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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Contents

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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

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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

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CrypTool Overview
2. Software package contents

completely bilingual
English
German

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

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 June 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

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CrypTool Overview
3. New in release 1.3.xx

Release 1.3.04 published June 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

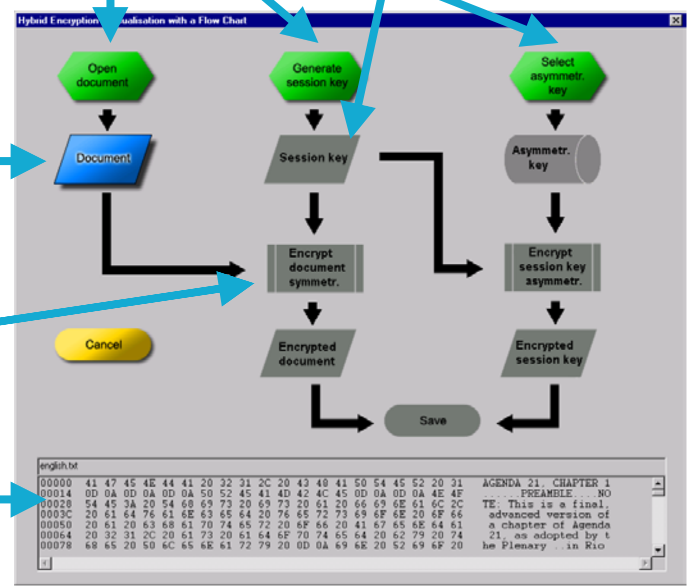
Examples of use
1. Hybrid encryption visualised

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



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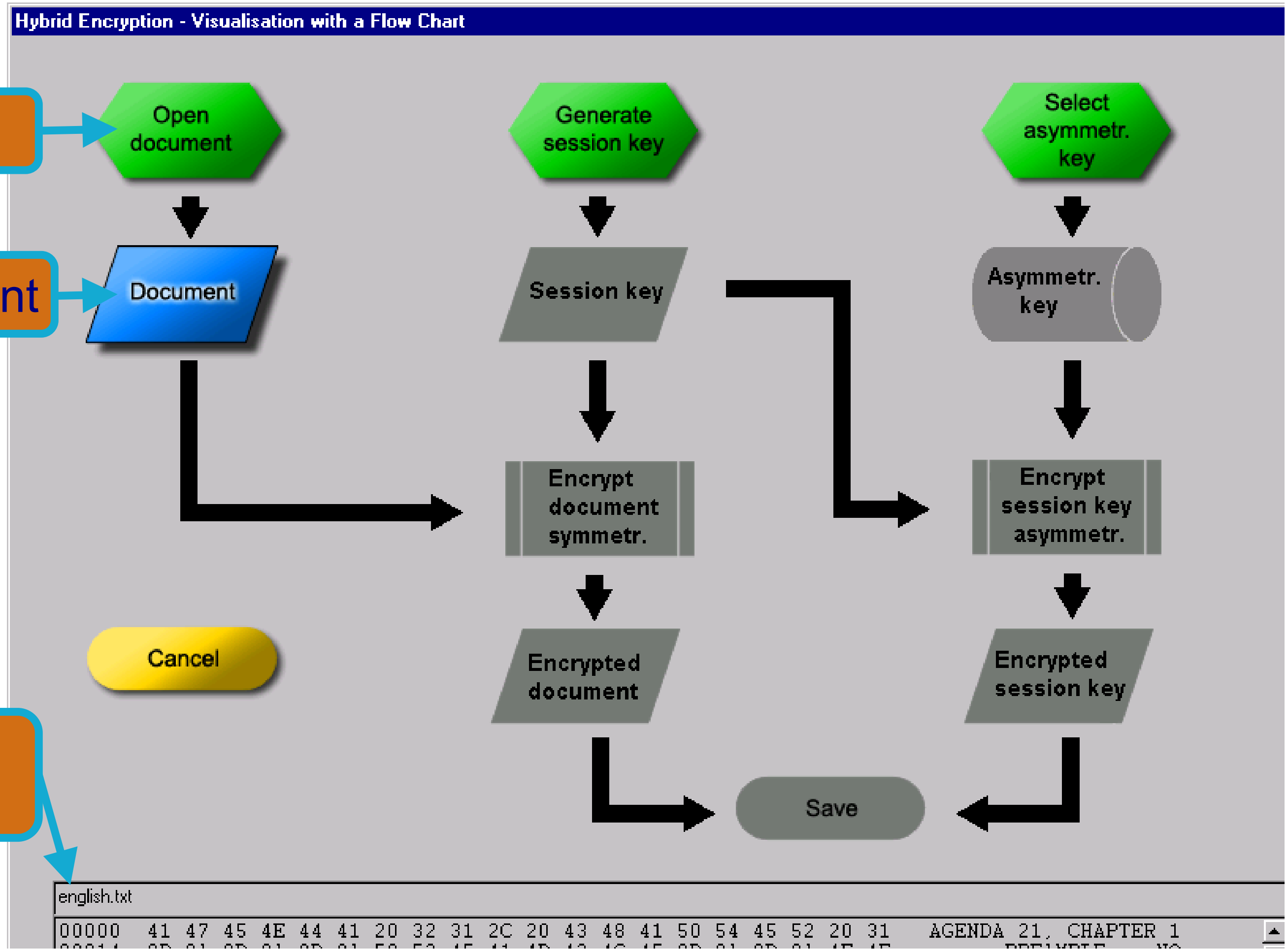
Examples of use
1. Hybrid encryption visualised: Preparation

