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DEPARTMENT OF INFORMATION SCIENCE AND ENGINEERING

DESIGN THINKING LABORATORY REPORT

IS237DL

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Huffman Coding

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DEPARTMENT OF INFORMATION SCIENCE AND ENGINEERING

CERTIFICATE

Certified that the Design thinking Laboratory work titled *'Huffman Coding'* is carried out by **Advith R Padyana(1RV22IS005), Arnav Jain(1RV22IS011), Parth Keshav Chaturvedi(1RV22IS041), Suraj Gorai(1RV22IS071)** in partial fulfillment for the requirement of degree of **Bachelor of Engineering in Information Science and Engineering** of the Visvesvaraya Technological University, Belagavi during the year 2023-2024. It is certified that all corrections/suggestions indicated for the Internal Assessment have been incorporated in the report.

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ACKNOWLEDGEMENT

ABSTRACT

The effectiveness of the Huffman Tree technique in optimizing network routing protocols, starting with a comprehensive explanation of Alan Hoffman's Huffman Tree algorithm. The algorithm's iterative construction process and goal of minimizing the maximum path length are outlined, along with its theoretical foundations and historical background. Practical applications and performance assessments of the algorithm in various network routing scenarios are then detailed, highlighting its capacity to enhance routing efficiency and reduce latency through simulation-based studies and comparisons with existing compression algorithms like Lempel-Ziv coding.

Huffman coding, known for its simplicity and effectiveness, finds widespread use in numerous fields and industries, particularly in reducing data transmission overhead in telecommunications and serving as the basis for compression formats like JPEG, MP3, and MPEG in multimedia applications. As data continues to proliferate across different domains, effective compression techniques like Huffman coding become increasingly vital. Despite its benefits, Huffman coding does have limitations, dependency on accurate symbol frequency analysis and its non-adaptive nature for dynamically changing data sets.

The motivation behind projects focusing on Huffman coding lies in its enduring relevance due to its simplicity and effectiveness, despite its drawbacks. These projects aim to put Huffman coding into practical use, analyze the process of building Huffman trees, assess computational complexity, and study compression ratios achieved. Phases of such projects typically involve research and analysis of theoretical foundations, design and planning using visualization software, implementation in selected programming languages, testing and evaluation for efficiency and performance, optimization based on feedback, and documentation for real-world deployment.

Throughout the project development process, effective data structures, algorithms, and error management techniques are paramount to achieve high compression efficiency while maintaining data integrity and mitigating data corruption. The iterative nature of these projects involves continuous refinement and optimization to enhance algorithmic efficiency and overall performance, ultimately culminating in documented findings ready for real-world deployment.

Contents

2. EMPATHY

Introduction to Empathy

The process of design thinking begins with empathy. Research is done by design teams to personally understand the needs of their users. They put aside presumptions in order to observe and speak with users to gain insights into their environment. They are able to comprehend user experiences, motives, and issues in this way.

The capacity to perceive the world from another person's perspective, to feel and see things as they do, and to see things as they see them, is known as empathy. While it's true that none of us can truly feel things in the same manner as others, we can try to come as close to this as we can. This can be accomplished by setting aside preconceived notions about the world and choosing to comprehend the concepts, ideas, and thoughts.

Client details

1) **Client name-Sarthak Gupta**.

Sarthak Gupta offered the following empathy-related insights:

Sarthak stressed the significance of creating algorithms that take into account the effects on end users in addition to performance and efficiency. He emphasized that in order to make sure that the compression and decompression procedures are smooth and easy for users to understand, engineers must have empathy for consumers who could deal with systems that use Huffman coding. Sarthak also stated that he expected the initiative to take into account the wide variety of users that could interact with Huffman coding.

Need Analysis with evidences

Challenges faced by client
- Understanding the creation of the tree and the encoding process in Huffman coding is difficult.
- Insufficient tools to efficiently compress the files using Huffman tree.
- Not enough to strengthen knowledge and use of Huffman coding methods.
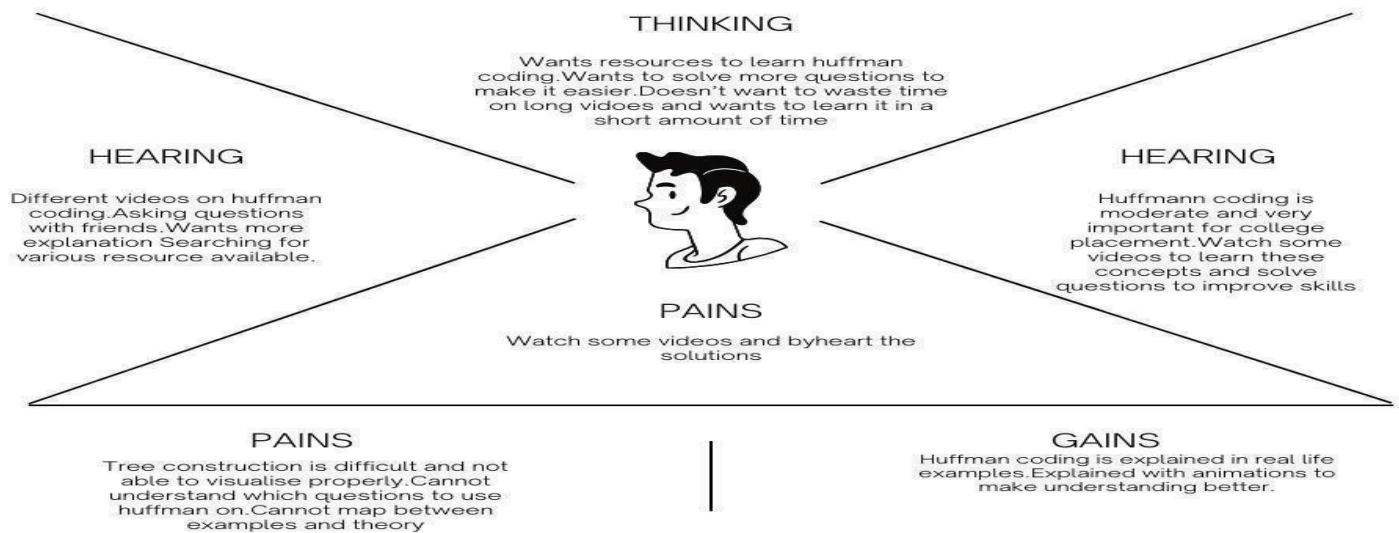- How to utilize Huffman coding in day to day life.

