Generating Accessibility: Using AI to Improve Higher Education for the Visually Impaired

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Abstract: Visually impaired students face many obstacles in higher education, including access to adapted course material. While accessibility is a legal requirement in many countries, its implementation is linked to practical challenges for educators. In this paper, we discuss the adaptation of existing course materials for blind students in a case study and propose using generative Artificial Intelligence to facilitate the creation of accessible educational materials, contributing to a more inclusive learning environment. We introduce and evaluate the tool TRAIL to generate accessible textual descriptions of lecture slides.

1 INTRODUCTION

In higher education, visually impaired students encounter barriers that hinder their access to and intake of information (Croft, 2020). These challenges, ranging from inaccessible materials to barriers in content delivery, highlight the need for innovative solutions to promote inclusive education (Firat, 2021). Artificial intelligence (AI) brings an opportunity to address these barriers and redefine the educational experiences of visually impaired students (Mohamady et al., 2023).

Visual impairment generally denotes a spectrum of reduced vision, ranging from mild to severe, where individuals may benefit from visual aids or adaptations (Kim et al., 2021). Blindness, on the other hand, implies a total loss of vision, often necessitating alternative means of learning and interacting with the environment, such as braille, auditory cues or assistive technology in the form of screen readers. Screen readers read content from a computer screen to the user for them to comprehend written text as well as graphical visualisations (Sharif et al., 2021). Recognising these distinctions is essential for tailoring support and accommodations to meet the specific needs of individuals along the spectrum of visual challenges (Permvattana et al., 2013).

However, inaccessible documents are only part of the problem. Accessible higher education extends beyond providing accessible documents but also includes accessible campus facilities and external financial support. Environmental barriers, such as access to campus or inadequate accommodations, add to the obstacles they encounter (Bishop and Rhind, 2011). The paper's focus narrows down to the challenges surrounding accessible documents for visually impaired individuals and brings attention to existing barriers.

As Kim et al. (2021) argue, there is a need for scalable, low-cost methods for making documents with visualisations accessible.

This paper explores the possibilities of "generating accessibility" and finds innovative strategies and technologies to allow visually impaired students to navigate educational contexts with greater autonomy. Generative AI refers to technologies that generate images, videos, sounds or, in our case, texts based on models learned from high volumes of training data. Generative AI has the potential to mitigate accessibility challenges by changing how educational content is created, adapted and delivered (Leiker et al., 2023). The inclusivity and accessibility for visually impaired students are discussed, beginning with fundamental principles of the right to accessibility and the current need for accessibility in educational settings. Inclusivity should not be viewed as an additional consideration but as an integral part of the initial solution. Embracing inclusivity from the start ensures that diverse needs are inherently addressed, regardless of background or ability (Heyer, 2021).

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To provide a practical context, the paper presents a prototype developed for parsing inaccessible documents into a screen-readable format. Ultimately, our study contributes to the discourse on enhancing accessibility in education. It advocates for integrating AI as a tool to empower visually impaired students with equitable access to educational resources, as well as giving lecturers a tool for producing accessible material.

2 ACCESSIBILITY IN HIGHER EDUCATION

2.1 Right to Accessibility

The right to inclusive education is recognised as a human right, particularly for people with disabilities. The United Nations Convention on the Rights of Persons with Disabilities (CRPD) from 2006 mandates an inclusive education system at all levels, emphasising the importance of learning together regardless of different learning styles and rates (United Nations, n d). In Article 24 on education in the CRPD, the right of persons with disabilities to education is outlined, highlighting the principles of non-discrimination and equal opportunity. The article calls for the establishment of inclusive education systems at all levels with a focus on the full development of human potential, respect for human rights and effective participation in society. Individuals with disabilities should not be excluded from the general education system based on their disability. It further addresses specific measures for academic and social development, such as the facilitation of learning braille, alternative communication modes and sign language with qualified teachers and professionals (United Nations, n d).

The CRPD shifts with Article 24 towards inclusion in response to the history of segregation and marginalisation of students with disabilities, to oppose discriminatory attitudes and to create an inclusive society. However, there is a significant gap between the aspiration of the CRPD and the global reality of exclusion that many students with disabilities are still facing (Heyer, 2021). Rethinking the purpose of education and rebuilding education systems is necessary to emphasise diversity as a positive aspect (De Beco, 2014).

