Morse Telegraph Alphabet and Cryptology as a Method of System Approach in Computer Science Education

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Abstract
The system approach is one of the education methods which can be widely applied in any subjects. The author has found this method as suitable for training of practical skill of computer science education. Application of system approach in computer science education develops logical thinking and correct understanding of using of computers in human life. Connection of Morse telegraph alphabet and cryptology has been chosen for the presentation of the system approach, modeling and simulation in this paper. The huge advantage of cryptology, which is a part of the curriculum in computer science, is that it enables the building of the system approach as well as interdisciplinary relations between such subjects as mother tongue, foreign languages, mathematics, history and geography, which is absolutely needed for prospective teacher of informatics. The use of the algorithm development and programming in the cryptoanalysis of the Morse telegraph alphabet cipher is specifically presented in the paper.

Keywords

Introduction

Teaching of the computer science education should develop all theoretical knowledge and practical skills reached in theoretical informatics subjects from education point of view. The system approach seems to be one of the most suitable methods to reach this goal.

Firstly, we briefly introduce the system approach methodology especially used in the education and then this methodology will be supplied by case study, based on e.g. (Milková, 2011; Hubálovský, Milková, Pražák, 2010).

The research investigation should confirm the hypothesis, that system approach implemented to computer science education positively influenced development of the cognition of the student about their role as teacher. What seem to be also important that the students – prospective teacher pass their knowledge about system thinking to their pupil, which is absolutely important in correct understanding of the real objects and real processes. With the term system approach are very closely connected the terms modeling and simulation. Similar research investigation can be found e.g. in (Hubálovský, 2011; Šedivý, Hubálovský, 2011)
System approach, modeling and simulation

System approach

System approach is closely related to the concept of system. Under the system, rather a systemic approach, however, can be understood also abstract issues like learning style. For a system approach is generally considered such way of solving the problems, where phenomena and processes are studied comprehensively in their internal and external contexts (Wilson, 2001). System approach in pedagogy means formulation, understanding and solutions of the studied problem under the consideration that the corresponding processes, events and phenomena that objectively exist in the world and which are transformed into the model learning situations.

In connection with the concepts of system and system approach is necessary to mention the other term that is commonly used in pedagogy – interdisciplinarity. This concept can be understood e.g. based on (Checklan and Poulter, 2006) as a method of linking and active cooperation between different sciences in order to achieve integrated and synergistic results in theoretical and practical professional activities, science and research.

Although the interdisciplinary approach in the context of learning process is frequently discussed, the concept of system approach in educational practice is not sufficiently specific and widely implemented (Checklan and Poulter, 2006). Unfortunately, this fact also applies to study computer science education, which in practical terms without system and multidisciplinary approach cannot be realized.

Modeling and simulation

Modeling and simulation are methods that are often used in professional and scientific practice in many fields of human activity.

The main goal of modeling and simulation is not only describing the content, structure and behavior of the real system representing a part of the reality but also describing the processes.

Simulation can be understood as process of executing the model. Simulation enables representation of the modeled real system or real process and its behavior in real time by means of computer. The simulation enables also visualization and editing of the model – see e.g. (Hubálovský, 2010; Šedivý, 2011).

The simulation model is usually represented by executable computer program. To create high quality computer simulation, it is important to create well done conceptual model of the process. The system approach one of the methods giving the rules for conceptual model and computer simulation creation.

Multidisciplinary approach

Another important benefit associated with the modeling and simulation of real processes is a multidisciplinary approach, without which the identification of the real processes using conceptual and simulation model and cannot be realized. This is also emphasized in this paper – (Hubálovský, Šedivý, 2010).

Multidisciplinary approach generally means that specialized disciplines are applied in a study of real process. These disciplines provide partial analysis of the process. These mono-disciplinary analyses are integrated to overall solution by integrating the solver who has basic multi-disciplines knowledge – see e.g. (Šedivý, 2011).
In the following text the application of the system approach will be presented in identification of the Morse telegraph alphabet and cryptology process.