Empathy Map

Figure 2.1 Empathy Map

Challenges faced by Teachers:

- Students can't imagine Huffman coding.

- Mapping between textbook problems and real-life examples is not done.

- Students don't have an outlet to actively compress and decompress the files that they submit for their projects.

Insights:

- Use of interactive website to help in better visualization

- Create assignment problems to help students retain their interest and learn how to compress and decompress the files using Huffman Coding.
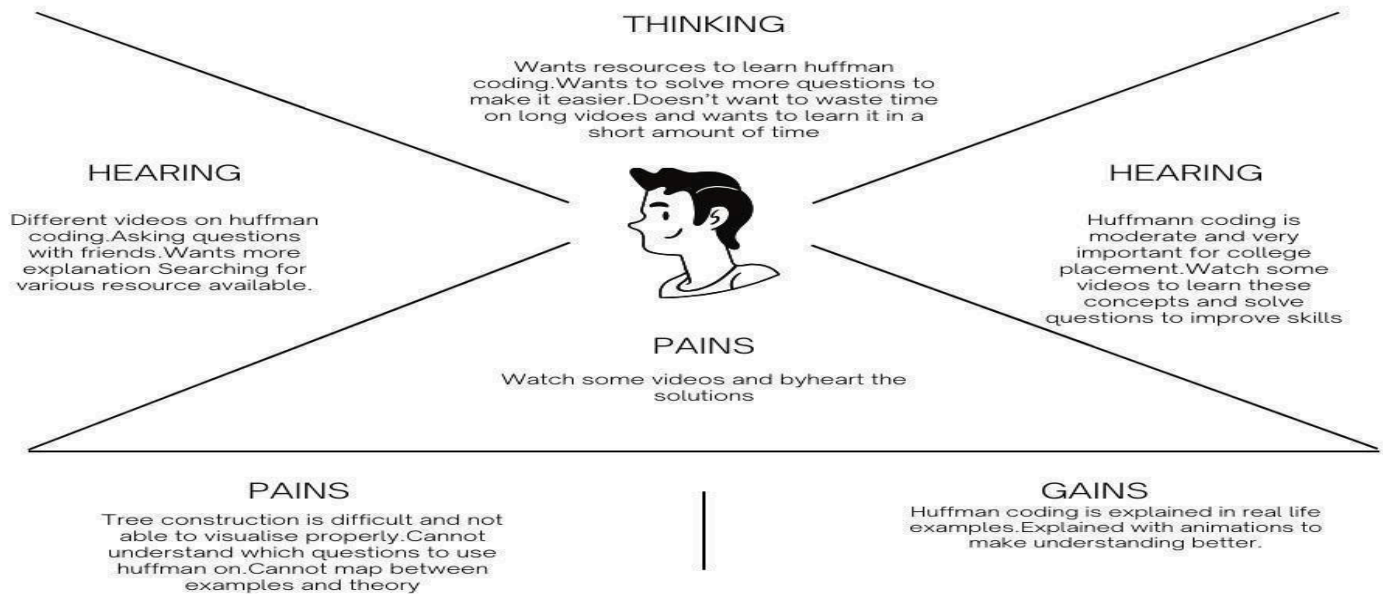
EMPATHY MAP TEACHERS

THINKING

Wants resources to learn huffman coding.Wants to solve more questions to make it easier.Doesn't want to waste time on long vidoes and wants to learn it in a short amount of time

HEARING

Different videos on huffman coding.Asking questions with friends.Wants more explanation Searching for various resource available.

HEARING

Huffmann coding is moderate and very important for college placement.Watch some videos to learn these concepts and solve questions to improve skills

PAINS

Watch some videos and byheart the solutions

PAINS

Tree construction is difficult and not able to visualise properly.Cannot understand which questions to use huffman on.Cannot map between examples and theory

GAINS

Huffman coding is explained in real life examples.Explained with animations to make understanding better.