2.2 Accessibility for Visually Impaired Students

The need for accessibility and inclusion in education for visually impaired students originates from the fundamental principles of ensuring equal rights and opportunities for people with disabilities, as stated in the United Nations CRPD (MacKay, 2006). The convention recognises the importance ”to promote, protect and ensure the full and equal enjoyment of all human rights and fundamental freedoms by all persons with disabilities, and to promote respect for their inherent dignity.”

Any limitations in accessibility to education for visually impaired students imply barriers to their inclusion and participation in society and everyday life. Barriers that visually impaired students face when enrolling at university can be grouped into four categories: attitudinal, institutional, environmental and physical (Hutchinson et al., 1998). Attitudinal relates ”to the attitudes of key individuals with whom a visually impaired student will interact” (Bishop and Rhind, 2011). Individuals, such as parents and institutional staff, play an important role in the academic journey of visually impaired students, and their attitudes can significantly shape the student's experience and development in higher education. Institutional barriers refer to the accessibility of educational resources and materials. Further, environmental factors can include access to buildings, classrooms and accommodation, which can be overcome through lifts, automatic doors, appropriate signs and assistive technology. Physical challenges, such as headaches and tiredness after learning periods, must be managed by the students themselves (Bishop and Rhind, 2011).

Educating staff members is necessary to best support students with visual impairments, including clear communication of the student's disability and provision of adequate materials (Bishop and Rhind, 2011). Similar findings are backed up by (Giese et al., 2022). They state that most barriers for students with visual impairments stem from a lack of qualified teachers and inaccessible learning materials as a result of short-term lesson planning. Thurston (2014) advocates for developing ”visually impaired literacy skills” that would allow real-time access to educational material for inclusive learning and teaching (Thurston, 2014).

Incorporating information and communication technology can help students with visual impairments access information independently and foster the development of new skills at a similar pace as students without disabilities. Bradea and Blâdel (2017) studied the training level and attitude of teachers toward using ICT for educational purposes for increased accessibility. Their research focused on students in Romania and found that the majority of teachers lacked the required skills and knowledge on how to use or adapt educational software to the scholar curriculum for visually impaired students. Their result showed that only 3% of interviewed teachers believed to have high-level skills to support school inclusion of students with visual impairments.

Vanderheiden (2008) coined the term "ubiquitous accessibility" to describe the ability of people with disabilities to access and use the same mainstream technologies. In this context, the concept of "pluggable interfaces" for computing devices is introduced. Pluggable interfaces adapt to a user's disability and are adjusted to the user's profile, interaction history and the specific kind of disability. A study found that the goal of ubiquitous accessibility can only be achieved through consistent screen reading experiences across different devices, applications and operating systems (Billah et al., 2017).

A comprehensive study review investigated factors for the academic success of students with visual impairments (Simui et al., 2018). Challenges were identified in inflexible time constraints for assessments, insufficient availability of adaptive technologies, technical issues with e-learning platforms, difficulties connecting to websites and course management systems and improper use of e-learning tools by lecturers. Problems that the students mentioned were incomplete online course notes, delay of material provision on the website and pacing of in-class presentation (Fichten et al., 2009). Consequently, students with visual impairments are less likely to attend courses in higher education (Athanasios et al., 2009). Factors for success emerging from a study were a positive attitude, self-advocacy and inventiveness (Simui et al., 2018).

2.3 Accessibility of Documents Used in Higher Education

Students with visual impairments use assistive technology to navigate educational material. While fully blind students might use screen or braille readers to narrate on-screen text, those with low vision can use magnifying software to enlarge documents. Graphical material, particularly diagrams, images and visual cues, on the other hand, are often more difficult or impossible to access (Armstrong and Murray, 2007). In many disciplines, these kinds of materials, however, make up an integral part of the studies. It has been discovered that in response, vision-impaired students skip graphical material and ultimately are less likely to enrol in STEM disciplines in comparison to arts and humanities (Butler et al., 2017).

