MANUAL OF CRYPTOGRAPHY pdf

1: A Cultural History of Early Modern English Cryptography Manuals: 1st Edition (Hardback) - Routledge

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Early history[edit] An early example of a book about cryptography was a Roman work,[which? At least one work by Trithemius was banned by the Catholic Church and put on the Index Librorum Prohibitorum as being about black magic or witchcraft. Many writers claimed to have invented unbreakable ciphers. None were, though it sometimes took a long while to establish this. In the 19th century, the general standard improved somewhat e. Colonel Parker Hitt and William Friedman in the early 20th century also wrote books on cryptography. These authors, and others, mostly abandoned any mystical or magical tone. Open literature versus classified literature[edit] With the invention of radio, much of military communications went wireless, allowing the possibility of enemy interception much more readily than tapping into a landline. This increased the need to protect communications. By the end of World War I , cryptography and its literature began to be officially limited. One exception was The American Black Chamber by Herbert Yardley , which gave some insight into American cryptologic success stories, including the Zimmermann telegram and the breaking of Japanese codes during the Washington Naval Conference. The Codebreakers[edit] From the end of World War II until the early s most aspects of modern cryptography were regarded as the special concern of governments and the military, and were protected by custom and, in some cases, by statute. In the US military, mere possession of a copy by cryptographic personnel was grounds for some considerable suspicion. Perhaps the single greatest importance of the book was the impact it had on the next generation of cryptographers. Whitfield Diffie has made comments in interviews about the effect it had on him. The Military Cipher of Commandant Bazeries. Cardanus Press, This book detailed cracking of a famous code from created by Commandant Bazeries, a brilliant French Army Cryptanalyst. Considered one of the classic books on the subject, and includes many sample ciphertext for practice. It reflects public amateur practice as of the inter-War period. The book was compiled as one of the first projects of the American Cryptogram Association. Some coverage of fundamental information theory. Requires some mathematical maturity ; is well written, and otherwise accessible. The most accessible single volume available covering modern cryptographic practice, and approachable by the non mathematically oriented. Extensive bibliography which can serve as an entry into the modern literature. It is a great book for beginners but note that it is getting a bit datedâ€”many important schemes such as AES or the eSTREAM candidates are missing entirely, others like elliptic curves are only very briefly treated. Less immediately mathematical than some others, e. Handbook of Applied Cryptography. Equivalent to Applied Cryptography in many ways, but somewhat more mathematical. For the technically inclined. Covers few meta-cryptographic topics, such as crypto system design. This is currently regarded[who? This technical overview of basic cryptographic components including extensive diagrams and graphics explains the evolution of cryptography from the simplest concepts to some modern concepts. Ferguson, Niels , and Schneier, Bruce A cryptosystem design consideration primer. Covers both algorithms and protocols. This is an in-depth consideration of one cryptographic problem, including paths not taken and some reasons why. At the time of its publication, most of the material was not otherwise available in a single source. Some was not otherwise available at all. According to the authors, it is in some sense a follow-up to Applied Cryptography. An up-to-date book on cryptography. Touches on provable security, and written with students and practitioners in mind. Similar in intent to Applied Cryptography but less comprehensive. Covers more modern material and is aimed at undergraduates covering topics such as number theory and group theory not generally covered in cryptography books. Covers topics in a textbook style but with more mathematical detail than is usual. Katz, Jonathan and Yehuda Lindell Presents modern cryptography at a level appropriate for undergraduates, graduate students, or practitioners. Assumes mathematical maturity but presents all the necessary mathematical and computer science background. Paar, Christof and Jan Pelzl Very accessible introduction to applied cryptography which covers most schemes of practical relevance. The focus is on being a textbook, i. The main target audience are readers without a background in pure mathematics. The Joy of Cryptography Presents modern cryptography at a level appropriate for undergraduates. Practical Cryptography also includes some contextual material in the discussion of crypto system design.

2: Formats and Editions of Manual of cryptography [www.enganchecubano.com]

The manual was written in anticipation of the outbreak of World War I. The manual, for its day, was an excellent treatise of a general nature on cryptography and cryptanalytic methods. It is in the Friedman Collection as a souvenir of his military service in World War I.