Figure 2.2 Empathy Map for Teachers

Questionnaire and Analysis

Have you ever used Huffman coding trees and the greedy technique?
43 responses

Legend:
- Yes
- No
- Maybe

62.8%
9.3%
27.9%
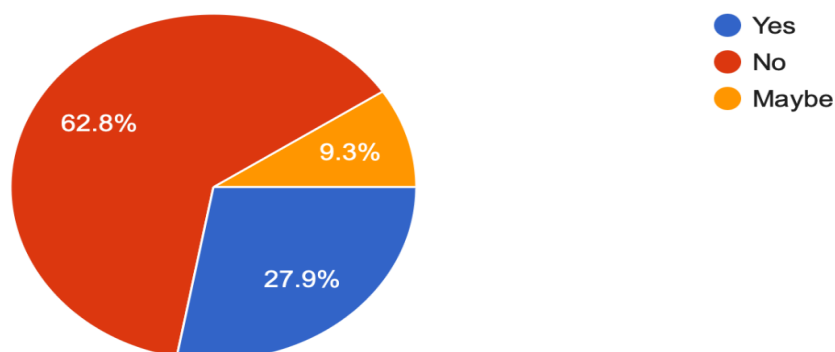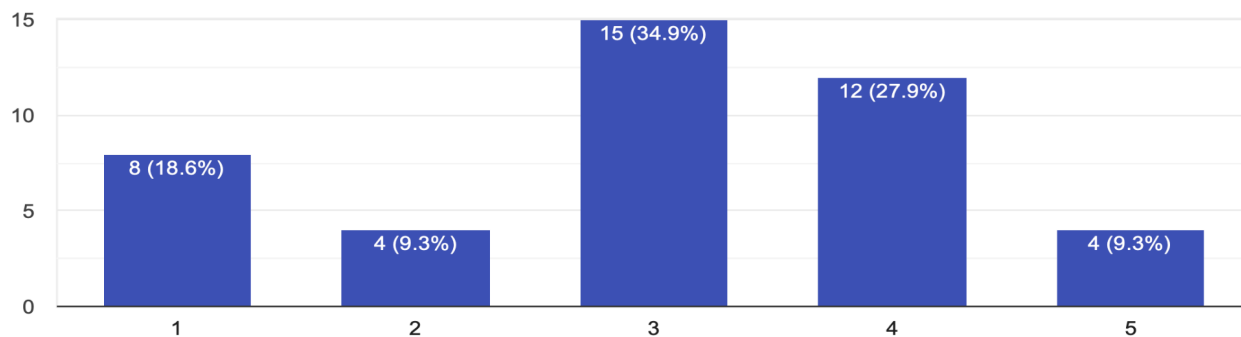
Question 2.1

On a scale of 1-5, how challenging do you find using the greedy technique to implement Huffman coding trees?
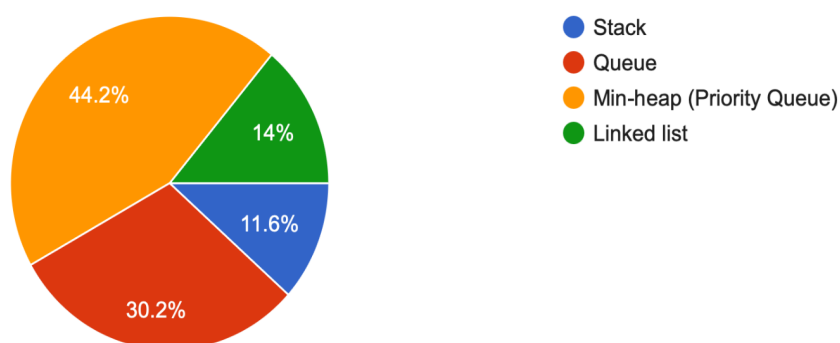
43 responses

Question 2.2

What data structure is commonly used in the greedy technique for Huffman coding to efficiently select nodes with the lowest frequencies?
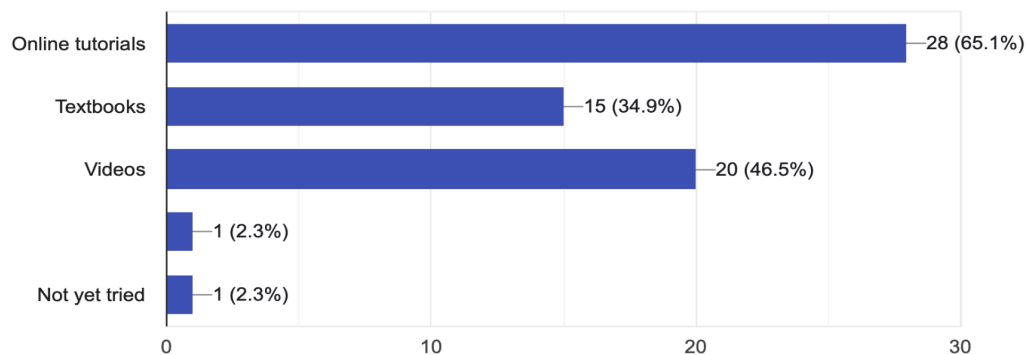
43 responses

Question 2.3

If you have tried to learn about the Greedy Technique: Huffman Coding Trees, what resources or methods did you find most helpful in understanding it?
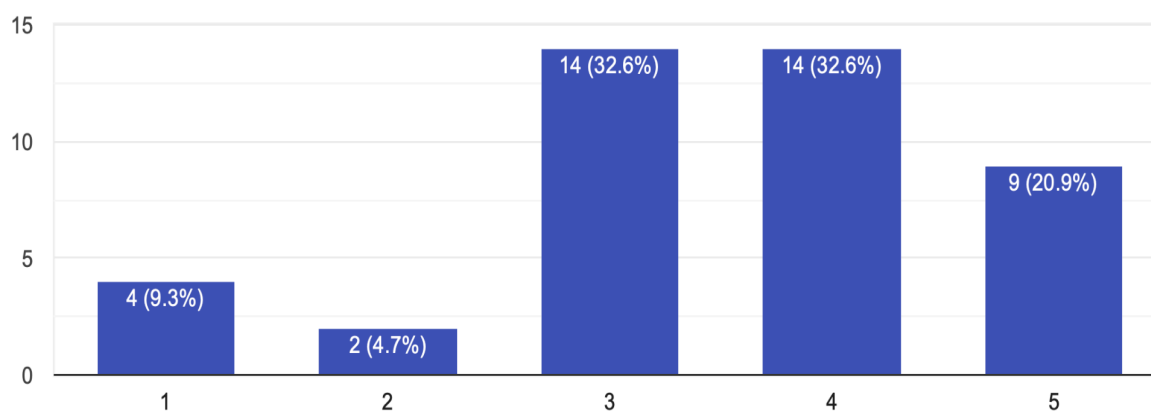43 responses