Visualisations are used frequently in higher educational classes to communicate concepts, create variety in study materials and help students keep and regain attention during learning (Naps et al., 2002). Visualisations can play a major role in education to help students create mental models of scientific concepts(Rapp, 2005; Vavra et al., 2011), course content or learning progress (Tervakari et al., 2014; Vieira et al., 2018). In biology, they help students understand structures on a cellular and subcellular level that cannot be observed without microscopes (Jenkinson, 2018). In chemistry, understanding of atomic or molecular structures can be enhanced using visualisations, experimental set-ups are communicated in sketches, experimental data is plotted, and simulations help understand molecular processes (Jones et al., 2005; Burewicz and Miranowicz, 2002). In computer science education, visualisations to illustrate algorithms or data structures (Naps et al., 2002; Fouh et al., 2012). Educational visualisations fulfil several functions (Jenkinson, 2018), such as schematic representations that point students to the central concepts to be understood, diagrams that display data, and flow schemes that describe dynamic processes and temporal order. However, even learners without visual impairments sometimes lack visual literacy to correctly interpret scientific images and understand spatial and temporal dependencies (Jenkinson, 2018; Jones et al., 2005). Visualisations can also replace educational experiments if those are too costly, time-consuming or dangerous to be executed in classrooms (Burewicz and Miranowicz, 2002). Several researchers thus argue that educational visualisation needs to be accompanied by textual explanations to help learners interpret the images and understand the underlying concepts (Vavra et al., 2011; Naps et al., 2002). Beyond education, domain-specific visualisations are commonly used, especially in the natural sciences, to communicate data or experimental results.

Three main methods for making graphical material accessible to visually impaired students were identified: enlargement, description and tactile graphics (Butler et al., 2017). Depending on the student's level of vision impairment, enlarging graphics might not be sufficient. While descriptions give students a general idea, creating an accurate mental model of layout and content is difficult. Tactile graphics provide students with haptic drawings through raised lines. However, this requires financial resources, time and tactile reading skills from the student (Butler et al., 2017).

To provide equal opportunities to visually impaired students, visualisations used in class need to be either described textually or provided as haptic experiences (Jones et al., 2006; Jung et al., 2021). Alternative text for educational visualisations should enable visually impaired learners to form visual mental models (Jung et al., 2021). Visually impaired users of alt texts to diagrams emphasised the need for a clear description of chart type, axes including range and data trend (Jung et al., 2021). They also preferred to learn about the colours used and longer texts and complete texts over shorter texts.

The need for accessible scientific PDF files was addressed in a study (Wang et al., 2021). Scientific papers in PDF format are often unusable on screen readers and, therefore, inaccessible to visually impaired students. SciA11y was proposed as a solution for extracting and rendering semantic content of PDFs as an accessible HTML document (Wang et al., 2021).

There is a large number of recommendations for accessible documents (Kim et al., 2021; Jung et al., 2021).

Alongside graphical material, the document layout can pose accessibility barriers to students with visual impairments when using assistive technology. New approaches have been tested with added spatial information and extra metadata, including information regarding the visual structure. As Moured et al. (2023) state, AI-based image-processing technologies can format accessible content automatically through the extraction and analysis of pixel information. They developed and evaluated a 2D interface for tactile displays that uses an annotated data set and real-time object detection. Users could "arrange a suitable reading order based on their needs" and make the overall process of creating an accessible document lightweight and time-efficient.

Three key criteria need to be met for making documents and presentations accessible: an appropriate reading order, alternative text for non-text objects and grouping of related graphical objects (Ishihara et al., 2006). Further, decorative elements commonly found on presentation slides must be appropriately marked for exclusion by screen-reading software. These mentioned guidelines and requirements can easily be integrated using standard software platforms, such as PowerPoint.

The German Association of the Blind and Visually Impaired in Study and Work has released a guide for the creation of accessible PowerPoint presentations. They highlight the importance of using predefined slide layouts that let users of screen readers navigate through text and graphics. They further stress the usage of titles for each slide since they indicate the most important point of orientation for screen readers. Additionally, they advise using alternative text for complex tables in which the key message is mentioned (DBSV e. V., n d).

3 METHODOLOGY

The enrolment of a student with total blindness in a business computing bachelor's degree program unveiled a critical need to assess and improve the accessibility of educational materials. This revelation prompted the conduction of a case study to decrease the barriers to accessibility in higher education, specifically of existing documents. It focused particularly on the documents' compatibility with commonly used screen readers and the development of an AI tool that parses documents into an accessible format.

Our approach to the case study involved three main steps in a participatory design process:

1. **Material Assessment.** The first phase entailed a detailed examination of the existing educational content. This review aimed to understand how these materials interacted with screen readers and identify areas of incompatibility or difficulty.
2. **Technology Integration.** In response to the challenges identified, we explored AI-based solutions, particularly those leveraging generative AI models. This step involved assessing the potential of these technologies to create more accessible versions of educational content tailored to the needs of visually impaired students.
3. **Evaluation.** The prototype was iteratively refined with human oversight for validation, prompt engineering to enhance the AI response consistency and user feedback from visually impaired individuals to assess usability and identify areas for improvement.