Sometimes people want to restrict it. Confidential messages require for their efficacy that they be known to and understood by only the single person or the few persons to whom they areâ€¦ General considerations Because much of the terminology of cryptology dates to a time when written messages were the only things being secured, the source information, even if it is an apparently incomprehensible binary stream of 1s and 0s, as in computer output, is referred to as the plaintext. As noted above, the secret information known only to the legitimate users is the key , and the transformation of the plaintext under the control of the key into a cipher also called ciphertext is referred to as encryption. The inverse operation, by which a legitimate receiver recovers the concealed information from the cipher using the key, is known as decryption. The fundamentals of codes , ciphers , and authentication The most frequently confused, and misused, terms in the lexicon of cryptology are code and cipher. Even experts occasionally employ these terms as though they were synonymous. A code is simply an unvarying rule for replacing a piece of information e. Employed in all personal computers and terminals, it represents characters and operations such as backspace and carriage return in the form of seven-bit binary numbersâ€"i. Occasionally such a code word achieves an independent existence and meaning while the original equivalent phrase is forgotten or at least no longer has the precise meaning attributed to the code wordâ€"e. Ciphers, as in the case of codes, also replace a piece of information an element of the plaintext that may consist of a letter, word, or string of symbols with another object. The difference is that the replacement is made according to a rule defined by a secret key known only to the transmitter and legitimate receiver in the expectation that an outsider, ignorant of the key, will not be able to invert the replacement to decrypt the cipher. In the past, the blurring of the distinction between codes and ciphers was relatively unimportant. In contemporary communications, however, information is frequently both encoded and encrypted so that it is important to understand the difference. A satellite communications link, for example, may encode information in ASCII characters if it is textual, or pulse-code modulate and digitize it in binary-coded decimal BCD form if it is an analog signal such as speech. Finally, the resulting cipher stream itself is encoded again, using error-correcting codes for transmission from the ground station to the orbiting satellite and thence back to another ground station. These operations are then undone, in reverse order, by the intended receiver to recover the original information. In the simplest possible example of a true cipher, A wishes to send one of two equally likely messages to B, say, to buy or sell a particular stock. The communication must take place over a wireless telephone on which eavesdroppers may listen in. In order to foil any eavesdroppers, A and B agree in advance as to whether A will actually say what he wishes B to do, or the opposite. Because this decision on their part must be unpredictable, they decide by flipping a coin. If tails comes up, however, he will say Buy when he wants B to sell, and so forth. The messages communicate only one bit of information and could therefore be 1 and 0, but the example is clearer using Buy and Sell. Encryption is the act by A of either saying what he wants done or not as determined by the key, while decryption is the interpretation by B of what A actually meant, not necessarily of what he said. This example can be extended to illustrate the second basic function of cryptography, providing a means for B to assure himself that an instruction has actually come from A and that it is unalteredâ€"i. Similarly, he could simply impersonate A and tell B to buy or sell without waiting for A to send a message, although he would not know in advance which action B would take as a result. In either event, the eavesdropper would be certain of deceiving B into doing something that A had not requested. They secretly flip a coin twice to choose one of four equally likely keys, labeled HH, HT, TH, and TT, with both of them knowing which key has been chosen. The outcome of the first coin flip determines the encryption rule just as in the previous example. The two coin flips together determine an authentication bit, 0 or 1, to be appended to the ciphers to form four possible messages: Buy-1, Buy-0, Sell-1, and Sell B will only accept a message as authentic if it occurs in the row corresponding to the secret key. The pair of messages not in that row will be rejected by B as non-authentic. If C waits and intercepts a message from A, no matter which message it is, he will be faced with a choice between two equally likely keys that A and B could be using. As in the previous example, the two messages he must choose between convey different instructions to B, but now one of the ciphers has a 1 and the other a 0 appended as the authentication bit, and only one of these will be accepted by B. Clearly, in either example, secrecy or secrecy with authentication, the same key cannot be reused. If, however, A and B chose as many random keys as they had messages to exchange, the security of the information would remain the same for all exchanges. When used in this manner, these examples illustrate the vital concept of a onetime key, which is the basis for the only cryptosystems that can be mathematically proved to be cryptosecure. Cryptology