Question 2.4

From your perspective, how important do you think it is for individuals interested in computer science and algorithms to be aware of and understand algorithms like the Greedy Technique?
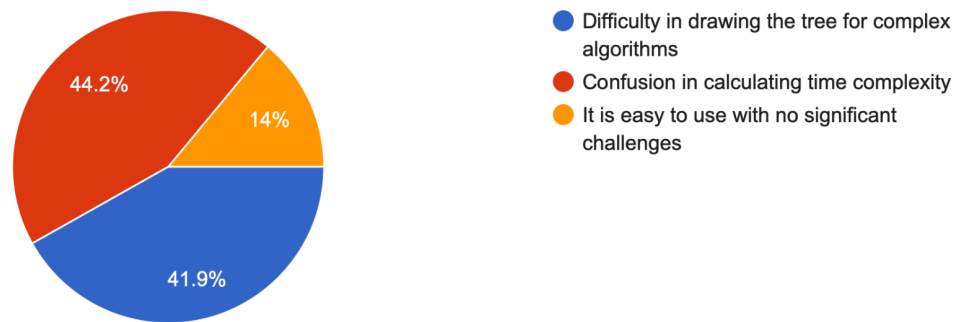43 responses

Question 2.5

Select the common challenge faced when learning a new algorithm:
43 responses

- Difficulty in drawing the tree for complex algorithms
- Confusion in calculating time complexity
- It is easy to use with no significant challenges

44.2%
14%
41.9%

Question 2.6

Would you like to have more sessions on different algorithms and problem solving techniques?
43 responses

- Yes
- No
- Maybe

14%
20.9%
65.1%
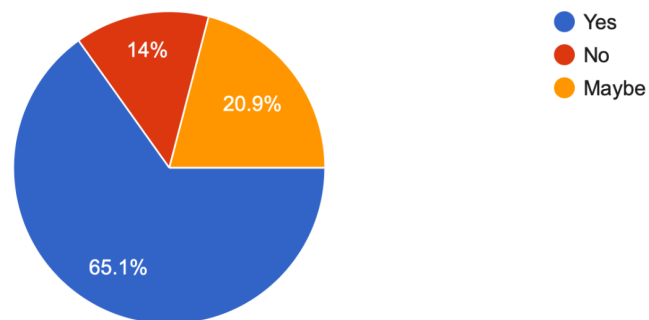
Question 2.7

3. DEFINE

Problem Statement

The goal of the project is to create an interactive website that is used to compress and decompress the files to help teachers and students better understand the Huffman Coding. Through the use of interactive websites, the tool aims to make abstract concepts more approachable, encourage experiential learning, and establish connections between abstract ideas and practical applications. The tool's objectives are to support teachers in effectively teaching key topics in the classroom and to improve student knowledge and engagement through the use of interactive websites. In the end, the initiative aims to improve science instruction's impact, accessibility, and engagement for learners of different backgrounds and learning preferences.

Design thinking challenges identified

During the first phase, it was possible to identify quite a few challenges that were faced by people. Via surveying, interviewing and discussing, it was found the following challenges that were prominent and most faced by people.

- Logical understanding
- Complexity Simplification
- Engagement and Retention
- Technology Integration
- Educator Empowerment
- Accessibility and Inclusivity

Specific Objectives:

- **Visualizing Huffman Structure:** Create an immersive website that represents Huffman Coding in, allowing students to see how files are being compressed or decompressed.
- **Simplifying Complex Concepts:** Use simple language and intuitive visualizations to explain the abstract principles behind Huffman Coding making these concepts easier for students to understand and for teachers to explain.
- **Hands-On Learning:** Incorporate interactive elements into the website, enabling students to

manipulate files.

- **Connecting to Real-World Examples:** Include real-world examples and applications of Huffman Coding to help students relate these concepts to everyday data manipulation.
- **Supporting Educators:** Provide educators with a comprehensive website, including interactive demonstrations, and assessment tools, to facilitate the integration of the website into classroom instruction.
- **Addressing Diverse Learning Styles:** Design the educational tool to accommodate different learning files, ensuring that it is accessible and engaging for students with varying levels of prior knowledge and understanding.

By addressing these objectives, the project aims to enhance student comprehension, engagement, and retention of concepts related to Huffman Coding, while also supporting teachers in effectively conveying these concepts. Ultimately, the goal is to democratize access to science education and inspire a passion for learning among students of all backgrounds and abilities.

4. IDEATE

Introduction to ideation

Ideation is the third stage of the design thinking process where participants in a design thinking workshop come up with ideas on how to solve a specific user problem. The design thinking process is made up of three phases: empathize, ideate, and prototype.

The ideation phase of design thinking is guided by the user problems that were defined during the empathize phase. Ideation is about the exploration and identification of potential solutions. Not all ideas will be viable solutions, and that's okay. The primary goal of ideation is to spark creativity and innovation.

Ideation techniques used and Ideation process followed

1. Brainstorming

Brainstorming is a well-known technique that leverages the interaction between a group of people to create solutions by building on one another's ideas. For more effective brainstorming, use this technique with a group of about five to seven participants.