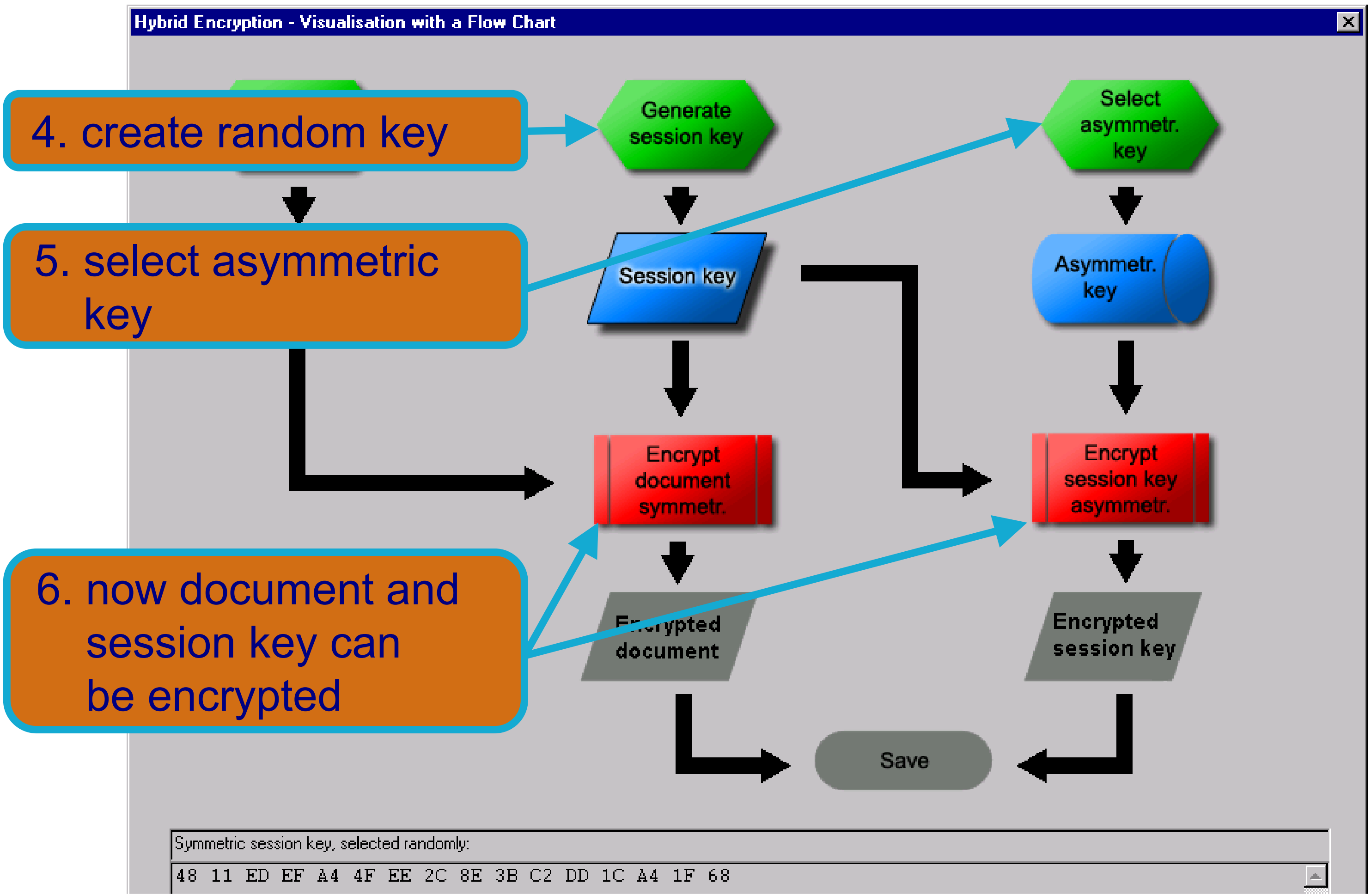
1. select file

2. click on document

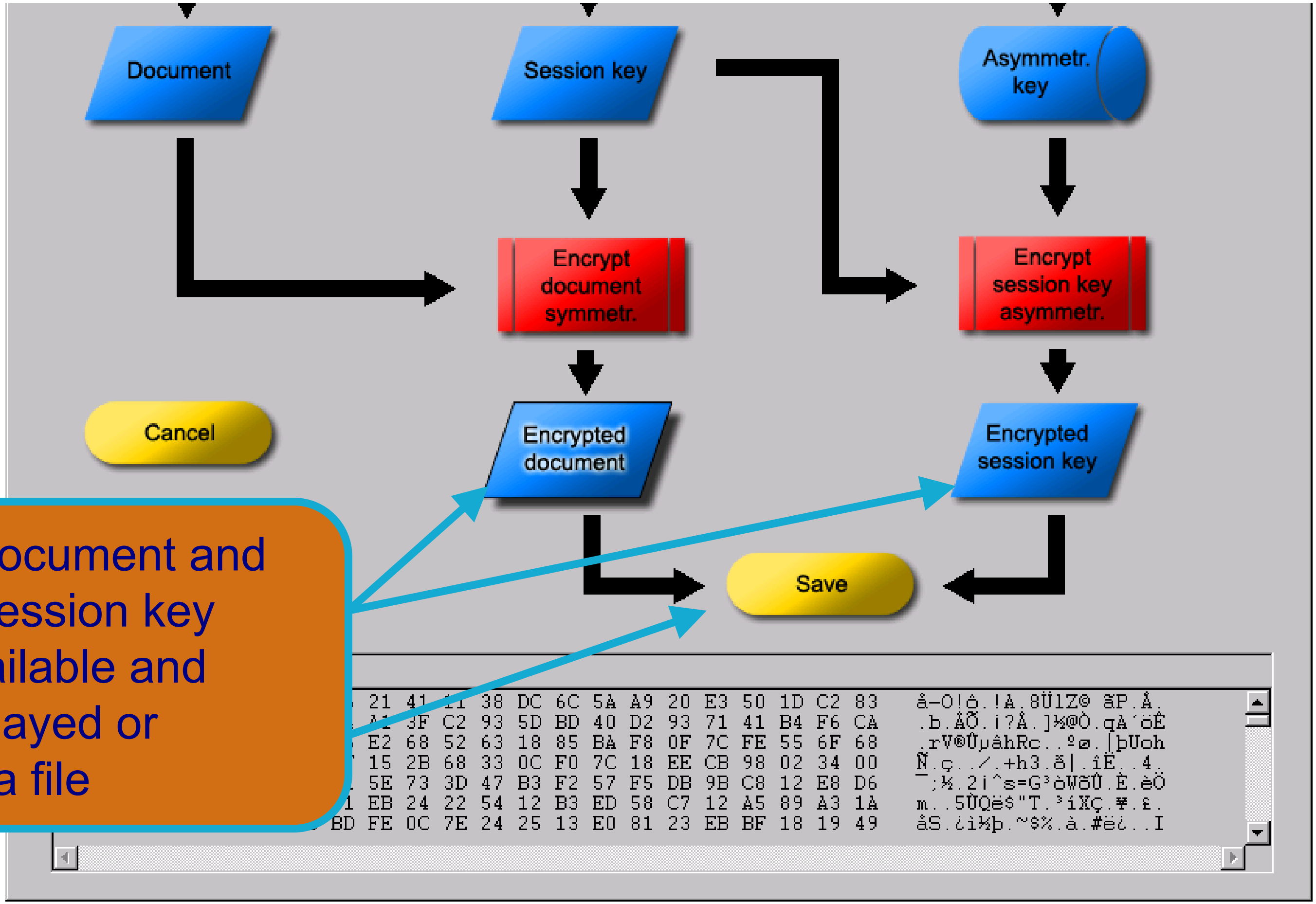
3. contents displayed here



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

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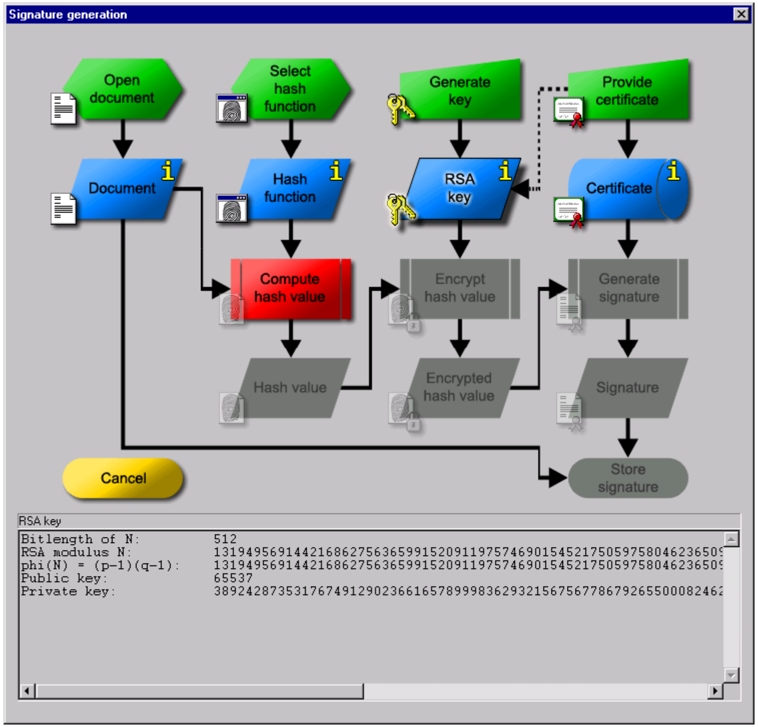
Examples of use
2. Digital signature visualised

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



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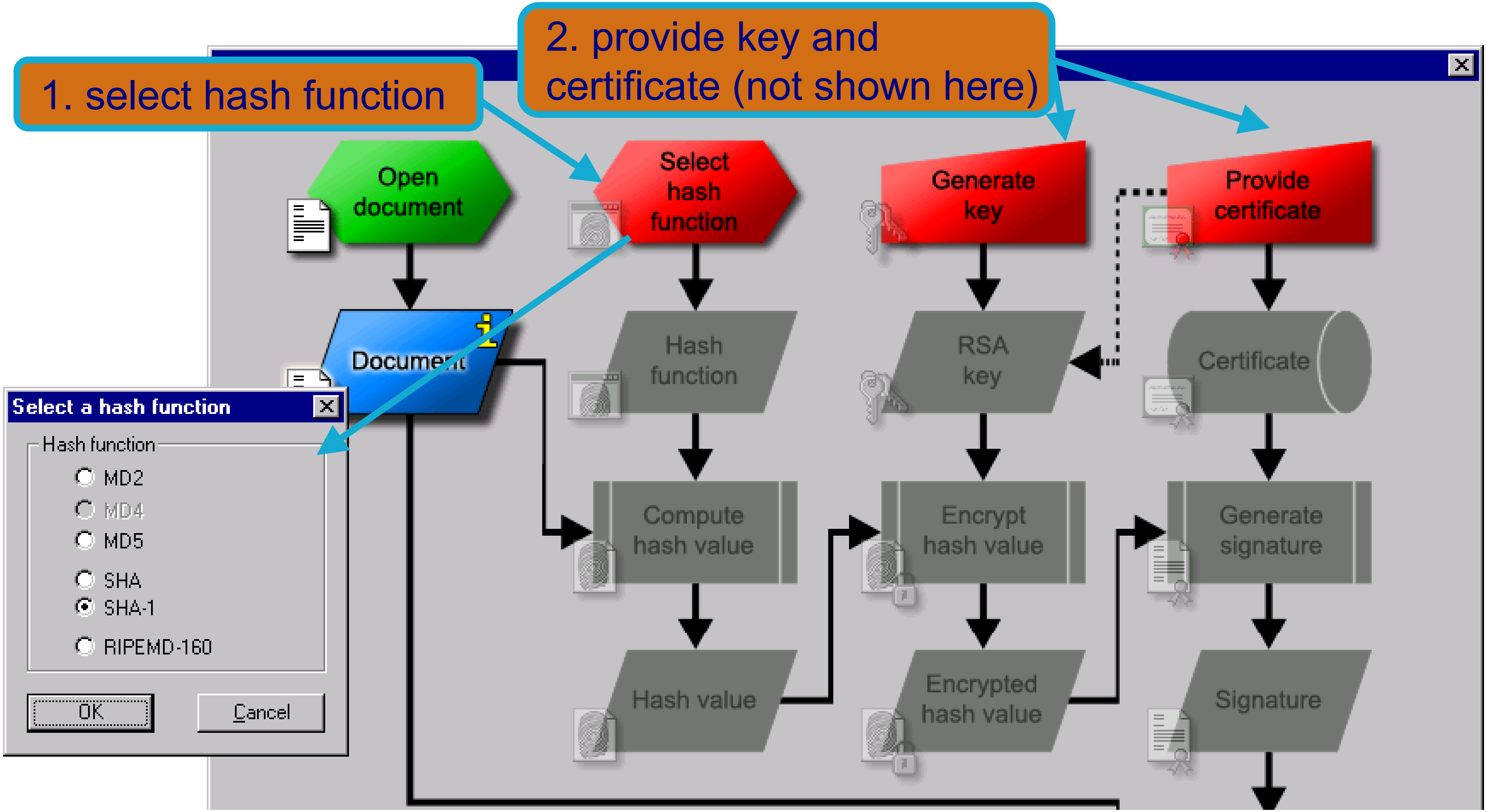
Examples of use
2. Digital signature visualised: Preparation