in private and commercial life At the very end of the 20th century, a revolution occurred in the way private citizens and businesses made use of and were dependent on pure information, i. This was sparked by two technical developments: To appreciate how this involved cryptology, contrast what is involved when a customer makes a noncash purchase in person with what is involved in a similar transaction in e-commerce. Neither party is ordinarily concerned with secrecy; both are vitally concerned with other aspects of information integrity. Next, consider an analogous transaction over the Internet. However, there is a whole gamut of new concerns. The customer must be assured that information he communicates to the merchant is confidential and protected from interception by others. All of these concerns, and more, have to be met before the simplest e-commerce transactions can be made securely. As a result, cryptology has been extended far beyond its original function of providing secrecy. The conduct of commerce, affairs of state, military actions, and personal affairs all depend on the existence of generally accepted means of authenticating identity, authority, ownership, license, signature, notarization, date of action, receipt, and so on. In the past these have depended almost entirely on documents, and on protocols for the creation of those documents, for authentication. Society has evolved and adopted a complex set of legal and forensic procedures, depending almost entirely on the physical evidence intrinsic to the documents themselves, to resolve disputes over authenticity. In the information age, however, possession, control, transfer, or access to real assets is frequently based on electronic information, and a license to use, modify, or disseminate valuable information itself is similarly determined. Thus, it is essential that internal evidence be present in the information itselfâ€”since that is the only thing available. Modern cryptology, therefore, must provide every function presently served by documentsâ€”public and private. In fact, it frequently must do more. When someone mails a document by certified mail with a request for a delivery receipt, the receipt only proves that an envelope was delivered; it says nothing about the contents. Digital certificates of origination and digital receipts, though, are inextricably linked to each electronic document. Many other functions, such as signatures, are also much more demanding in a digital setting. In June the U. Congress gave digital signatures the same legal status as written signaturesâ€”the first such legislation in the world. In classical cryptology the participants trust each other but not outsiders; typical examples include diplomatic communications and military commands. In business and personal transactions, though, the situation is almost the opposite, as the participants may have various motives for cheating. For example, the cheater may wish to impersonate some other participant, to eavesdrop on communications between other participants, or to intercept and modify information being communicated between other users. The cheater may be an insider who wishes to disavow communications he actually originated or to claim to have received messages from other participants who did not send them. He may wish to enlarge his license to gain access to information to which he is not supposed to have access or to alter the license of others. He may wish simply to subvert the system to deny services to others or to cause other users to reject as fraudulent information that is in fact legitimate. Therefore, modern cryptology must also prevent every form of cheating or, failing that, detect cheating in information-based systems where the means for cheating depends only on tampering with electronic information. At the beginning of the s, most people would likely have been hard-pressed to say where cryptology had an impact on their day-to-day lives. Today, people who have purchased merchandise over the Internet are familiar with warnings that they are about to exchange information over a secure link. Only a few consumers are aware, however, that behind this exchange of authentications is a bit cryptography key that has been in common use around the world for transactions over the Internet since it was approved for export by the U. Cryptology, indeed, has long been a part of modern daily life. In particular, electronic banking and various financial, medical, and legal databases depend on cryptology for security. One example is the personal identity number PIN , a coded identification that must be entered into an automated teller machine ATM along with a bankcard to corroborate that the card is being used by an authorized bearer. The transformation used in this type of cryptography is called one-way; i. The user must corroborate his identity to the card each time a transaction is made, in much the same way that a PIN is used with an ATM. Once this has been established, the transaction itself is carried out in encrypted form to prevent anyone, including the cardholder or the merchant whose card reader is involved, from eavesdropping on the exchange and then later impersonating either party to defraud the system. This elaborate protocol is carried out in a way that is invisible to the user, except for the necessity of entering a PIN to initiate the transaction. Page 1 of 3.

3: Books on cryptography - Wikipedia

Manual of U.S. Patent Classification as of June 30, Class CRYPTOGRAPHY Class definitions may be accessed by clicking on the class title, above.