Brainstorming on the various ideas that could be on the different techniques that could be used for making the videos.
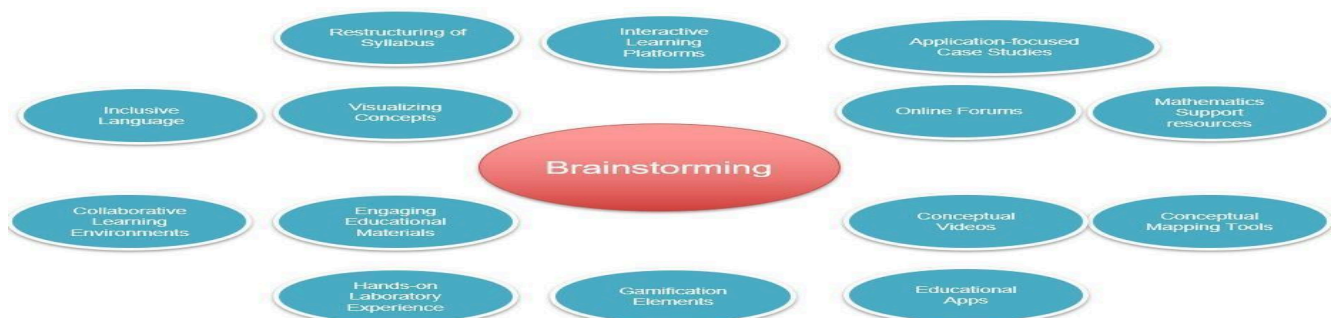

Figure 4.1: Brainstorming

2. Worst Idea

The worst idea technique asks participants to come up with their worst solutions to a problem. While a brainstorming session encourages all ideas, some people may still feel nervous about potential criticism—this technique removes that fear because it welcomes bad ideas. Through this method possible demerits of the application were found.

3. Mind mapping

Mind mapping is a visual technique that establishes relationships between the problem your team is trying to solve and potential solutions.
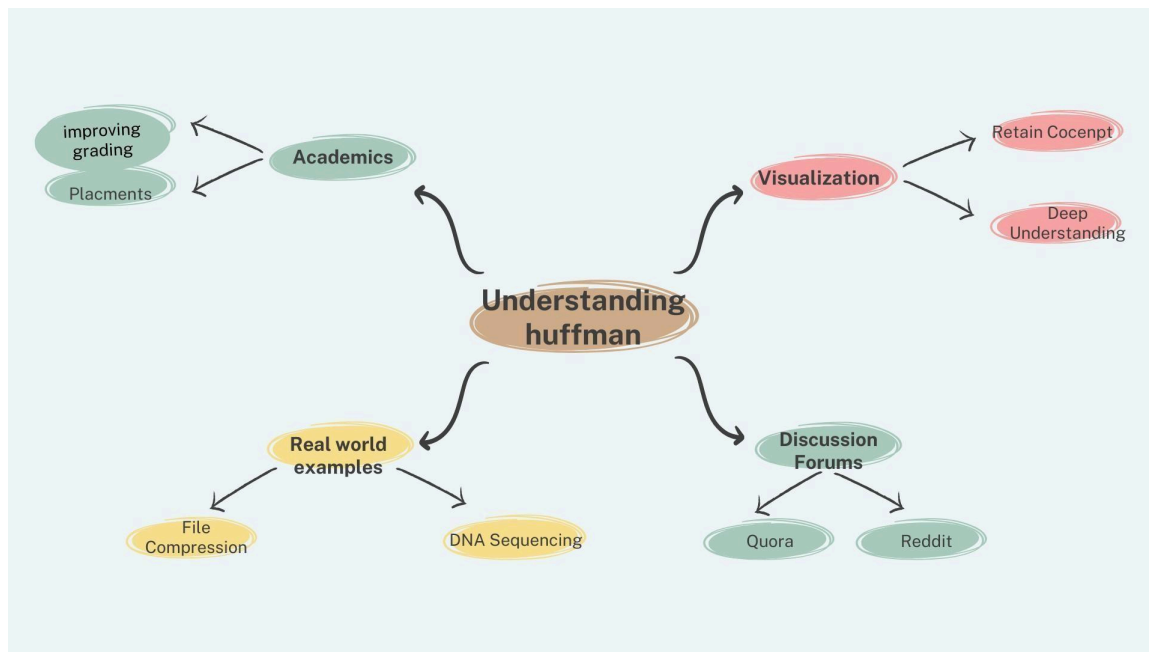
Figure 4.2: Mind Map

4. Questioning assumptions

Many industries have an assumed set of beliefs about how to do things, but this technique challenges those beliefs to try to create more original ideas. The already made assumptions of a problem were questioned and new ways to think of the problem was thought of.
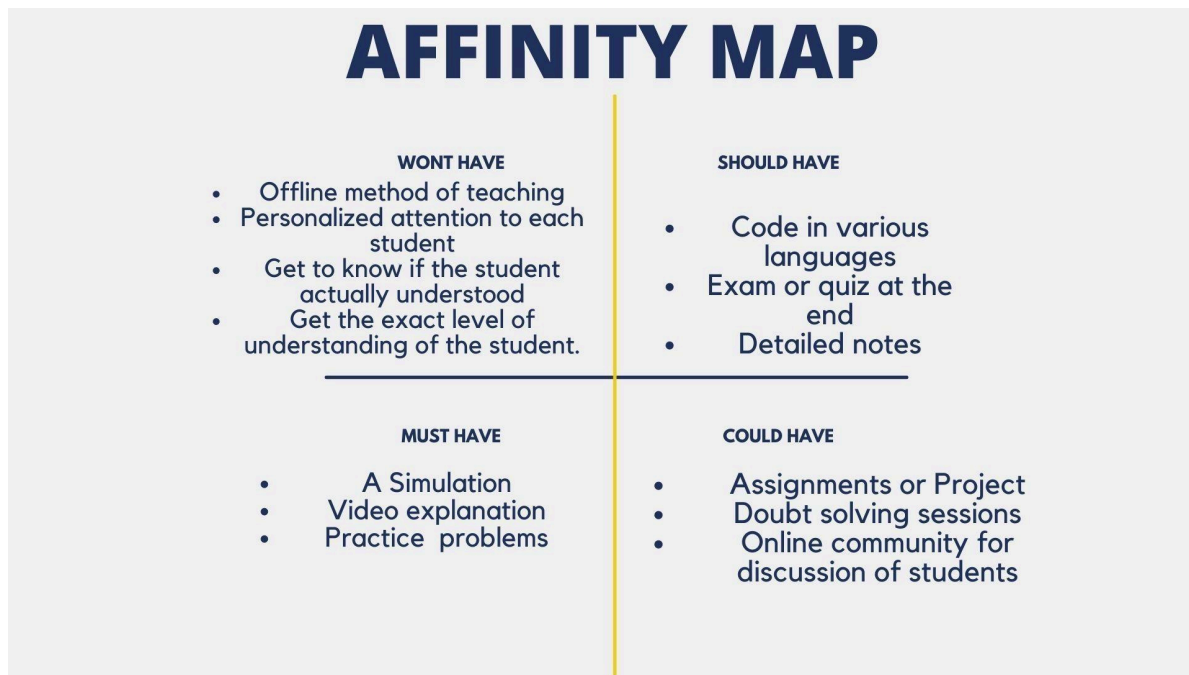
Affinity Map