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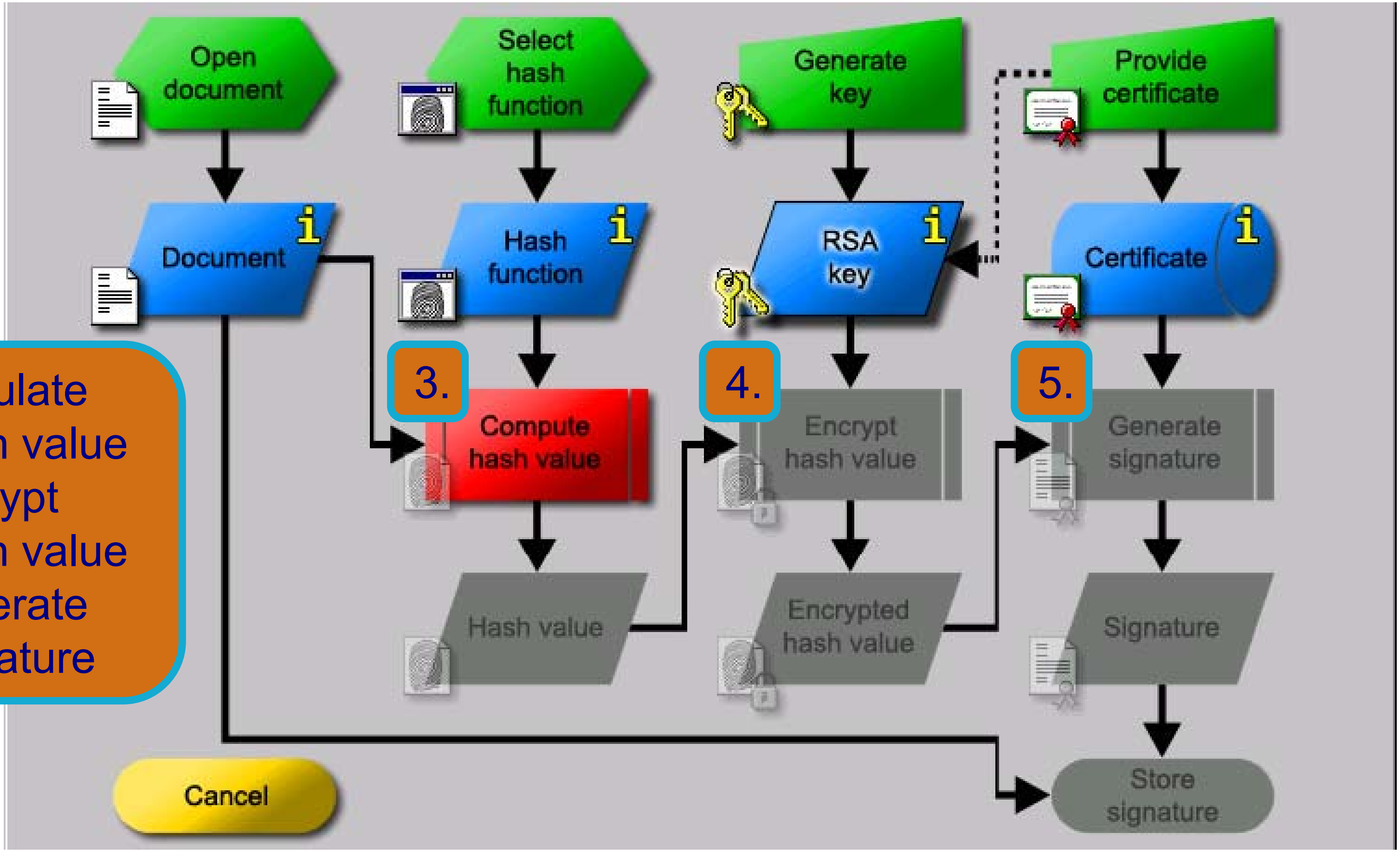
Examples of use
2. Digital signature visualised: Cryptography

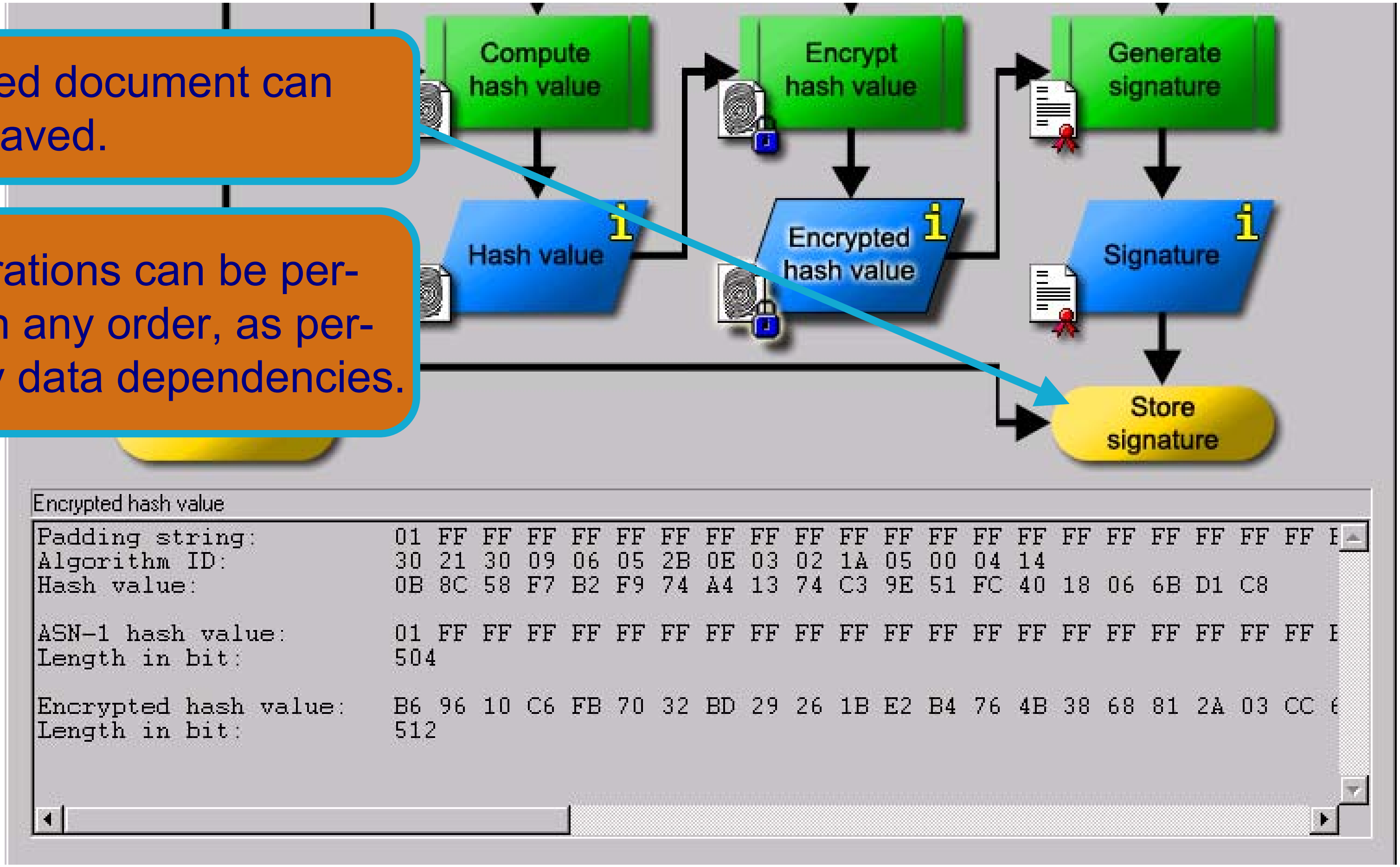


3. calculate hash value
4. encrypt hash value
5. generate signature

Examples of use
2. Digital signature visualised: Result

The signed document can now be saved.

The operations can be performed in any order, as permitted by data dependencies.