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4: History of cryptography - Wikipedia

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Classical cipher A Scytale, an early device for encryption. The earliest known use of cryptography is found in non-standard hieroglyphs carved into the wall of a tomb from the Old Kingdom of Egypt circa BCE. This was also likely a simple substitution cipher. The scytale transposition cipher was used by the Spartan military, [5] but it is not definitively known whether the scytale was for encryption, authentication, or avoiding bad omens in speech. Another Greek method was developed by Polybius now called the " Polybius Square ". Voynich Manuscript David Kahn notes in The Codebreakers that modern cryptology originated among the Arabs , the first people to systematically document cryptanalytic methods. The ciphers tend to be fairly straightforward, but sometimes they deviate from an ordinary pattern, adding to their complexity and, possibly, to their sophistication as well. This information was attributed to Ibn al-Durayhim who lived from AD to , but whose writings on cryptography have been lost. The list of ciphers in this work included both substitution and transposition , and for the first time, a cipher with multiple substitutions for each plaintext letter. Also traced to Ibn al-Durayhim is an exposition on and worked example of cryptanalysis, including the use of tables of letter frequencies and sets of letters which cannot occur together in one word. The earliest example of the homophonic substitution cipher is the one used by Duke of Mantua in the early s. The cipher is ahead of the time because it combines monoalphabetic and polyalphabetic features. Essentially all ciphers remained vulnerable to the cryptanalytic technique of frequency analysis until the development of the polyalphabetic cipher, and many remained so thereafter. The polyalphabetic cipher was most clearly explained by Leon Battista Alberti around the year AD , for which he was called the "father of Western cryptology". Trithemius also wrote the Steganographia. They were regularly broken. In the absence of knowledge, guesses and hopes, predictably, are common. Robert Hooke suggested in the chapter Of Dr. Outside of Europe, after the Mongols brought about the end of the Muslim Golden Age, cryptography remained comparatively undeveloped. Cryptography in Japan seems not to have been used until about , and advanced techniques were not known until after the opening of the country to the West beginning in the s. Edgar Allan Poe used systematic methods to solve ciphers in the s. His success created a public stir for some months. Cryptographers were also involved in exposing the machinations which had led to the Dreyfus affair; Mata Hari, in contrast, was shot. However its most important contribution was probably in decrypting the Zimmermann Telegram , a cable from the German Foreign Office sent via Washington to its ambassador Heinrich von Eckardt in Mexico which played a major part in bringing the United States into the war. In , Gilbert Vernam proposed a teleprinter cipher in which a previously prepared key, kept on paper tape, is combined character by character with the plaintext message to produce the cyphertext. This led to the development of electromechanical devices as cipher machines, and to the only unbreakable cipher, the one time pad. During the s, Polish naval-officers assisted the Japanese military with code and cipher development. World War II cryptography[edit] See also: By World War II, mechanical and electromechanical cipher machines were in wide use, althoughâ€”where such machines were impracticalâ€”manual systems continued in use. Great advances were made in both cipher design and cryptanalysis , all in secrecy. Information about this period has begun to be declassified as the official British year secrecy period has come to an end, as US archives have slowly opened, and as assorted memoirs and articles have appeared. The Germans made heavy use, in several variants, of an electromechanical rotor machine known as Enigma. This was the greatest breakthrough in cryptanalysis in a thousand years and more, according to historian David Kahn. Soon after the Invasion of Poland by Germany on 1 September , key Cipher Bureau personnel were evacuated southeastward; on 17 September, as the Soviet Union attacked Poland from the East, they crossed into Romania. This enabled them to track and sink Atlantic convoys. It was only Ultra intelligence that finally persuaded the admiralty to change their codes in June This is surprising given the success of the British Room 40 code breakers in the previous world war. The break into one of them, JN , famously led to the US victory in the Battle of Midway ; and to the publication of that fact in the Chicago Tribune shortly after the battle, though the Japanese seem not to have noticed for they kept using the JN system. The German military also deployed several mechanical attempts at a one-time pad. The German Foreign Office began to use the one-time pad in ; some of this traffic was read in World War II partly as the result of recovery of some key material in South America that was discarded without sufficient care by a German courier. The Japanese Foreign Office used a locally developed electrical stepping switch based system called Purple by the US , and also had used several similar machines for attaches in some Japanese embassies. All were broken, to