Figure 4.3: Affinity Map

Ideas generated with descriptions

The various ideas for the prototype were

- Normal website that only compresses or decompresses the file.

    This kind of prototype aims on using a frontend and backend development to help students compress their files.[4]

- Giving out some practice problems after the user learns how to use our website so that they can easily compress or decompress their files.

- Tutorial on usage of our website

    The aim is to use tutorials along with pictures to explain the concept of Huffman Coding. Using pictures and tutorials make it easier for students to understand the concepts of Huffman Coding.

- This website helps the students and the teachers to compress and decompress their files and it is easily accessible and can be used without any hassle. In the website basics

concepts of Huffman Coding are also explained so that the students can learn the concept behind the file compression and decompression which will help the students to know better how our website works.

5. PROTOTYPE

Introduction to Prototyping

As a crucial stage in the design thinking process, prototyping enables end users to evaluate the suggested solution. Additionally, it lets end users provide input that can assist the suggested
the solution gets better. Prototypes come in a variety of forms, and the kind that is employed will rely on the issue being addressed.

List of options available for prototyping

The various types of prototype options available were

- Video showcasing Huffman Coding
  This kind of prototype aims at using a video of Huffman Coding. This traditional method aims to use the technique that the students are the most familiar with.
- Video using animations
- The aim is to use animations along with pictures to explain the concept of Huffman Coding. Using pictures and animations make it easier for students to understand the concepts of Huffman Coding and to help them to visualize.
- Website Prototype
- The final method is to create a website with which the students can easily compress and decompress the files easily. Due to the interaction achieved between the student and the application it was felt that this method will better immerse the student and help him understand the concepts way better.

Prototype selected and reasons

The final prototype selected was an interactive website which shows the simulation of the compression or decompression of files. The user would be able to do 2 things in the
website . He is greeted with the main screen with which he would be able to access these 2 things. In the main screen he can either go for compression or decompression of the file.

Some of the learning videos that which was provided are

- Slides Link: This is the link to the slides that the student can use for learning more about the concept.

- Huffman Coding Algorithm and its applications: This video gives the explanation of the Huffman Coding and the various concepts such as recursion. A brief explanation of Huffman Coding is given. After that an explanation of Huffman Coding is given with real life examples. This will help in giving the student the required intuition. After watching this video, the student should be able get the basics Huffman Coding and be able to understand Huffman Coding problems.[4]

- The website demo: Though the website is completely user friendly and easy to use a video was provided to further help the user.. After going through this video, the user would be able to understand the website usage completely and access its features.

Another option which the user can have after this to try out the simulation. After watching the video, a user should be able to get the simulation of Huffman Coding and be able to completely understand its importance. Easy to use controls and instructions and the demo video should be able to further help the students understand. Having a degree of immersion will help even more. If the student feels any doubts, they can just watch the videos to help them.