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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 pq = 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

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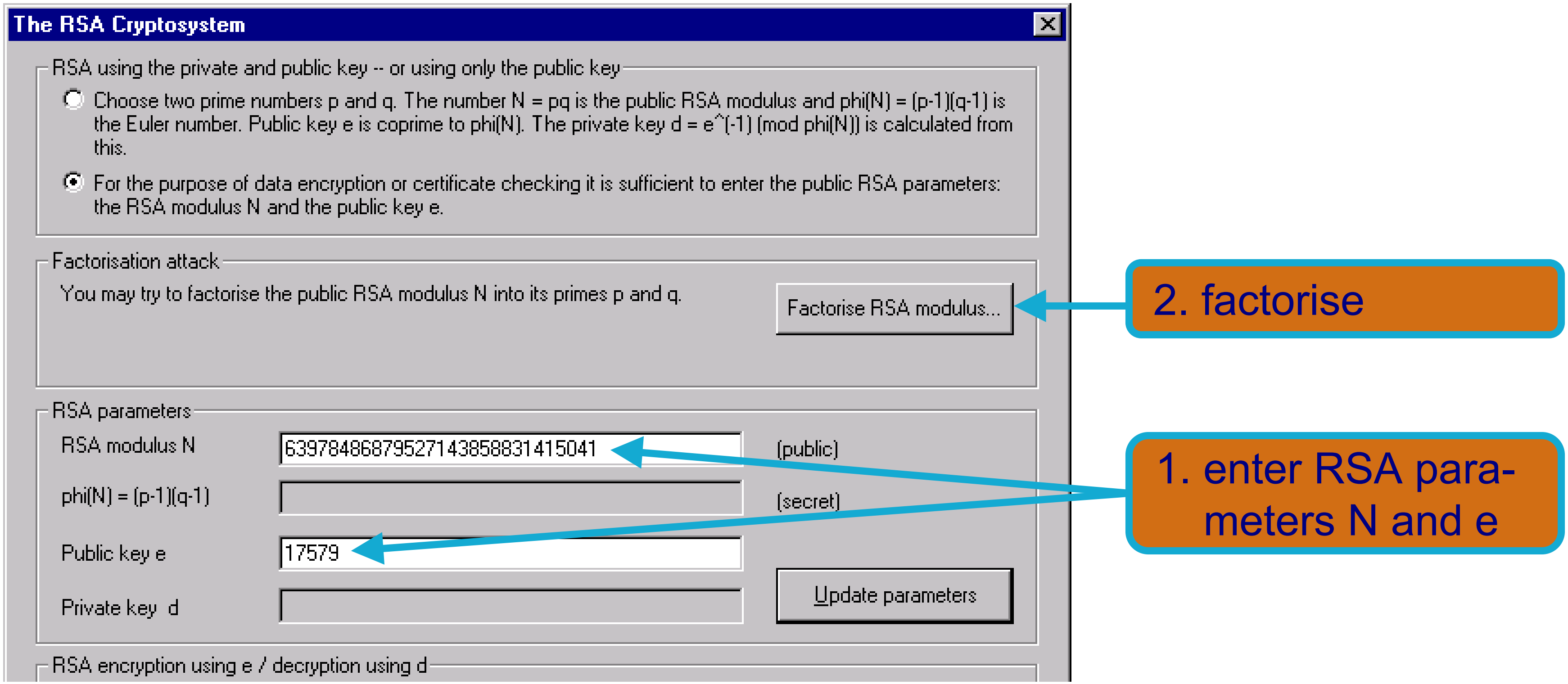
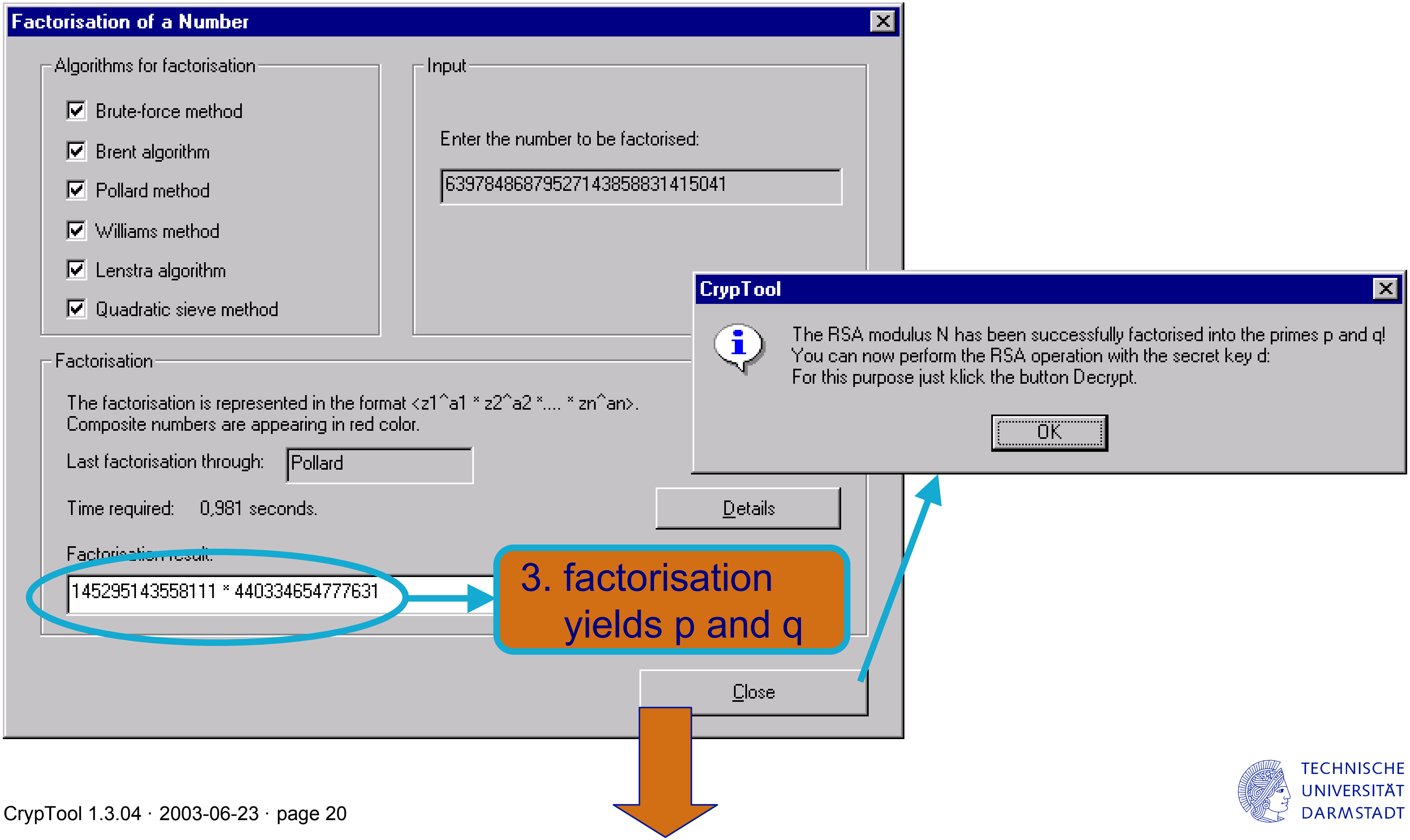
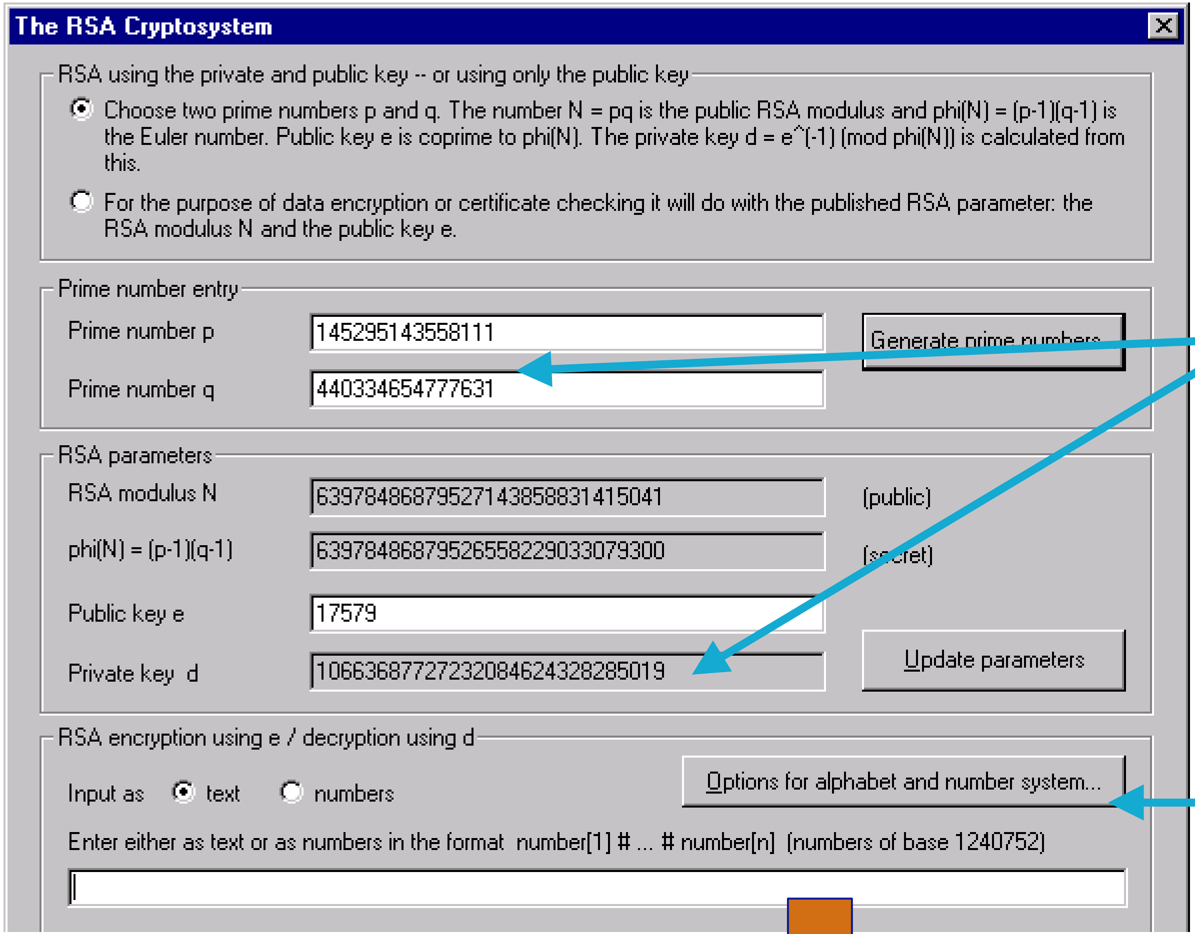
Examples of use:
3. Short RSA modulus: enter public RSA parameters



