



Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

A computer-based learning environment aimed for students at the 3rd and 4th grade level

Bachelor's Thesis

Florian Bütler

`flbuetle@ethz.ch`

Chair of Information Technology and Education
ETH Zürich

Supervisor:

Prof. Juraj Hromkovič

February 11, 2021



Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Eigenständigkeitserklärung

Die unterzeichnete Eigenständigkeitserklärung ist Bestandteil jeder während des Studiums verfassten Semester-, Bachelor- und Master-Arbeit oder anderen Abschlussarbeit (auch der jeweils elektronischen Version).

Die Dozentinnen und Dozenten können auch für andere bei ihnen verfasste schriftliche Arbeiten eine Eigenständigkeitserklärung verlangen.

Ich bestätige, die vorliegende Arbeit selbständig und in eigenen Worten verfasst zu haben. Davon ausgenommen sind sprachliche und inhaltliche Korrekturvorschläge durch die Betreuer und Betreuerinnen der Arbeit.

Titel der Arbeit (in Druckschrift):

Verfasst von (in Druckschrift):

Bei Gruppenarbeiten sind die Namen aller Verfasserinnen und Verfasser erforderlich.

Name(n):

Vorname(n):

Ich bestätige mit meiner Unterschrift:

- Ich habe keine im Merkblatt „[Zitier-Knigge](#)“ beschriebene Form des Plagiats begangen.
- Ich habe alle Methoden, Daten und Arbeitsabläufe wahrheitsgetreu dokumentiert.
- Ich habe keine Daten manipuliert.
- Ich habe alle Personen erwähnt, welche die Arbeit wesentlich unterstützt haben.

Ich nehme zur Kenntnis, dass die Arbeit mit elektronischen Hilfsmitteln auf Plagiate überprüft werden kann.

Ort, Datum

Unterschrift(en)

Bei Gruppenarbeiten sind die Namen aller Verfasserinnen und Verfasser erforderlich. Durch die Unterschriften bürgen sie gemeinsam für den gesamten Inhalt dieser schriftlichen Arbeit.

Acknowledgements

I thank Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet. Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. At vero eos et accusam et justo duo dolores et ea rebum. Stet clita kasd gubergren, no sea takimata sanctus est Lorem ipsum dolor sit amet.

Abstract

a brief introduction describing the discipline that the paper belongs to a clear and concise statement of your problem a brief explanation of your solution and its key ideas a brief description of the results obtained and their impacts

Contents

Acknowledgements	ii
Abstract	iii
1 Introduction	1
1.1 Motivation and Background	1
1.2 Goals	1
1.3 Related Work	1
1.4 Outline	2
2 Concepts	3
2.1 Representing Information with Symbols	3
2.1.1 Similar Words	3
2.1.2 Representing Numbers like the Maya	5
2.1.3 Representing Numbers with Coins	6
2.2 Keeping Information Secret	7
2.2.1 Cipher Texts from Reversed Letters	8
2.2.2 Cipher Texts from New Characters	8
2.3 Learning from Data	9
2.3.1 Row of Trees	9
2.3.2 Tree Sudoku	10
3 Implementation	11
3.1 Introduction	11
3.2 Vue.js	11
3.3 Typescript	11
3.4 Basic functionality	11
3.5 Representing Information with Symbols	11

CONTENTS	v
3.6 Keeping Information Secret	11
3.7 Learning from Data	11
3.8 Testing	11
3.8.1 Unit and Snapshot Testing	11
3.8.2 End to End Testing	11
3.9 Continuous Integration	11
4 Conclusion, Drawbacks and Further Work	12
4.1 Conclusion	12
4.2 Drawbacks	12
4.3 Further Work	12
Bibliography	13
A First Chapter Title	A-1
A.1 First Section Title	A-1
A.1.1 First Subsection Title	A-1

Introduction

1.1 Motivation and Background

With the introduction of Lehrplan 21 Computer Science became an integral part of the Swiss education curriculum [1]. Pupils learn to understand the basic concepts of Computer Science and how to use them for problem solving. These concepts include methods on how to process, evaluate and summarize data, how to securely communicate and how to develop solution strategies for simple problems of information processing [2]. The Education and Counselling Center for Computer Science Education at ETH Zurich (ABZ) supports schools to teach these concepts among others by providing teaching resources and learning environments.