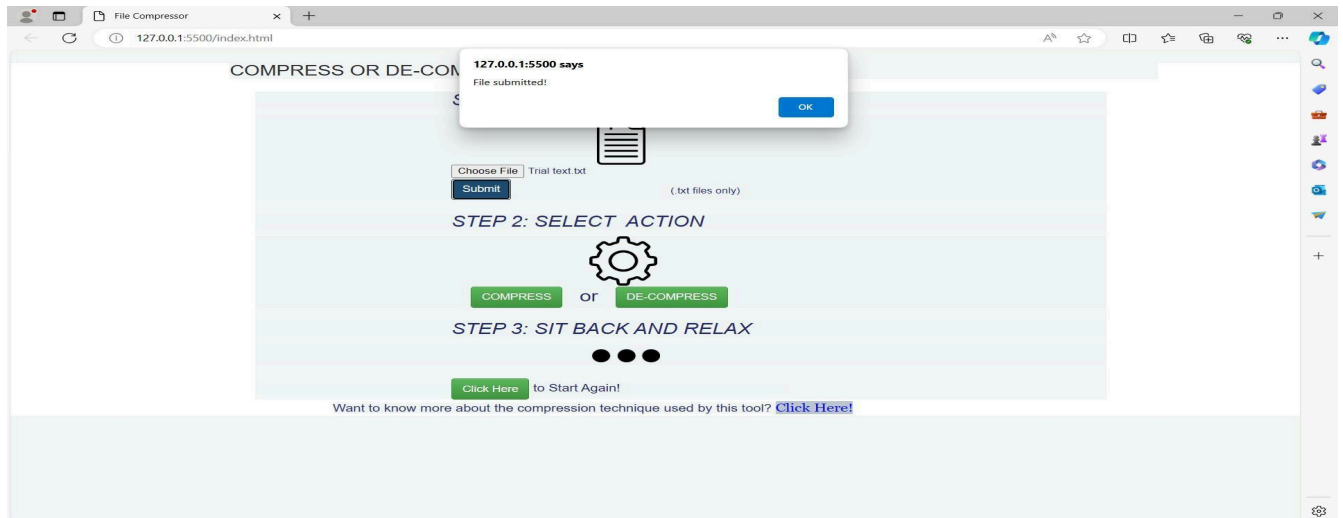# Prototype implementation details and Screenshots
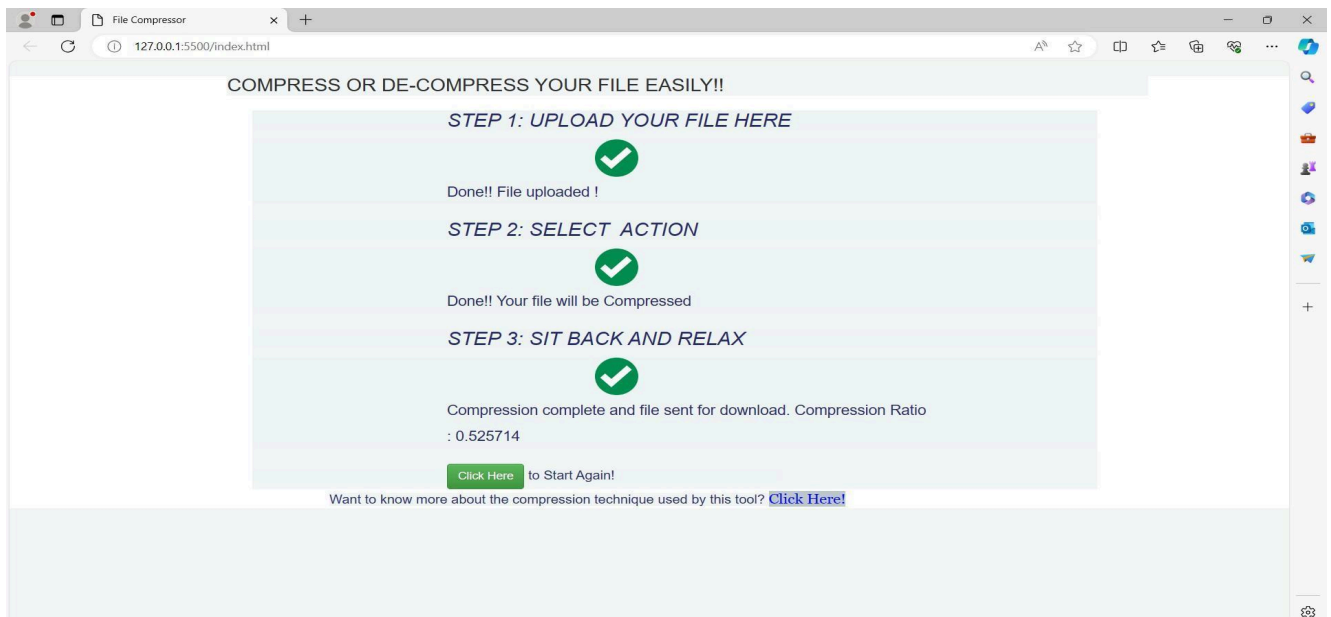

