30 CC 47, 24 D5 70 D8 84 71. A blue box at the bottom states: 'The first 32 bits of the hash values are identical.'

Harmless message: MD5, <A9 76 34 AB>

Dear Mr Shopaholic,
please order a typewriter.
Regards
Honest John ABBDBCBCDBAAAADABB

Dangerous message: MD5, <A9 76 34 AB>

Dear Mr Shopaholic,
please order a Porsche and a prepaid insurance scheme for Mr. Dodgy.
Regards
Honest John ABBBCCDDAABADCDDDC

MD5: A9 76 34 AB
65 53 37 21 6F 70
1F 6C 6C 3F 2F 6D

MD5: A9 76 34 AB
AC 10 96 30 CC 47
24 D5 70 D8 84 71

The first 32 bits of the hash values are identical.

Experimental results

- 72 Bit *partial collision* (equality of the first 72 hash value bits) were found in a couple of days on a single PC.
- Signatures using hash values of up to 128 bit can be attacked today using massive parallel search!

Further development

Work in process

- visualisation of challenge-response authentication
- attack on single-sided authentication with CR and weak encryption
- mass pattern search

Planned for near future

- visualisation of SSL protocol
- visualisation of Man-in-the-Middle attack
- demonstration of a side-channel attack

Planned for remote future

- visualisation of different security protocols (e.g. Kerberos)
- visualisation of attacks on these different security protocols
- port to Linux or Java
- many more ideas can be found in the readme file, chapter 6

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