1.2 Goals

The main goal in this bachelor thesis is to implement tasks and riddles based on the textbook “einfach Informatik 3/4” in a computer-based learning environment that teaches the following concepts:

- representing information with symbols,
- keeping information secret and
- learning from data

for pupils in the second cycle. Along with solving tasks and riddles about the mentioned topics the ability of reading, writing, counting and calculating is trained as well.

1.3 Related Work

Todo:
abz.inf.ethz.ch
other learning environments

1.4 Outline

This report first explains how the aforementioned concepts are thought by hands-on exercises, then gives in-depth technical insight on how a learning environment is developed and how these exercises are implemented. Finally, the report ends with a conclusion with a review of the project.

CHAPTER 2

Concepts

This chapter is split into three parts. Each part discusses a basic concept of Computer Science and its corresponding exercises. Throughout all exercises beavers are used as protagonists to illustrate the concepts. The beaver comes from a project of the Swiss Association for Information Technology in Education and is intended to arouse interest in Computer Science for children and teenagers between 8 and 20 years old [3].

2.1 Representing Information with Symbols

Representing information with symbols is a fundamental concept of Computer Science as information should be represented clear and concisely. Words can be seen as a sequence of symbols, namely a sequence of letters.

2.1.1 Similar Words

Transmitting information includes representing it in a message, sending it to the destination and the receiver being able to make sense of it even though the message might contain errors such as a spelling mistake. To achieve this sender and receiver agree to only send messages with a minimal editing distance [4] between each of them.

Editing distance

The editing distance is the amount of operations that need to be done to transform a message in another. Operations are deleting, inserting and changing a letter . A cost function exists that defines the cost of each operation, and in our case each operation has a cost of 1 (unit cost model). The editing distance is then the minimal cost to transform a message into another one by a sequence of operations. In our case a message is a word.

Todo: add some TI explanation

Example 2.1. The editing distance between **LIKE** and **BIKE** is 1, since changing the first letter from an L to and B transforms the first word into the second.

If sender and receiver agree to only transmit words with a minimal editing distance of e.g 3, then the receiver can still uniquely determine what word the sender has sent even when at most 1 spelling mistake has been made. The receiver calculates the minimal editing distance between the received word and each of the agreed words and chooses the word with the least editing distance. The receiver assume that this was the word the sender wanted to sent. This of course work only if there are not more than 1 error in the word. If this happens the editing distance to another word is closer than to the original word and hence the word is misinterpreted. To counter this, sender and receiver might agree on a bigger minimal distance, but this comes with a tradeoff. When chosing a bigger minimal distance for a fixed alphabet, the number of words that can be used shrinks. To maintain the same amount of words the size of the lphabet can be increased too, resulting in longer words.

The purpose of the **similar words** exercises is to learn these operations. Therefore an exercise is dedicated to each opertion: adding, changing and removing a letter from a word. Additionally, an exercise about swapping adjacent letters in a word is included. Swapping adjacent letters is not part of the mentioned operations and usually consists of 2 operations: removing and adding or changing twice. However, when typing on a keyboard typing mistakes happen often and most of the time only two adjacent letters are swapped. This exercises is supposed to train the ability to spot these sort of mistakes.

Adding a letter

In the **adding a letter** exercise pupils are presented a word, the alphabet from A to Z and spaces between each letter of the word as well as at the beginnig and the end of the word, where a letter can be added. Pupils are supposed to choose a letter from the alphabet and add it to one of the mentioned spaces to form a new valid word.