Figure 5.1: Selecting a file
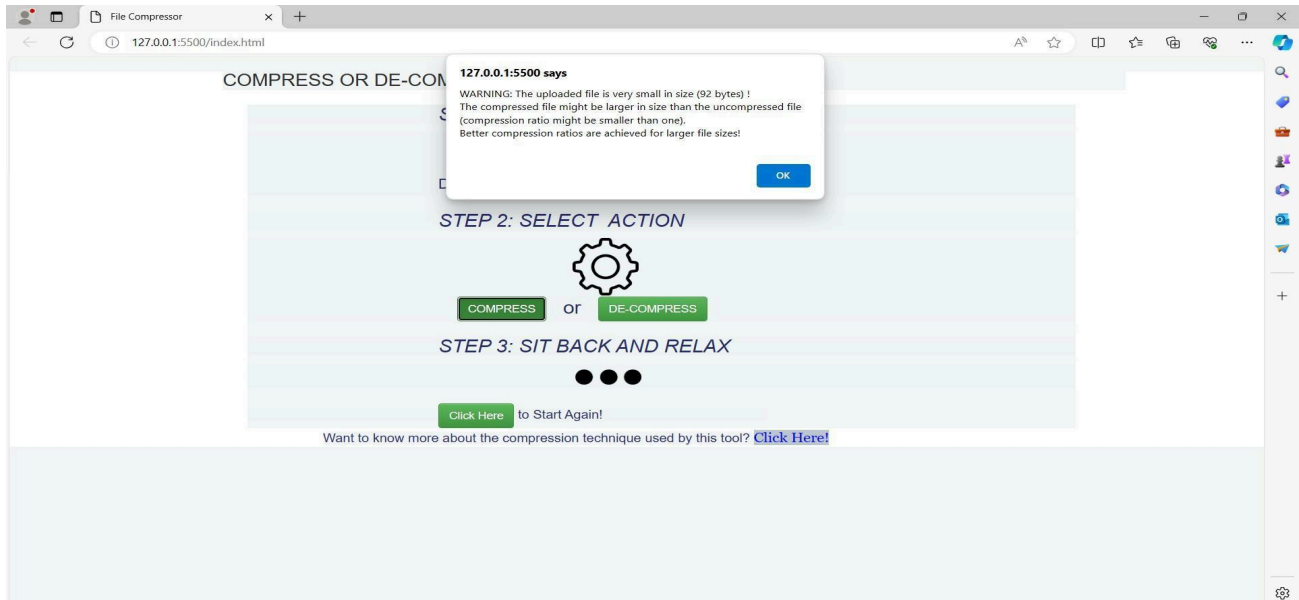

Figure 5.2: Downloading the file

Figure 5.3:Boundary Condition

Figure 5.4: Information about Huffman Coding

6. TESTING

Introduction to testing

Prototyping and testing go hand in hand in the Design Thinking process. Designers are able to produce user-centric products thanks to user testing. Designers can detect potential usability problems before the product is released onto the market by doing frequent prototype testing. As a result, in the project's case, the prototype and testing phases coincided.

The user review served as the basis for all of the testing. The product was further modified thanks to the reviews. This made it possible to ensure that the final product was far superior than what was first intended.

Types of testing done

The various type of testing done are:

Testing the Website: In simple words, it is the process of improving and enhancing the interactivity of a website. It focuses on the look and design of the Website. Every screen, buttons, page and various other visual components that you see at the time of using a website. A good design offers the users simple navigation and engaging content. This makes the visitors satisfied with the services of the website. Since the website should be as smooth as possible.

Student Review: Product was shown to various students, asked them could they understand it. Feedback of various forms was also asked for. These reviews were also very helpful in improving the videos and website.

Clients and their Feedback

A stakeholder is any person, organization, or group that is affected by how a project or business endeavor turns out. Stakeholders might be people or organizations other than the one funding the project, and they all want to see it succeed. Teachers and students are the project's two major

investors.

Students: Students are perhaps the greatest stakeholders in education because they are the ones who are doing the learning. A good education can provide students with the knowledge and skills they need to be successful in life. But if their teachers fail them, students will have lesser access to educational, cultural, and social capital in adulthood. Because students are stakeholders in their own education, there is an argument from progressive educators that students should be consulted about what and how they are taught.

Teachers: Teachers are the ones who actually carry out the work of educating students, making them examples of internal stakeholders. They have a great deal of control over what and how students learn in their classrooms. Teachers also have a vested interest in ensuring that schools are effective because their jobs depend on their success. If parents think their child is not learning, they may withdraw their child from the school and the school will fail. As an educator, another reason teachers feel they have a big stake in education is that they feel they have the expertise to know what to teach and how it should be taught to their students. Thus, teachers try to engage closely with other stakeholders (in particular, parents) to come up with the best approaches to educate each child. Since teachers are also going to use the website, their reviews enable them to make the required changes.

Changes/modifications incorporated after feedback from the customers

After the valuable feedback from the teachers and students some changes were incorporated in the prototype.

Adjustments done

The following changes were incorporated.

- Adding the details of file along with the simulation: In the initial phase of the product there was only a simulation of the compression and decompression of files. It was under the assumption that the student already knew about the size and limit of the files. But since students who don't know about this might also want to try to use the application they were

taken into account and some changes were made in the application. This helped in making sure that the application was accessible to all.

- Adding text in the simulation: After some more inputs from the user, a decision was taken in showing why it was important to know about Huffman Coding. Texts were added in it to show that Huffman Coding was actually used. This helped in assuring that the product would even teach a person who doesn't know much about Huffman Coding problems.

- Better design: The design at the start was to be honest quite bland. Since UI/ UX is one of the most important aspects of attracting the user. Various designs were tried and problems were found and one was finalized. Menu was added to further help the user.

Learnings

The following was the learning while doing the prototype

- Importance of Survey: The importance of survey and knowing about what the end user actually wants was learnt. This helped in concentrating on what the product should
- concentrate on.
- Importance of being connected with the user: Due to being connected with the user in
- each phase of the design thinking process changes were made in the earlier stages of the prototype itself. This saved a lot of precious time.
- Changing prototypes: Changes were made to the prototype again and again to make sure that final prototype came out to be quite good.

7. CONCLUSION AND FUTURE SCOPE

Conclusion

Huffman coding has shown to be a very successful technique for lossless data compression, especially for applications like picture, audio, and video reduction and data transfer over networks where it is essential to reduce file size without sacrificing content.

Huffman coding's ease of use and effectiveness in creating variable-length codes dependent on the frequency of symbols in the input data are two of its main features. This results in the best compression ratios possible for various kinds of data. Huffman coding does, however, have certain drawbacks. It functions best when the symbol probabilities are known ahead of time and stay constant. However, it makes the encoding and decoding procedures more difficult.

Future Scope

Integration with Contemporary Compression Techniques: To reach even greater compression ratios, Huffman coding can be combined with other compression techniques such as dictionary-based approaches, run-length encoding, and arithmetic coding.

Hardware Acceleration: Hardware-accelerated Huffman coding techniques may be used in response to the growing need for real-time data processing. The speed and effectiveness of compression and decompression operations could be greatly increased by using custom hardware designs or integrating into already-existing hardware platforms.

Application in Internet of Things and Edge Computing: With the increasing popularity of edge computing and Internet of Things (IoT) devices, there is an increasing demand for effective data storage and transfer. Huffman coding might be widely used in these sectors to optimize bandwidth and storage utilization due to its lightweight implementation and low computational overhead.

Quantum Huffman Coding: With the development of quantum computers, it may be possible to investigate Huffman coding variations with quantum influences. In terms of data compression, quantum algorithms may provide fresh perspectives that go beyond the constraints of traditional techniques and pave the way for further investigation and advancement

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