Case study

American Samuel Finley Morse (1791 - 1872) worked out his proposal of the telegraph in practically usable form 175 years ago, then in 1837. It was after a lawsuit with the American physicist Joseph Henry (1797-1878), inventor of the electromagnetic relay, the same year it entered the patenting. Along with telegraph alphabet suggested by Morse that while still been modified several times, but the basic principle - alternating short and long pulses - telegraphic dots and dashes - has been preserved till present. It is interesting that in the same year Charles Wheatstone (1802 - 1875) and Sir William Fothergill Cooke (1806 - 1879) patented electromagnetic telegraph based on an entirely different principle.

Electromagnetic telegraphs and in particular good practice to use Morse's telegraph began to develop rapidly in the second half of the nineteenth century telegraph services began to be widely available to the public. Public Service, which had to text messages transmitted by several people approach (employments of the telegraph office on the sending and the receiving station) but did not provide in a foolproof guarantee the confidentiality of the message content from third parties. It was such an unpleasant for businessmen, for whom confidential information may represent a competitive advantage, but also necessary for the lover who, when their relationship revealed disclosure of a society scandal. That comes with the development of telegraphy social demand for cryptographic systems that are easy to use and yet sufficiently encrypted to protect confidentiality.

For example polyalphabetic substitution described by an English admiral and meteorologist (known for its wind force scale) Sir Francis Beaufort (1774 - 1857) popularized his brother, a table of encryption known as tabula recta sold along with instructions and recommendations for creating passwords for six pence by 1857. The amount designated by the versatile British scientist Charles Wheatstone (1802 - 1875) suggested in 1854 a new type of bigram substitution, which is somewhat wrongly called Playfair’s cipher, according to his great friend and promoter of this cipher. His name was Lyon Playfair (1818 - 1898) and it was well-known scientist and member of British Parliament, who succeeded because of his political influence to promote the use of ciphers in Britain for diplomatic and military purposes.

Since the nineteenth century it probably becomes a custom to divide encrypted messages to groups of five letters. The average length of words in the English language is oscillated (by type of text) about 4.5 letter and telegraph companies traditionally charge sending message by the number of words (or number of groups in the ciphertext), not by the number of letters. Soon, they refused to accept encrypted telegram, which would include more than a five-character groups.

Methods of encrypting by Morse alphabeth

Samuel Finley Morse certainly did not anticipate that its invention indirectly affect the development of cryptology, the less that his telegraph alphabet will become an interesting tool for type doubling substitutions, which convert plaintext into Morse code is the first step, serving to create middletext. Middletext uses three-character alphabet (dot, dash, slash), with the termination letter, composed of dots and dashes. Slash is used to separate letters, and two slashes are used to separated two words. Slash is also usually added at the beginning of the middletext. The next operation is division of the text into groups of two characters in the cipher called Morbit or three characters in the cipher Fractionated Morse. If the number of characters was not even in the case
Morbit cipher, we’ll add a slash at the end of the middle text, analogously for the middletext of Fractionated Morse cipher slashes to specify that the number of characters, from which it is composed is divisible by three. Finally, in the case Morbit cipher replaces each pair of characters, depending on the conversion table. If we lined up alphabetically character pairs (dot < dash < slash) and sort the numbers assigned to them by size in the normal way (1 < 2 < 3 <... < 9), we get the following table:

Table 1: Conversion table with digits in the normal order

<table>
<thead>
<tr>
<th>./</th>
<th>.</th>
<th>\</th>
<th>.</th>
<th>./</th>
<th>.</th>
<th>//</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>

Of course, that in fact we use numbers to assign a different permutation of digits. Digits is not ordered by size but by a suitably chosen numerical password. If we choose as a password eg date of birth of Samuel Finley Morse, a 27. 4. 1791, then to the bottom line of the table write gear in sequence 2, 7, 4, 1, then the digit 9 (seven we can’t enter a second time, as well as one at the end of the year of birth) and they write the remaining numbers, already sorted by size, ie gradually 3, 5, 6 and 8. Conversion table will look like this:

Table 2: Conversion table with digits ordered by password

<table>
<thead>
<tr>
<th>./</th>
<th>.</th>
<th>\</th>
<th>.</th>
<th>./</th>
<th>.</th>
<th>//</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>7</td>
<td>4</td>
<td>1</td>
<td>9</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Analogously, we proceed in the case of cipher Fractionated Morse, with the difference that the middletext divided into triplets of characters convert according to the table, which corresponds to 26 international alphabet letters. Number of possible triplets is total $3^3 = 27$, but because it can’t occur three consecutive slashes in middle text, it just comes to us. Let’s see how it would look conversion table with alphabetically sorted letters, although even here, in practice we use permutations of the password:

Table 3: Conversion table with letters in the alphabetical order

<table>
<thead>
<tr>
<th>...</th>
<th>.-</th>
<th>.//</th>
<th>.-</th>
<th>.-</th>
<th>.//</th>
<th>.//</th>
<th>//</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td>G</td>
<td>H</td>
</tr>
<tr>
<td>J</td>
<td>K</td>
<td>L</td>
<td>M</td>
<td>N</td>
<td>O</td>
<td>P</td>
<td>Q</td>
</tr>
<tr>
<td>S</td>
<td>T</td>
<td>U</td>
<td>V</td>
<td>W</td>
<td>X</td>
<td>Y</td>
<td>Z</td>
</tr>
</tbody>
</table>

Let the whole procedure encryption on a short example. It will be the first report, broadcast by Samuel Finley Morse at May 24th 1844 through the first line of his telegraph from Washington to Baltimore: „What hath God wrought“. For cipher Morbit was used the above password - date of birth, for cipher Fractionated Morse arranged alphabetically leave conversion table.

Plaintext: WHAT HATH GOD WROUGHT

Middletext: .-/.../-/.../.../-/.../.../-/.../.../-/.../.../-/.../.../-/.../.../-/.../.../-/.../.../-/.../.../-/.../.../-/.../.../-/.../.../-/"...

Ciphertext 1: 59524 76822 53322 89493 14595 16957 61524 3
Ciphertext 2: TPATX SCFPA ZLNVI ETHOB WGAX

From this brief example, we see that the number of ciphertext characters (36 and 25 for Morbit and Fractionated Morse) is larger than the number of plaintext characters (18 letters). For Fractionated Morse cipher we can also compare the index of coincidence with plaintext, as both open and ciphertext are using the international alphabet with 26 letters. For this comparison, however, we use more text taken from book by HG Wells’ The War of the Worlds, of course, the original English version. This text is about 266 thousand letters long and his index of coincidence is 0.0662. Cipher text obtained by fractionated Morse with any password has about 336 000 characters and the coincidence index is 0.0478. Recall that a random text with absolutely equal representation of all characters has coincidence index of 0.0385.

To decrypt the ciphertext with the password and the resulting conversion table is easy. Inverted conversion table and each digit in the case of Morbit cipher, or each letter in the case of Fractionated Morse cipher replace sequences of characters from the alphabet dot - dash - slash. So we get middletext entry representing the plaintext in Morse telegraph alphabet. It is decoded and plaintext written in the international alphabet letters is obtained. Is possible use script at web (Musilek, 2011) for encrypt and decrypt.

Discussion about deciphering of Morbit

More complex problem is deciphering the ciphertext, which we know that it is encrypted by system Morbit or Fractionated Morse cipher, but we don’t know a password. We know that the cipher alphabet characters can arbitrarily permute in the conversion table and that the number of permutations of $n$ elements is calculated as $n!$. For the 9 digits in the system Morbit we get a total of $9! = 362 \, 880$ possible keys, for 26 letters in the Fractionated Morse system we get a lot more, a total of $26! = 403 \, 291 \, 461 \, 265 \, 606 \, 358 \, 400 \, 000 \, (403 \, quadrillion)$ possible keys. The question is whether and how it is possible to decipher the encrypted texts mentioned systems.

Morbit system has considerably smaller key space and is considered for the cipher that can be deciphered only with pencil and paper (American Cryptogram Association). However, the number $9! = 362 \, 880$ seems to be too large for us trying all possibilities. In fact, we can’t assign individual digits (each character of cipher alphabet) to all possible couples from characters of the middletext alphabet. If we agree that middletext will always start with a slash, we have only two options for the first digit ciphertext: / or / -. Conversely, if a slash at the beginning middletext omitted, there are six possibilities. Other estimates are based on the fact that each letter of the plaintext is coded into middletext in Morse Code using one to four characters, dot or dash, which is always followed by a slash. Ciphertext digits representing the combination with a slash may be close to one another, through one or a maximum through two digits. If characters are trough two digits, the first in the sequence must end with a slash and the other begins. In four-characters sequences cannot any sequence of dots and dashes emerge, because they are not expressing any of the 26 letters of the international alphabet. Specifically, the sequence:

| .- | - | ---- | ---- |

These sequences are sometimes used to write letters with umlaut (ü, ä, ö), or the letter ch. But this isn’t an international alphabet letters and in Morbit encryption it isn’t commonly used. If in the ciphertext occur the same two digits in a row, then this certainly can’t be a digit or two characters - or pair of characters -- because it would generate "forbidden" sequences -. - , respectively ----. Similarly, another may be deduced, although slightly more complex rules. Let’s take, but rather deciphering ciphertext, which was Morbit system generated, for example:
We know about the ciphertext that the system was Morbit, the first character of middletext is a slash and an plaintext was written in English. Furthermore, we have marked out the ciphertext pair of consecutive identical digits. If we use the above considerations, it has something we know about the first two digits of ciphertext. Digit 4 can only mean /, or /- and digit 5 can't mean either -. or -- or the same character as the digit 4. As digit 5 the cipher text ends, we know that will mean either //, or ./, or -. But if it were //, which represents the space between words, it would open the first word of the body of the letter E or the letter T itself, which is not probably. Thus, we will only consider the option ./, or -. Mark what we already know in tabular form:

Table 4: Cipher Morbit deciphering matrix – non complete

<table>
<thead>
<tr>
<th></th>
<th>..</th>
<th>-</th>
<th>/</th>
<th>--</th>
<th>-/</th>
<th>./</th>
<th>//</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>2</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>3</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>4</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>5</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>6</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>7</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>8</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>9</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>

After the first replacement remains a recurring pair of digits (89 or 27) and some more groups (2239). From the location of the 89 pairs of characters we can estimate that either 8 or 9, or both, probably are representing a combination of numbers with a slash:


We can try to start as an plaintext "I AM". Then 1 would have imagined -. 8/-. and 9/-. We got a partially decrypted text (we canceled the spaces between groups of digits):

/./.-/-/-/-3/.327/.37327/./.-/./6/.63/./223/-2././

-./.-32/./.-67/.-2./.-23.-77/./.-2./.-37/.-2././223/6

72/.-327/./.3272/.7/.-7/./.-276/./6/.3/.-2./.-223/.7/

.-276/./6/.3/.-77./.-223/-2././.-32/.-62332

/2./.-6./.-3/-3.-/-.-233./.-763./.-2./.-27223/6./

In this text, however, we see the "forbidden" sequence --, so we wandered into a blind alley. We start therefore from the beginning starting with other substitutions. What if the text started instead of the personal pronoun "I" by possessive pronoun "WE". So digit 4 would correspond to /-, digit 5 would be /-, 1 would be --, and 8 would be --. Then they had to answer nine // in order to finish the word "WE" and the resulting partially decrypted text would be:
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\(--/\--/-.\-3/-.327/-.73727/-/\--/-.6/-.63/-.//223/2/-/-.\--/-32/--/-.67/-.\--/-.23/-/.77/-/\--/-.2/-/223/672/
-.327/-/-.3272/7--/7/----/276/-/6/-3/-/2/-/223/-/7/----/276/-/6/-37/-/3--/37/-/22//-/223/-/2/-/----/32/-/62332/-/2/-/6/-/-.3/----3-.--/-.//-.233/-/763/-/2//27223/6/-

In this text, no "forbidden" sequences don’t see, so once again we return to our table, add to it to make a refund and considering how to proceed:

Table 5: Cipher Morbit deciphering matrix – nearly complete

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>./</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>2</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>3</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>4</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>5</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>6</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>7</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>8</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>9</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
</tbody>
</table>

The table clearly shows the value of the digit 6, that is .-. For the remaining digits 2, 3 and 7 are offered meanings ./. a/. Trial - error we find that best matches the digit 3 is /. and substituting for 6 and 3, we go to the text:

\(--/\--/-.\-3/-.327/-.73727/-/\--/-.6/-.63/-.//223/2/-/-.\--/-32/--/-.67/-.\--/-.23/-/.77/-/\--/-.2/-/223/672/
-.327/-/-.3272/7--/7/----/276/-/6/-3/-/2/-/223/-/7/----/276/-/6/-37/-/3--/37/-/22//-/223/-/2/-/----/32/-/62332/-/2/-/6/-/-.3/----3-.--/-.//-.233/-/763/-/2//27223/6/-

By reading this text, we get clear assignment of values to the last two digits. Number 2 is .. and number 7 ./. After substitution we get the complete decrypted middletext in Morse Code:

\(--/\--/-.\-3/-.327/-.73727/-/\--/-.6/-.63/-.//223/2/-/-.\--/-32/--/-.67/-.\--/-.23/-/.77/-/\--/-.2/-/223/672/
-.327/-/-.3272/7--/7/----/276/-/6/-3/-/2/-/223/-/7/----/276/-/6/-37/-/3--/37/-/22//-/223/-/2/-/----/32/-/62332/-/2/-/6/-/-.3/----3-.--/-.//-.233/-/763/-/2//27223/6/-

A simple decoding well known Morse telegraph alphabet, finally, open the original plaintext:

MY METHOD IS TO TAKE THE UTMOST TROUBLE TO FIND THE RIGHT THING TO SAY AND THEN TO SAY IT WITH THE UTMOST LEVITY

GEORG BERNARD SHAW
Research investigation

Let’s return now to the issue of research in which we have investigated the influence of a systematic approach to development of students' skills to create a web application. The investigation was conducted among students of 3rd year of bachelor's degree in the subject of “Web technology”. The aim of this subject is to acquaint students with the technology of static and dynamic Web markup languages like HTML, XML and XHTML, the rules of language of CSS and principles to various degrees using cascade and scripting language for client-side scripting (JavaScript) and server (PHP).

Characteristic of the first group of students was that in the previous semester the students study optional subject “Introduction to systems theory, modeling and simulation”. The aim of the subject is to familiarize students with basic concepts of systems approach, modeling and simulation.

The second group of students the subject “Introduction to systems theory, modeling and simulation” has not studied.

Output of the work of students in the subject of “Web technology” is final web project, which must contain interactive sections and functionality. Quantitative evaluation of web project was based on the percentage evaluation parameters. The evaluation parameters are listed in the table 6. 0% is completely wrong, 100% is quite correct.

Table 6: Research results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1. group</th>
<th>2. group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web architecture, web design</td>
<td>89</td>
<td>88</td>
</tr>
<tr>
<td>Using of graphics and pictures</td>
<td>92</td>
<td>94</td>
</tr>
<tr>
<td>Using of cascade language - CSS</td>
<td>85</td>
<td>75</td>
</tr>
<tr>
<td>Correctness of XHTML code</td>
<td>75</td>
<td>65</td>
</tr>
<tr>
<td>Correctness of using of CSS code</td>
<td>78</td>
<td>52</td>
</tr>
<tr>
<td>Correctness of using of JavaScript</td>
<td>82</td>
<td>65</td>
</tr>
<tr>
<td>Web hierarchy</td>
<td>68</td>
<td>59</td>
</tr>
<tr>
<td><strong>Total result:</strong></td>
<td><strong>81</strong></td>
<td><strong>71</strong></td>
</tr>
</tbody>
</table>

Discussion of the results

The above results indicates that students who completed the course "Introduction to systems theory, modeling and simulation" make less mistakes when creating their web project, than students without system approach knowledge / thinking. We can say that awareness of fundamental systems approach increases students' ability to create complex Web applications in which they make fewer mistakes. These students respect the basic rules and principles of Web programming.

The above research is the first of the anticipated researches. It is further assumed that the influence of a system approach in other subjects such as algorithms, programming, computer graphics, multimedia systems, etc. will be observed.
Conclusion

There are various approaches how to provide learning of computer science education, how to introduce and develop basic theoretical and practical skills.

The paper offered one of the kinds of the possible teaching / learning strategies using the system approach. The system approach can be set as the default paradigm for a wide integration of this principle to computer science education. The paper emphasizes the fact that system approach is one of the suitable methods of using computer technology.

Solution of the Connection of Morse telegraph alphabet and cryptology has been chosen as one possible example of how to present the application of the system approach.

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