Example 2.2. The word **PACE** is given. By adding the letter S before the first letter, the valid word **SPACE** is formed.

Changing a letter

In this exercise there is again a word and the alphabet from A to Z shown. Again pupils should select a letter from the alphabet, but this time, instead of adding it to a space, the selected letter should be replace a letter from the word itself to create a new valid word.

Example 2.3. The word BIKE is given. By changing the first letter from a B to a L the new valid word LIKE is formed.

Removing a letter

In this exercise pupils receive a word and they should select a character from within the word and move it to the trashcan to remove the letter from the word itself to form a new valid word.

Example 2.4. The word SPACE is given. By removing the first letter the new valid word PACE is formed.

Swapping two adjacent letters

To learn to recognize typing mistakes in a word pupils are presented a word with swapped adjacent letters and they are supposed to identify those and swap them back to restore to original word. Here are multiple difficulty levels possible, where on the easy level only one pair of adjacent letters is swapped and on harder levels multiple pairs of adjacent letters are swapped.

Example 2.5. The word BKIE is given. By swapping the second and third letter the original word BIKE is restored.

2.1.2 Representing Numbers like the Maya

Today one is used to the decimal number system (base number 10), with 10 symbols. The Maya used a different number system with a base number of 20 i.e the vigesimal number system. It is believed that the Maya used their ten fingers and ten toes to count adding up to twenty. But instead of having a symbol for each number as in the decimal system, the Maya used three different symbols: zero (a turtle shell, belly side up), one (a dot) and five (a bar) [5]. The mayan representation of the decimal number from 0 to 19 can be found in figure 2.1.

The following exercises are supposed to familiarize pupils with a new number system, the mayan number system. First converting numbers between the decimal number system and the mayan numbers is trained topped of an exercise about adding two mayan numbers.

Representing mayan numbers

A decimal number is presented to the pupils and they need to choose the correct amount of dots and bars representing the decimal number. For the purpose of simplicity, only decimal numbers between 1 and 19 are chosen.

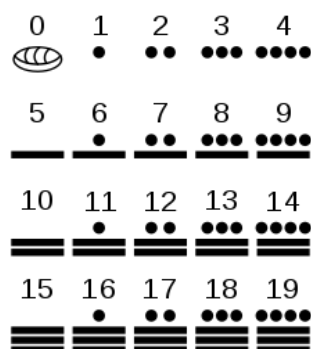


Figure 2.1: Representation of the Maya numbers from 0 to 19

Example 2.6. The decimal number 17 is written as three bars and two dots.

Understanding mayan numbers

In this exercise the pupils learn to understand mayan numbers. Again only decimal numbers between 1 and 19 are used and the pupils need to understand what mayan number is shown and write down the decimal equivalent.

Adding mayan numbers

To sum this section up, adding mayan numbers is learned. This exercise combines the previous two, since the pupils need to understand the summands given in the mayan number system, add them and write the sum down in either decimal number system or the mayan number system.

2.1.3 Representing Numbers with Coins

The following exercises introduce a new number system and train an already learned one: the binary number system and the decimal number system. Both number systems are practiced with coins with numbers. The binary coins include the following numbers: 1, 2, 4, 8, 16, 32 and 64 (Fig. 2.3). The decimal coins include 1, 2, 5, 10, 20 and 50 (Fig. 2.2). Overall, the same concepts are practiced for both number systems with the limitation that every binary coin can at most be used once. For both number systems the following exercises are given:

- Conversion of a decimal number to its coin representation
- Conversion of a number given in its coin representation to a decimal number

Additionally, for the decimal number system the following exercise is given:



Figure 2.2: Representation of the decimal coins



Figure 2.3: Representation of the binary coins

- Reducing the number of decimal coins in a given set of decimal coins

Conversion of a decimal number to its coin representation

This exercise includes two difficulty levels:

- Converting a decimal number to a coin representation, where the sum of all coins are equal to the decimal number
- Converting a decimal number to a coin representation, where the sum of all coins are equal to the decimal number **and** the amount of used coins is minimal.