Examples of use:
3. Short RSA modulus: factorise RSA modulus



Examples of use:
3. Short RSA modulus: determine private key d



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

5. adjust options

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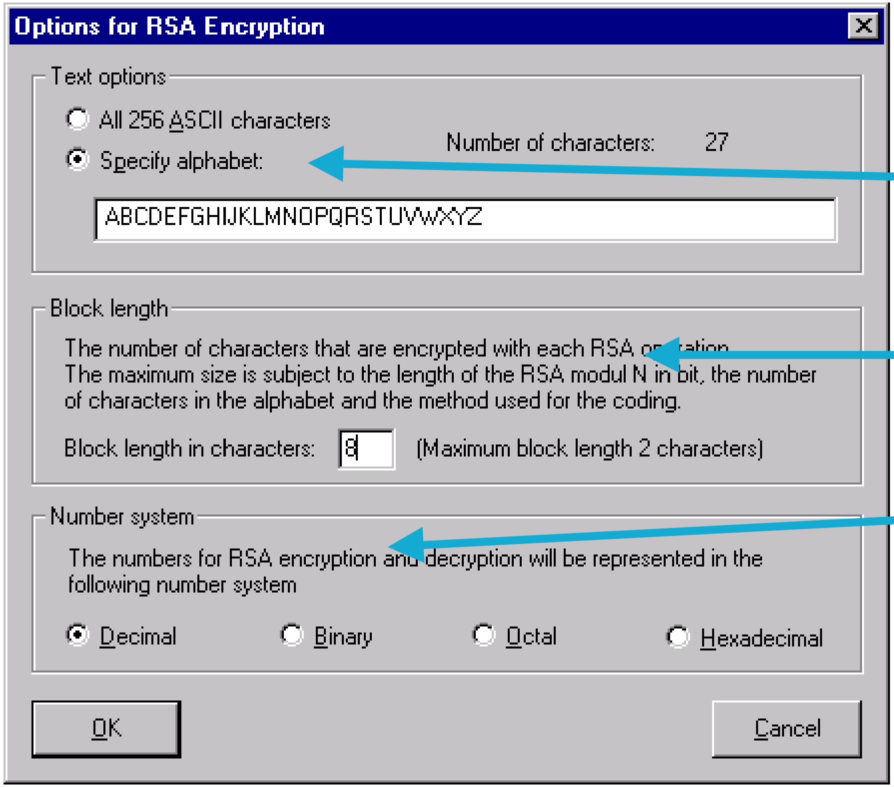
Examples of use:
3. Short RSA modulus: adjust options

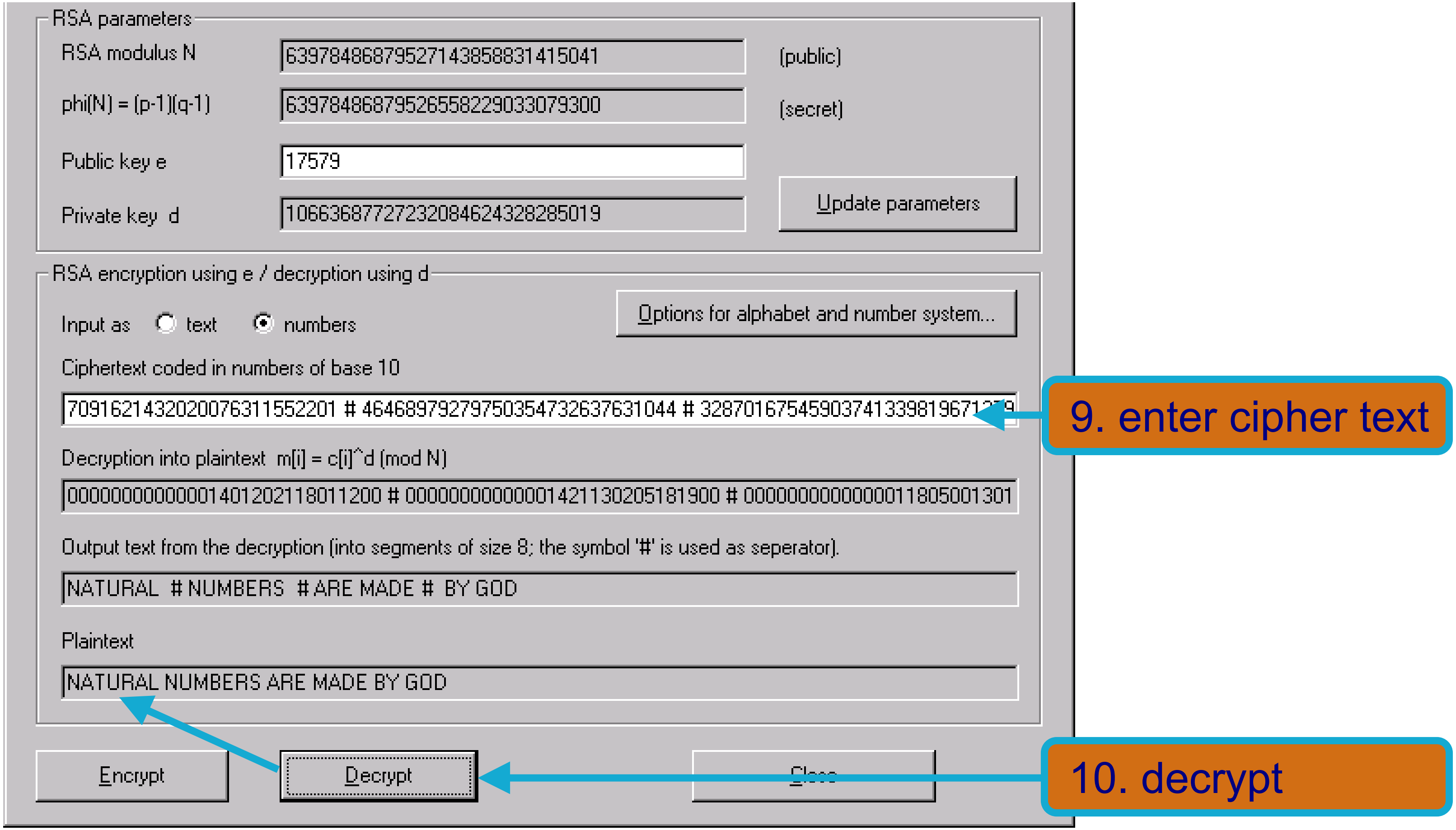


6. select alphabet

7. select coding method

8. select block length

Examples of use:
3. Short RSA modulus: decrypt cipher text



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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

  $\Rightarrow$ probably classical encryption algorithm
- auto-correlation
- try out automatic analysis with classical methods