one degree or another, by the Allies. Patent 6,, , filed in but not issued until Neither is known to have been broken by anyone during the War. The Poles used the Lacida machine, but its security was found to be less than intended by Polish Army cryptographers in the UK , and its use was discontinued. US troops in the field used the M and the still less secure M family machines. For the decrypting of Soviet ciphers particularly when one-time pads were reused , see Venona project. Modern cryptography[edit] Encryption in modern times is achieved by using algorithms that have a key to encrypt and decrypt information. These keys convert the messages and data into "digital gibberish" through encryption and then return them to the original form through decryption. In general, the longer the key is, the more difficult it is to crack the code. This holds true because deciphering an encrypted message by brute force would require the attacker to try every possible key. To put this in context, each binary unit of information, or bit, has a value of 0 or 1. With modern technology, cyphers using keys with these lengths are becoming easier to decipher. DES, an early US Government approved cypher, has an effective key length of 56 bits, and test messages using that cypher have been broken by brute force key search. However, as technology advances, so does the quality of encryption. Since World War II, one of the most notable advances in the study of cryptography is the introduction of the asymmetric key cyphers sometimes termed public-key cyphers. These are algorithms which use two mathematically related keys for encryption of the same message. Some of these algorithms permit publication of one of the keys, due to it being extremely difficult to determine one key simply from knowledge of the other. This had been approved by NBS a US Government agency for its security, after public call for, and a comptetition among, candidates for such a cypher algorithm. DES was approved for a short period, but saw extended use due to complex wrangles over the use by the public of high quality encryption. Around the late s to early s, the use of public-key algorithms became a more common approach for encryption, and soon a hybrid of the two schemes became the most accepted way for e-commerce operations to proceed. Additionally, the creation of a new protocol known as the Secure Socket Layer, or SSL, led the way for online transactions to take place. Transactions ranging from purchasing goods to online bill pay and banking used SSL. Furthermore, as wireless Internet connections became more common among households, the need for encryption grew, as a level of security was needed in these everyday situations. Shannon worked for several years at Bell Labs, and during his time there, he produced an article entitled "A mathematical theory of cryptography". This article was written in and eventually was published in the Bell System Technical Journal in Shannon was inspired during the war to address "[t]he problems of cryptography [because] secrecy systems furnish an interesting application of communication theory". Shannon identified the two main goals of cryptography: His focus was on exploring secrecy and thirty-five years later, G. Simmons would address the issue of authenticity. Shannon wrote a further article entitled "A mathematical theory of communication" which highlights one of the most significant aspects of his work: The first are those designed with the intent to protect against hackers and attackers who have infinite resources with which to decode a message theoretical secrecy, now unconditional security , and the second are those designed to protect against hackers and attacks with finite resources with which to decode a message practical secrecy, now computational security. If a cipher was determined "unbreakable", it was considered to have "perfect secrecy". In proving "perfect secrecy", Shannon determined that this could only be obtained with a secret key whose length given in binary digits was greater than or equal to the number of bits contained in the information being encrypted. Furthermore, Shannon developed the "unicity distance", defined as the "amount of plaintext thatâ€¦ determines the secret key. His work also impacted modern designs of secret-key ciphers. First was the publication of the draft Data Encryption Standard in the U. Federal Register on 17 March The proposed DES cipher was submitted by a research group at IBM , at the invitation of the National Bureau of Standards now NIST , in an effort to develop secure electronic communication facilities for businesses such as banks and other large financial organizations. The release of its specification by NBS stimulated an explosion of public and academic interest in cryptography. DES, and more secure variants of it such as Triple DES , are still used today, having been incorporated into many national and organizational standards. However, its bit key-size has been shown to be insufficient to guard against brute force attacks one such attack, undertaken by the cyber civil-rights group Electronic Frontier Foundation in , succeeded in 56 hours. There was suspicion that government organizations even then had sufficient computing power to break DES messages; clearly others have achieved this capability. Public key[edit] The second development, in , was perhaps even more important, for it fundamentally changed the way cryptosystems might work. It introduced a radically