Conversion of a number given in its coin representation to a decimal number

This exercise is straight forward. A number given in its coin representation, either binary or decimal coins, have to be converted to a decimal number.

Reducing the amount of decimal coins in a given set of decimal coins

Similar to the previous exercise, a number in its coin representation is given and pupils have to display the same number but with less coins.

2.2 Keeping Information Secret

The previous section [2.1](#) was about representing information with symbols. This section is about keeping information secret. Ciphers have been used for thousands of years [\[6\]](#). They are used to keep information secret from people, that are not supposed to have knowledge of it. Not encrypted information is called

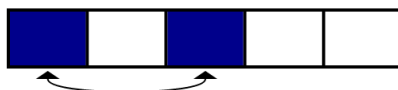


Figure 2.4: Pattern



Figure 2.5: Cipher text of an encrypted number

clear text. Once one encrypted a clear text, it is called a cipher text and only people who know how to decrypt the cipher text can read originally encrypted information. The exercises in this section are introducing pupils to the concepts of ciphers.

2.2.1 Cipher Texts from Reversed Letters

The cipher used in these exercises is a simple mix up of letters and both directions are trained: encryption and decryption. In the decryption exercise, the pattern, on which the clear text was encrypted with, is shown. The pupils need to understand the pattern and move the letters in the cipher text accordingly to retrieve the clear text. The encryption exercise is set up analogously. Multiple difficulty levels are possible by changing the amount of moved letters.

Example 2.7. The cipher text is ULFSS and the pattern is shown in figure 2.4. By moving the letter in the cipher text according to the pattern, the clear text can be retrieved: FLUSS.

2.2.2 Cipher Texts from New Characters

Sometimes, only moving symbols is not enough to keep information secret. A better way is to substitute symbols with new symbols. These symbols may be letters, numbers or completely new symbols, that are solely invented for the purpose of encrypting information. In the following exercises the last approach is followed. Again both direction, encryption and decryption, are trained. But this time, instead of having a pattern, there is a symbol table showing how the letters are encrypted.

Example 2.8. The cipher text is shown in figure 2.5 and the symbol table in figure 2.6. By using the symbol table one can decrypt the cipher text to 52.

	.	:	:	:
□	0	1	2	3
○	4	5	6	7
△	8	9		

Figure 2.6: Symbol table to encrypt numbers



Figure 2.7: Trees from height 1 to 3

2.3 Learning from Data

The following exercises are logic-based, combinatorial puzzles. The idea is that pupils need to conclude the solution by a partially completed grid.

2.3.1 Row of Trees

The row of trees is a one dimensional grid i.e a row either of size 3 or 4. In every row there is exactly one tree of every height between 1 and 3 (Fig. 2.7) or 4 (Fig. 2.8) respectively. At both ends of the row the amount of tree visible from this end of the row is given. Pupils are given an empty row with only the number of trees seen from both ends of the row and need to place a tree of each height such the aforementioned rules are met.

Example 2.9. For a row of size 3, if given the value 2 for both ends of the row, then one possible solution to the puzzle is shown in figure 2.9.