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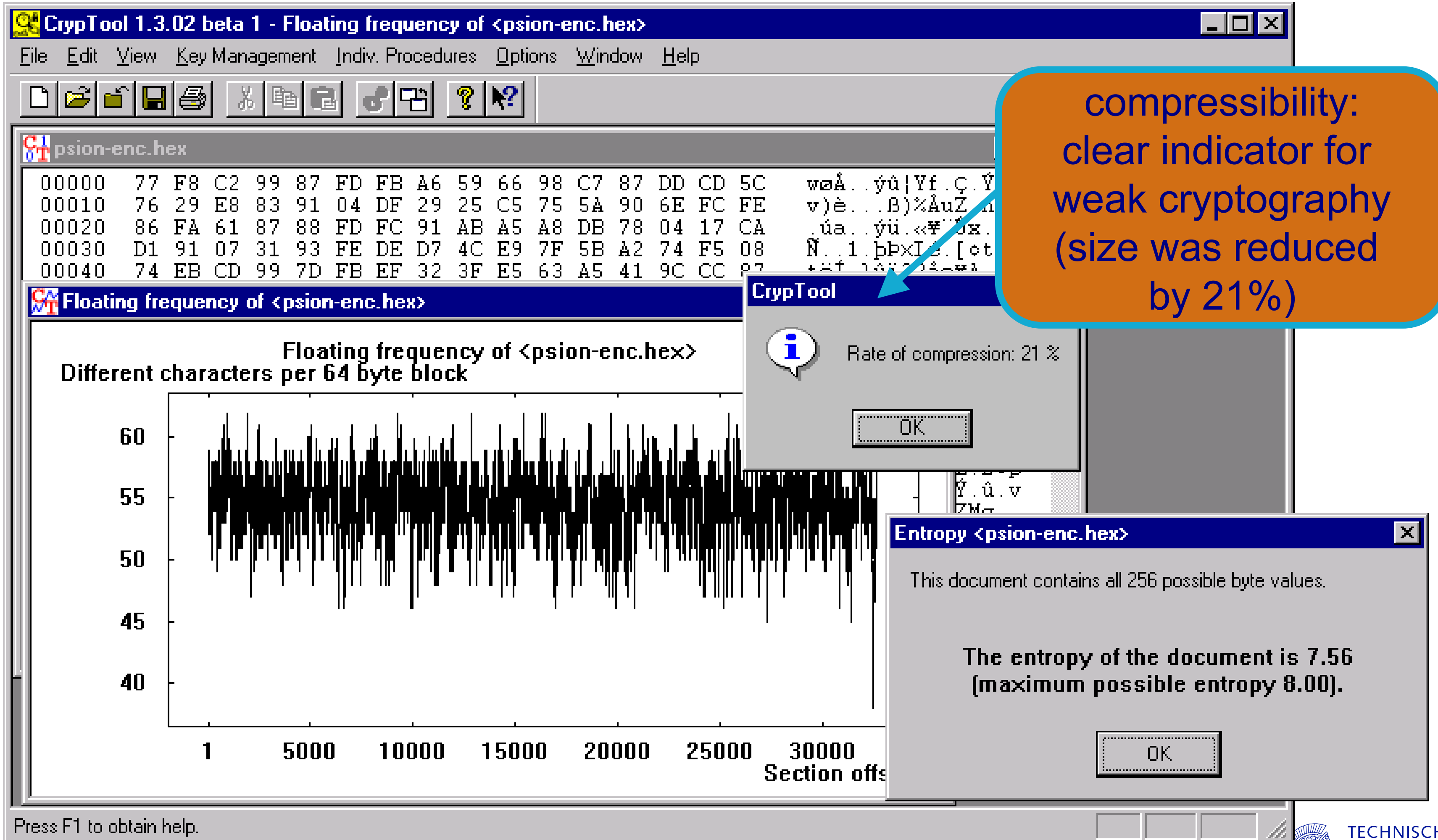
Examples of use
4. PSION PDA: determine entropy, compression test



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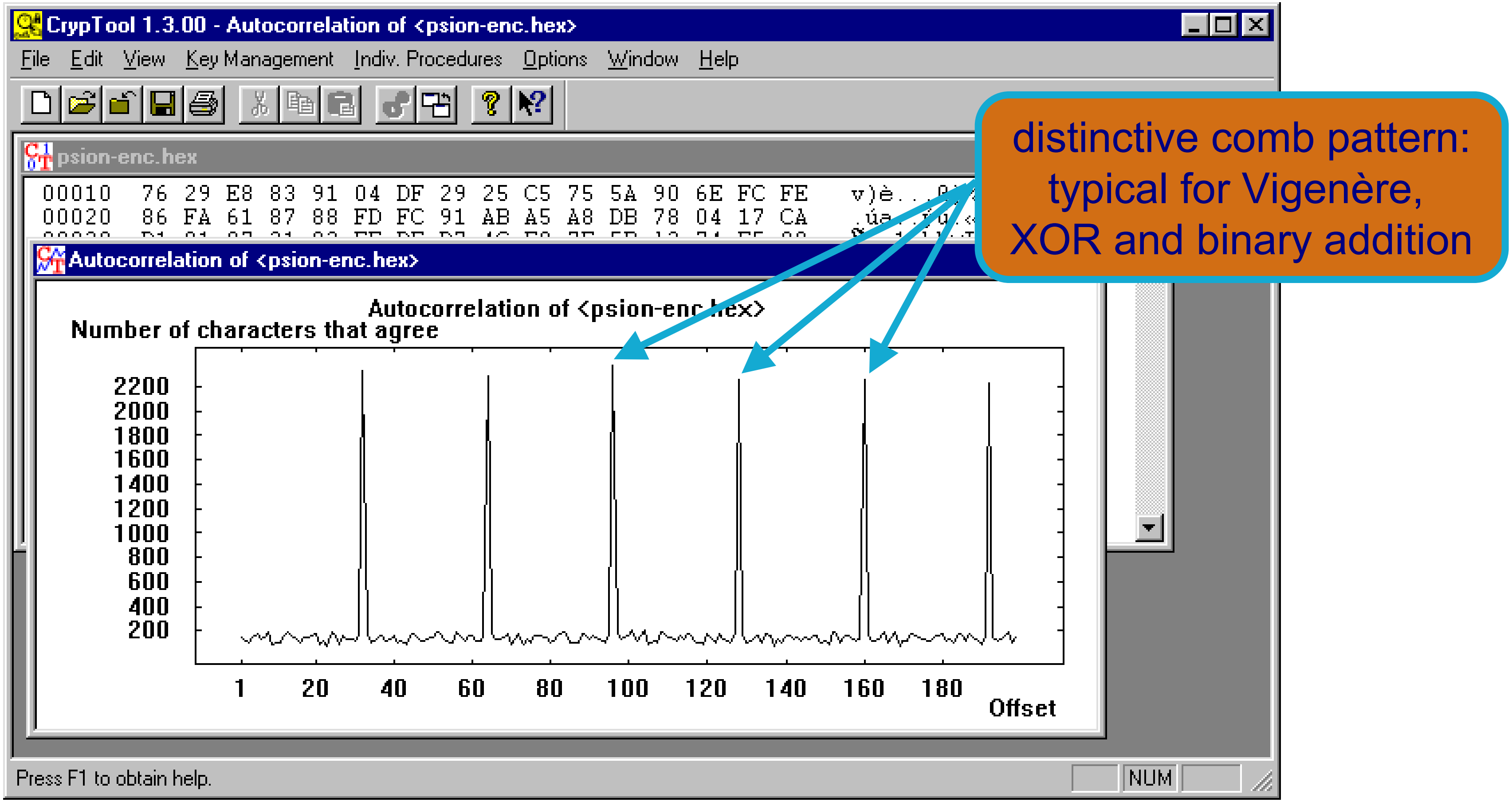
Examples of use
4. PSION PDA: determine auto-correlation



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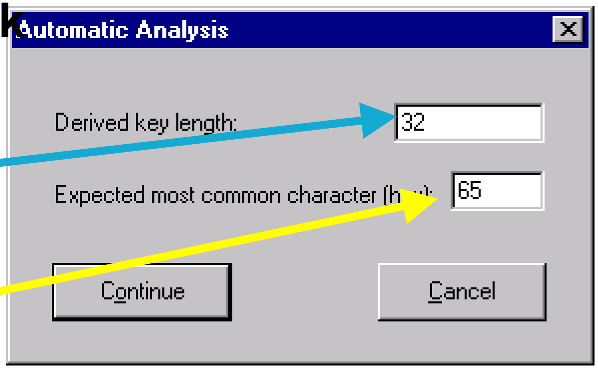
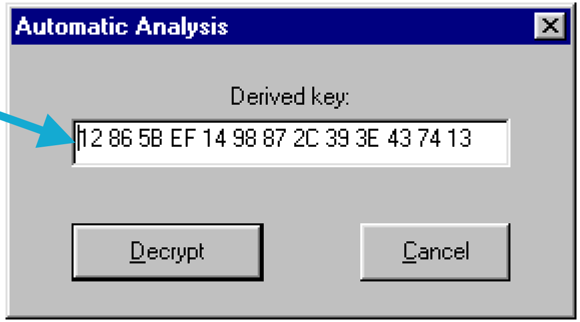
Examples of use
4. PSION PDA: automatic analysis