new method of distributing cryptographic keys, which went far toward solving one of the fundamental problems of cryptography, key distribution, and has become known as Diffieâ€"Hellman key exchange. The article also stimulated the almost immediate public development of a new class of enciphering algorithms, the asymmetric key algorithms. Prior to that time, all useful modern encryption algorithms had been symmetric key algorithms , in which the same cryptographic key is used with the underlying algorithm by both the sender and the recipient, who must both keep it secret. All of the electromechanical machines used in World War II were of this logical class, as were the Caesar and Atbash ciphers and essentially all cipher systems throughout history. In particular, if messages are meant to be secure from other users, a separate key is required for each possible pair of users. A system of this kind is known as a secret key, or symmetric key cryptosystem. D-H key exchange and succeeding improvements and variants made operation of these systems much easier, and more secure, than had ever been possible before in all of history. In contrast, asymmetric key encryption uses a pair of mathematically related keys, each of which decrypts the encryption performed using the other. Some, but not all, of these algorithms have the additional property that one of the paired keys cannot be deduced from the other by any known method other than trial and error. An algorithm of this kind is known as a public key or asymmetric key system. Using such an algorithm, only one key pair is needed per user. By designating one key of the pair as private always secret , and the other as public often widely available , no secure channel is needed for key exchange. So long as the private key stays secret, the public key can be widely known for a very long time without compromising security, making it safe to reuse the same key pair indefinitely. Take this basic scenario: At the start of their message, they exchange public keys, unencrypted over an insecure line.

5: Crypto6e-Instructor

Cryptology - Cryptography: Cryptography, as defined in the introduction to this article, is the science of transforming information into a form that is impossible or infeasible to duplicate or undo without knowledge of a secret key.

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DEFENCE ENGINEERING UNIVERSITY. College of Engineering Bishoftu, Ethiopia Department of Computer and Information Technology LAB MANUAL for Cryptography and.

Cryptography Cryptography, as defined in the introduction to this article, is the science of transforming information into a form that is impossible or infeasible to duplicate or undo without knowledge of a secret key. These three types of system are described in turn below. Cipher systems The easiest way to describe the techniques on which cryptography depends is first to examine some simple cipher systems and then abstract from these examples features that apply to more complex systems. There are two basic kinds of mathematical operations used in cipher systems: Transpositions rearrange the symbols in the plaintext without changing the symbols themselves. Substitutions replace plaintext elements symbols, pairs of symbols, etc. Transposition ciphers In manual systems transpositions are generally carried out with the aid of an easily remembered mnemonic. The rail fence is the simplest example of a class of transposition ciphers, known as route ciphers , that enjoyed considerable popularity in the early history of cryptology. In general, the elements of the plaintext usually single letters are written in a prearranged order route into a geometric array matrix â€”typically a rectangleâ€”agreed upon in advance by the transmitter and receiver and then read off by following another prescribed route through the matrix to produce the cipher. The key in a route cipher consists of keeping secret the geometric array, the starting point, and the routes. Clearly, both the matrix and the routes can be much more complex than in this example; but even so, they provide little security. One form of transposition permutation that was widely used depends on an easily remembered key word for identifying the route in which the columns of a rectangular matrix are to be read. For example, using the key word AUTHOR and ordering the columns by the lexicographic order of the letters in the key word In decrypting a route cipher, the receiver enters the ciphertext symbols into the agreed-upon matrix according to the encryption route and then reads the plaintext according to the original order of entry. A significant improvement in cryptosecurity can be achieved by reencrypting the cipher obtained from one transposition with another transposition. Because the result product of two transpositions is also a transposition, the effect of multiple transpositions is to define a complex route in the matrix, which in itself would be difficult to describe by any simple mnemonic. See Product ciphers , below. In the same class also fall systems that make use of perforated cardboard matrices called grilles; descriptions of such systems can be found in most older books on cryptography. In contemporary cryptography, transpositions serve principally as one of several encryption steps in forming a compound or product cipher. Substitution ciphers In substitution ciphers, units of the plaintext generally single letters or pairs of letters are replaced with other