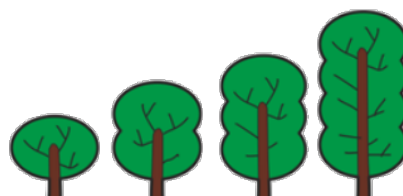


Figure 2.8: Trees from height 1 to 4

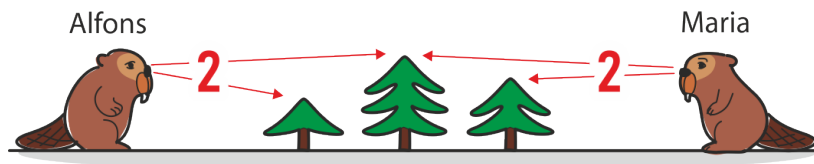


Figure 2.9: Visualization of the puzzle solution from the tree row example

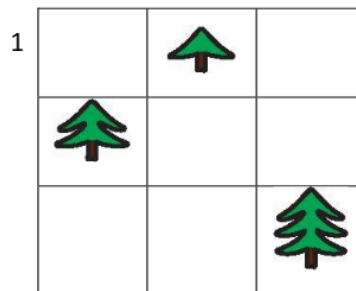


Figure 2.10: Example of an unsolved 3x3 tree sudoku

2.3.2 Tree Sudoku

Tree sudoku is similar to the well known traditional sudoku with the difference that trees of different heights are placed instead of numbers, and for end of every row and collumn the number of visible trees is given. Otherwise, the puzzle follows the same rules as the row of trees and is either of size 3x3 or 4x4.

Example 2.10. An example of a 3x3 tree sudoku is shown in figure [2.10](#)

Implementation

3.1 Introduction

3.2 Vue.js

Vue.js is developed by a company, but by Evan You and was first published in 2014. It is an alternative to Angular and React and was supposed to be a lightweight version of Angular. Vue.js is also based on reusable components, each having its own HTML, Javascript and CSS [7].

3.3 Typescript

3.4 Basic functionality

3.5 Representing Information with Symbols

3.6 Keeping Information Secret

3.7 Learning from Data

3.8 Testing

3.8.1 Unit and Snapshot Testing

3.8.2 End to End Testing

3.9 Continuous Integration

Conclusion, Drawbacks and Further Work

4.1 Conclusion

4.2 Drawbacks

- Not all exercises per topic
- Own learning environment

4.3 Further Work

- Inegrate into existing learning environment
- Add additional exercises

Bibliography

- [1] Lehrplan 21. Accessed on 01.02.2021. [Online]. Available: <https://lehrplan21.ch>
- [2] Medien und informatik. Accessed on 01.02.2021. [Online]. Available: <https://www.regionalkonferenzen.ch/medien-und-informatik>
- [3] Informatik-biber. Accessed on 11.02.2021. [Online]. Available: <https://www.informatik-biber.ch>
- [4] T. Ottmann and P. Widmayer, *Algorithmen und Datenstrukturen*. Spektrum, 2012.
- [5] S. A. Kallen, *The Mayans*. Lucent Books, 2001.
- [6] A brief history of cryptography. Accessed on 11.02.2021. [Online]. Available: http://www.cypher.com.au/crypto_history.htm
- [7] Vue.js. Accessed on 11.02.2021. [Online]. Available: <https://vuejs.org/>

First Chapter Title

Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua.

Todo: This is a TODO annotation.

A.1 First Section Title

Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua.

A.1.1 First Subsection Title

Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua.

Remark: This is a REMARK annotation.

Theorem A.1 (First Theorem). *This is our first theorem.*

Proof. And this is the proof of the first theorem with a complicated formula and a reference to Theorem A.1. Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua. Lorem ipsum dolor sit amet, consetetur sadipscing elitr, sed diam nonumy eirmod tempor invidunt ut labore et dolore magna aliquyam erat, sed diam voluptua.

$$\frac{d}{dx} \arctan(\sin(x^2)) = -2 \cdot \frac{\cos(x^2)x}{-2 + (\cos(x^2))^2} \quad (\text{A.1})$$

□

Lemma A.2. *lorem ipsum dolor sit amet*

Corollary A.3. *lorem ipsum dolor sit amet*

Observation A.4. *lorem ipsum dolor sit amet*

Definition A.5. lorem ipsum dolor sit amet

Problem A.6. lorem ipsum dolor sit amet

Assumption A.7. lorem ipsum dolor sit amet

Example A.8. lorem ipsum dolor sit amet

Claim A.9. lorem ipsum dolor sit amet

Remark A.10. lorem ipsum dolor sit amet

Note that in L^AT_EX, “quotes” do not use the usual double quote characters.