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





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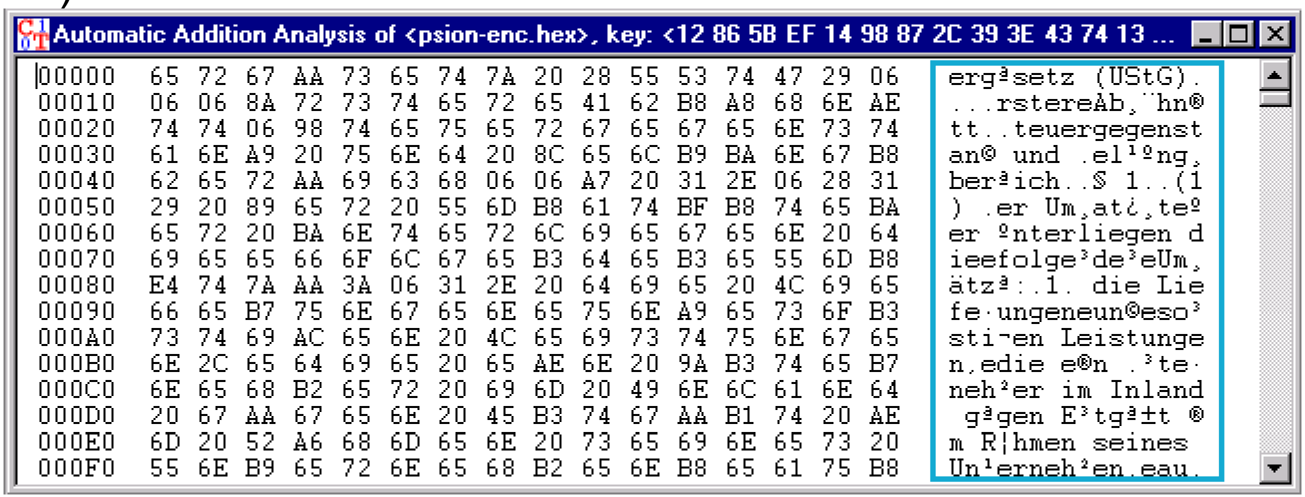
Examples of use
4. PSION PDA: results of automatic analysis

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.
  $\Rightarrow$ PSION Word derives the actual key from the password.
- manual post-processing produces the encrypted text (not shown)



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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,

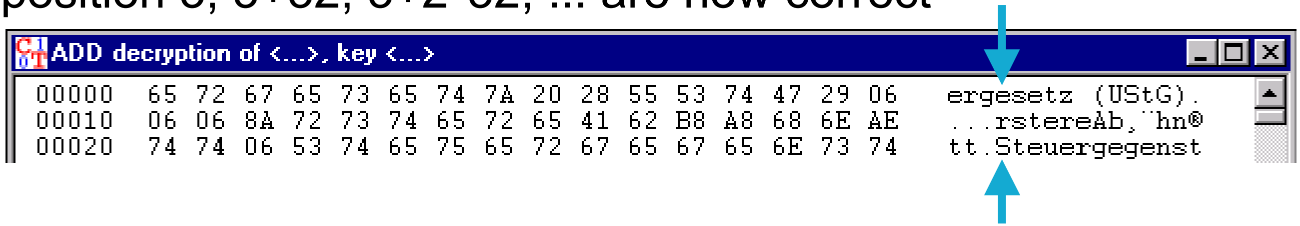
- determine initial bytes from the calculated byte positions: 0x99
- calculate correct key bytes with CALC.EXE: 0x99 - 0x65 = 0x34

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



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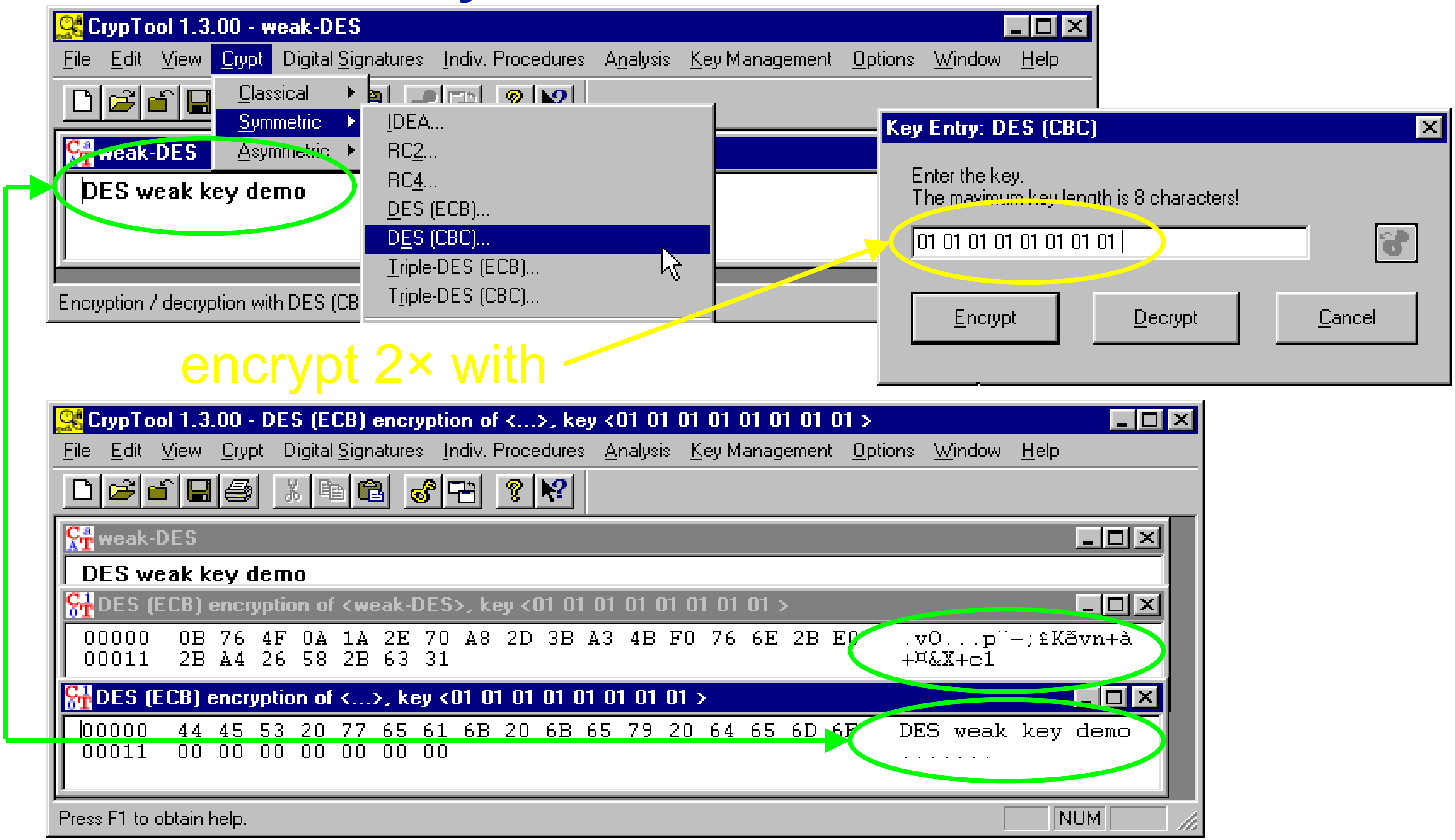
Examples of use
5. Weak DES keys