symbols or groups of symbols, which need not be the same as those used in the plaintext. The simplest of all substitution ciphers are those in which the cipher alphabet is merely a cyclical shift of the plaintext alphabet. As many a schoolboy has discovered to his embarrassment, cyclical-shift substitution ciphers are not secure. And as is pointed out in the section Cryptanalysis , neither is any other monoalphabetic substitution cipher in which a given plaintext symbol is always encrypted into the same ciphertext symbol. Because of the redundancy of the English language , only about 25 symbols of ciphertext are required to permit the cryptanalysis of monoalphabetic substitution ciphers, which makes them a popular source for recreational cryptograms. The explanation for this weakness is that the frequency distributions of symbols in the plaintext and in the ciphertext are identical, only the symbols having been relabeled. There are two main approaches that have been employed with substitution ciphers to lessen the extent to which structure in the plaintextâ€”primarily single-letter frequenciesâ€”survives in the ciphertext. One approach is to encrypt elements of plaintext consisting of two or more symbols; e. The other is to use several cipher alphabets. When this approach of polyalphabetic substitution is carried to its limit, it results in onetime keys, or pads. Playfair ciphers In cryptosystems for manually encrypting units of plaintext made up of more than a single letter, only digraphs were ever used. By treating digraphs in the plaintext as units rather than as single letters, the extent to which the raw frequency distribution survives the encryption process can be lessened but not eliminated, as letter pairs are themselves highly correlated. Plaintext digraphs are encrypted with the matrix by first locating the two plaintext letters in the matrix. They are 1 in different rows and columns; 2 in the same row; 3 in the same column; or 4 alike. The corresponding encryption replacement rules are the following: When the two letters are in different rows and columns, each is replaced by the letter that is in the same row but in the other column; i. An X is appended to the end of the plaintext if necessary to give the plaintext an even number of letters. If the frequency distribution information were totally concealed in the encryption process, the ciphertext plot of letter frequencies in Playfair ciphers would be flat. The loss of a significant part of the plaintext frequency distribution, however, makes a Playfair cipher harder to cryptanalyze than a monoalphabetic cipher. The resulting ciphers, known generically as polyalphabetics, have a long history of usage. The systems differ mainly in the way in which the key is used to choose among the collection of monoalphabetic substitution rules. To decrypt ciphertext, the plaintext letter is found at the head of the column determined by the intersection of the diagonal containing the cipher letter and the row containing the key letter. Nevertheless, in Friedrich W. Cryptanalysts look for precisely such repetitions. In the example given above, the group VTW appears twice, separated by six letters, suggesting that the key i. Consequently, the cryptanalyst would partition the cipher symbols into three and nine monoalphabets and attempt to solve each of these as a simple substitution cipher. With sufficient ciphertext, it would be easy to solve for the unknown key word. The figure shows how the relative frequency distribution of the original plaintext is disguised by the corresponding ciphertext, which more closely resembles a purely random sequence supplied as a baseline. Such a cipher is produced when a nonrepeating text is used for the key. Even though running-key or autokey ciphers eliminate periodicity, two methods exist to cryptanalyze them. In one, the cryptanalyst proceeds under the assumption that both the ciphertext and the key share the same frequency distribution of symbols and applies statistical analysis. For example, E occurs in English plaintext with a frequency of 0. The second method of solving running-key ciphers is commonly known as the probable-word method. In this approach, words that are thought most likely to occur in the text are subtracted from the cipher. For example, suppose that an encrypted message to President Jefferson Davis of the Confederate States of America was intercepted. Now these nine numbers are added modulo 27 for the 26 letters plus a space symbol to each successive block of nine symbols of ciphertextâ€”shifting one letter each time to form a new block. Almost all such additions will produce random-like groups of nine symbols as a result, but some may produce a block that contains meaningful English fragments. These fragments can then be extended with either of the two techniques described above. If provided with enough ciphertext, the cryptanalyst can ultimately decrypt the cipher. What is important to bear in mind here is that the redundancy of the English language is high enough that the amount of information conveyed by every ciphertext component is greater than the rate at which equivocation i. In principle, when the equivocation is reduced to zero, the cipher can be solved. The number of symbols needed to reach this point is called the unicity distanceâ€”and is only about 25 symbols, on average, for simple substitution ciphers. Vernam suggested a means of introducing equivocation at the same rate at which it was