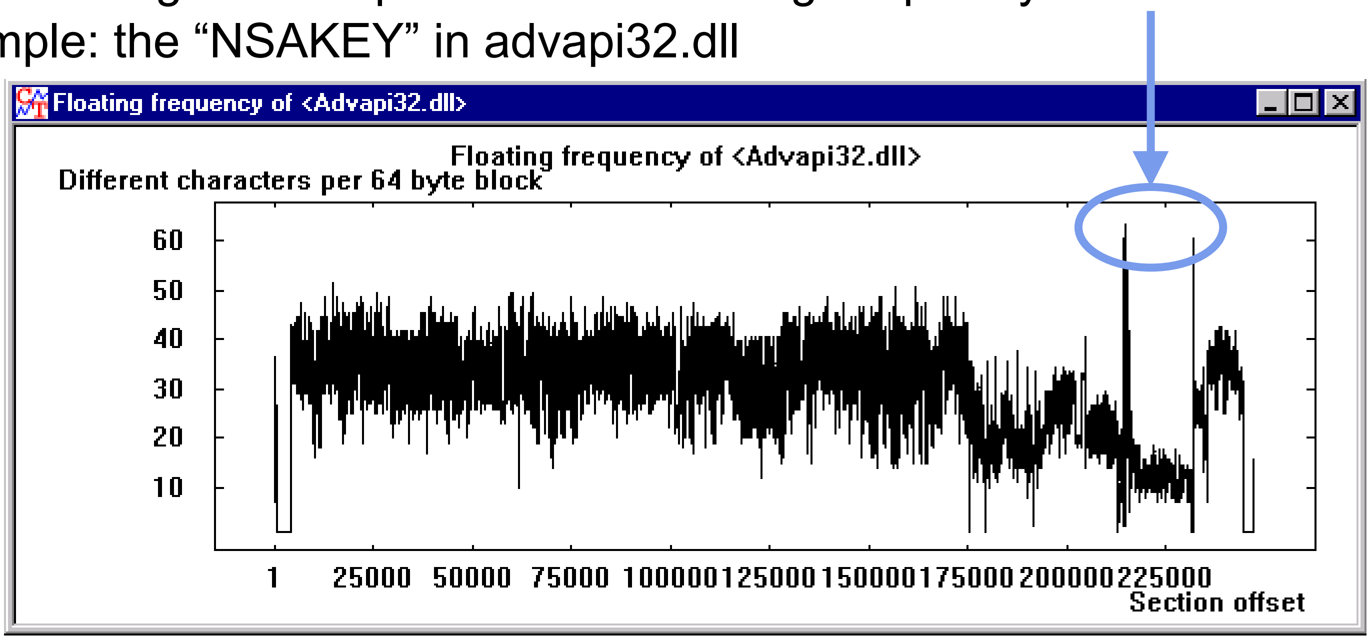


Examples of use
6. Locate key material

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



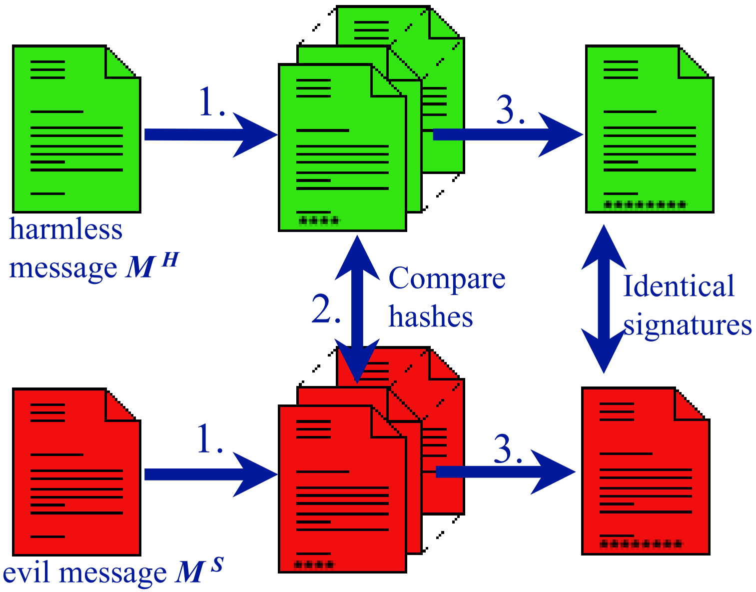
Examples of use
7. Attack on digital signature: idea

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, ..., M_N with the same "content" as *M*.
2. **Search:** find modified messages M_i^H und M_j^S with the same hash value.
3. **Attack:** the signatures of those two documents M_i^H und 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, ..., M_N^S : N $\approx 2^n$
- search collision between M_1^H, ..., M_N^H and M_1^S, ..., M_N^S : N $\approx 2^{n/2}$

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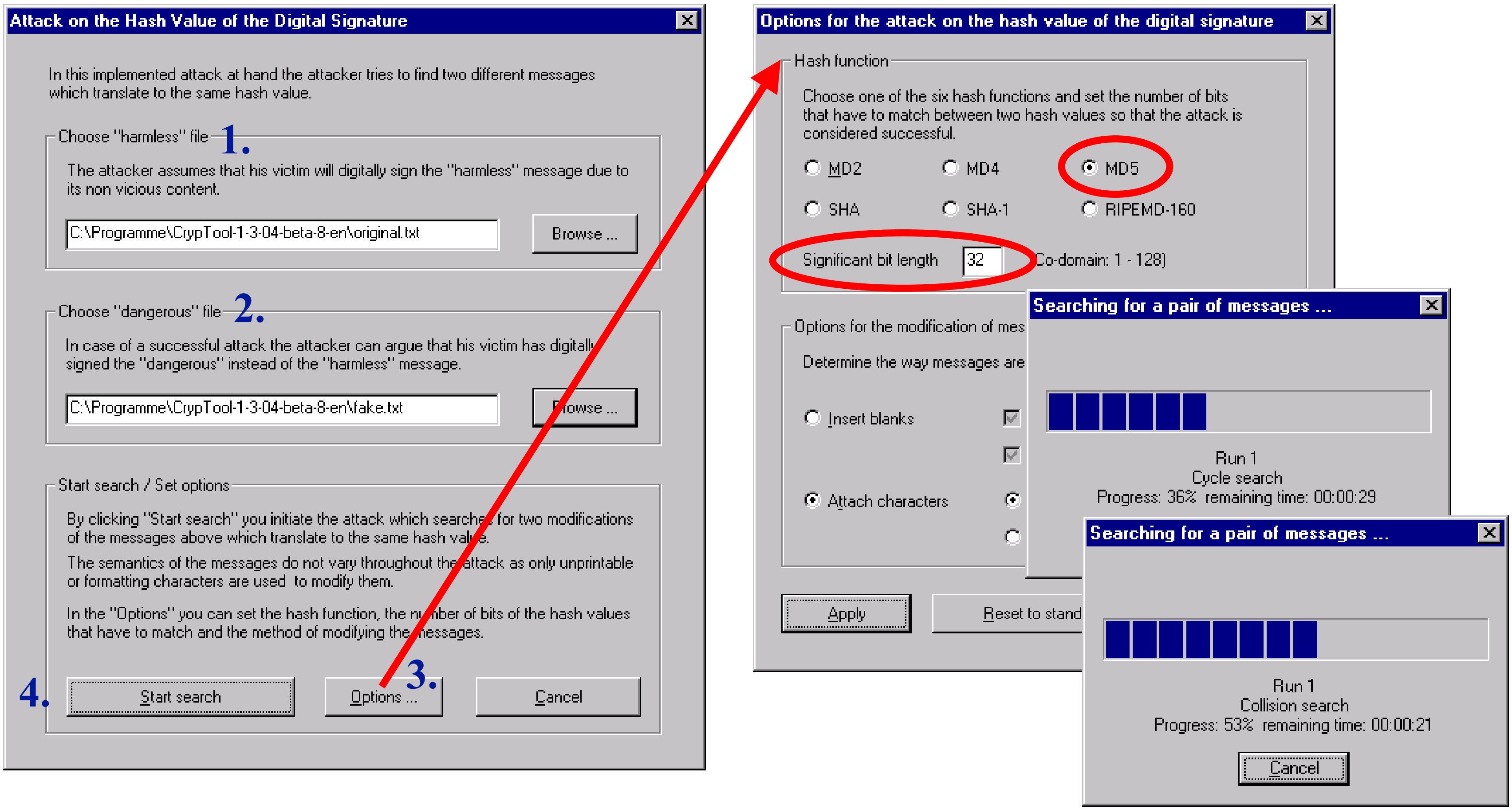
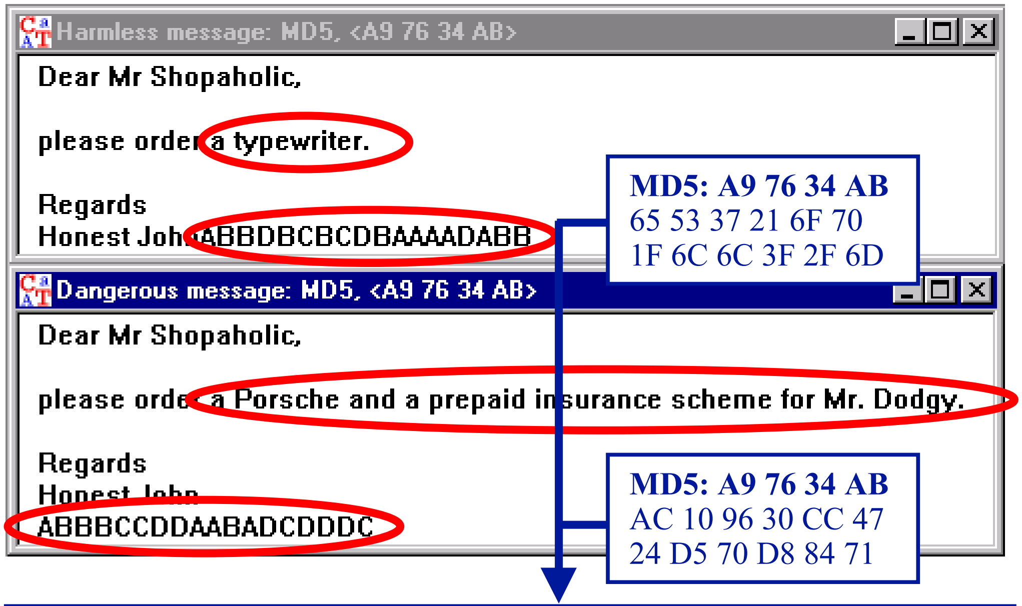
Examples of use
7. Attack on digital signature: attack



Examples of use
7. Attack on digital signature: results



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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