reduced by redundancy among symbols of the message, thereby safeguarding communications against cryptanalytic attack. It required one key symbol for each message symbol, which meant that communicants would have to exchange an impractically large key in advanceâ€”i. The key itself consisted of a punched paper tape that could be read automatically while symbols were typed at the teletypewriter keyboard and encrypted for transmission. This operation was performed in reverse using a copy of the paper tape at the receiving teletypewriter to decrypt the cipher. Vernam initially believed that a short random key could safely be reused many times, thus justifying the effort to deliver such a large key, but reuse of the key turned out to be vulnerable to attack by methods of the type devised by Kasiski. Vernam offered an alternative solution: A bit stream so computed does not repeat until mn bits of key have been produced. This version of the Vernam cipher system was adopted and employed by the U. Army until Major Joseph O. Mauborgne of the Army Signal Corps demonstrated during World War I that a cipher constructed from a key produced by linearly combining two or more short tapes could be decrypted by methods of the sort employed to cryptanalyze running-key ciphers. Of far greater consequence to modern cryptologyâ€”in fact, an idea that remains its cornerstoneâ€—was the conclusion drawn by Mauborgne and William F. Friedman that the only type of cryptosystem that is unconditionally secure uses a random onetime key. In a streaming cipher the key is incoherentâ€”i. The dotted curve in the figure indicates that the raw frequency of occurrence pattern is lost when the draft text of this article is encrypted with a random onetime key. The same would be true if digraph or trigraph frequencies were plotted for a sufficiently long ciphertext. In other words, the system is unconditionally secure, not because of any failure on the part of the cryptanalyst to find the right cryptanalytic technique but rather because he is faced with an irresolvable number of choices for the key or plaintext message. Product ciphers In the discussion of transposition ciphers it was pointed out that by combining two or more simple transpositions, a more secure encryption may result. In the days of manual cryptography this was a useful device for the cryptographer, and in fact double transposition or product ciphers on key word-based rectangular matrices were widely used. There was also some use of a class of product ciphers known as fractionation systems , wherein a substitution was first made from symbols in the plaintext to multiple symbols usually pairs, in which case the cipher is called a biliteral cipher in the ciphertext, which was then encrypted by a final transposition, known as superencryption. The resulting biliteral cipher was then written into a rectangular array and route encrypted by reading the columns in the order indicated by a key word, as illustrated in the figure. The great French cryptanalyst Georges J. Key cryptosystems Single-key cryptography Single-key cryptography is limited in practice by what is known as the key distribution problem. Since all participants must possess the same secret key, if they are physically separatedâ€”as is usually the caseâ€”there is the problem of how they get the key in the first place. Diplomatic and military organizations traditionally use couriers to distribute keys for the highest-level communications systems, which are then used to superencrypt and distribute keys for lower-level systems. This is impractical, though, for most business and private needs. In addition, key holders are compelled to trust each other unconditionally to protect the keys in their possession and not to misuse them. Again, while this may be a tolerable condition in diplomatic and military organizations, it is almost never acceptable in the commercial realm. Another key distribution problem is the sheer number of keys required for flexible, secure communications among even a modest number of users. While only a single key is needed for secure communication between two parties, every potential pair of participants in a larger group needs a unique key. To illustrate this point, consider an organization with only 1, users: Such a system would require , different keys in all, with each user having to protect keys. The number of different keys increases in proportion to the square of the number of users. Secure distribution for so many keys is simply insolvable, as are the demands on the users for the secure storage of their keys. In other words, symmetric key cryptography is impractical in a network in which all participants are equals in all respects. Each user then has only to protect one key, while the burden for the protection of all of the keys in the network is shifted to the central authority. Two-key cryptography Public-key cryptography In , in one of the most inspired insights in the history of cryptology, Sun Microsystems, Inc. Since most of the systems devised to meet points 1â€”4 satisfy these conditions as well, we will assume they hold hereafterâ€”but that is not necessary. The encryption and decryption operation, T, should be computationally easy to carry out. At least one of the keys must be computationally infeasible for the cryptanalyst to recover even when he knows T, the other key, and arbitrarily many matching plaintext and ciphertext pairs.

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