The following chapter will detail how the material was assessed, and the findings were translated into the development and deployment of the AI tool.

4 IMPLEMENTATION

4.1 Material Assessment

In the business computing program in question, students are typically provided with lecture notes, usually slides, in PDF format. Lecturers also use standard software such as integrated development environments in programming courses, the enterprise resource planning (ERP) software SAP and the statistics package R. A first analysis revealed that the standard software solutions were found to be accessible, but not the lecture notes.

Lecturers in the bachelor's degree program in business computing were interviewed about the use of domain-specific visualisations. As a result, several diagram types were identified as relevant for business computing studies. In software engineering and object-oriented programming courses, class diagrams are used to visualise relationships between classes as well as their functions and attributes using the widely established Unified Modelling Language (UML). Business process model notation (BPMN) diagrams depict the flow of events and activities in business processes. In several classes, graphical representations of functions are used, such as the linear cost function in cost accounting or linear regression functions in statistics.

As UML diagrams can be viewed as a hierarchical representation of textual elements, they can be made accessible to blind students more easily. BPMN diagrams, however, contain a variety of symbols with different meanings, elements are ordered in so-called "swim lanes" to represent sub-organisational areas of responsibility, while the arrangement of elements represents the order of process flow. As BPMN diagrams are a major tool in business computing and are more difficult to describe textually, the study program used tactile printing for an exemplary BMPN diagram.

To assess the current state of accessibility in the presentations and documents used at our institution, we initially tested an exemplary presentation slide (Figure 1) in both the open-source software PAVE and closed-source software Eye-Able for evaluation. These applications are designed to analyse PDF structures, identifying key elements such as alternative texts for images, logical structural trees that dictate reading order and the marking of non-essential elements as decorative.

The analysis revealed a significant deficit in accessibility: a majority of the educational materials utilised were almost entirely inaccessible for screen readers and, therefore, for blind students. Many tables were saved as graphics and code snippets or mathematical formulas were inserted as screenshots instead of markdown or LaTeX. In addition, even if diagrams or plain text were readable with a screen reader, the missing structure meant they were not easily comprehensible or otherwise made navigation difficult for screen readers. Lecturers also used unreadable graphics to transfer information. For example, the course structure, deadlines and grading criteria could have been presented tabularly. We primarily attributed this to the lack of consideration for the key elements during the initial creation of the documents, namely an appropriate reading order, alternative text and grouping of related graphical objects.

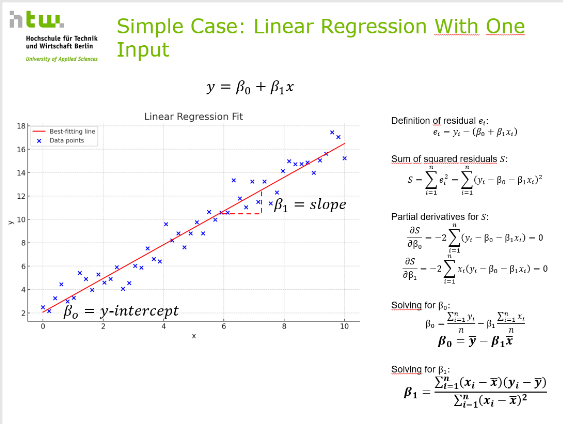

Figure 1: This exemplary slide showcases a Linear Regression graph with relevant formulas on the right side. The graphic contains decorative elements, a graph and formulas for intelligibility. For screen reader users, neither the reading order nor the difference between decorative elements and those for comprehensibility is clear.

The lecturers were surprised to learn that not only slides with visualisations were unusable for the blind student but also slides with mainly textual elements that only made sense with a specific reading order. While a typical course often provided hundreds of slides as lecture notes, the material used only in the six courses of the first semester added up to dozens of documents with hundreds of pages. The lack of attention to accessibility during course creation led to the need to quickly improve the accessibility of many documents created iteratively over several years.

To solve these deficits, initially, Microsoft PowerPoint's built-in accessibility tab was considered to provide a list of images without alternative texts where a structure or reading sequence was missing or where elements were not marked as decorative. Despite its limitations, the built-in suggestions indicated that manually making the material accessible would require significant time. It became apparent that recreating the material entirely while incorporating key accessibility principles from the outset would be more time-efficient. This led to the question of how the pre-existing course materials could be adapted and made available to blind students quickly.

The main requirements for the envisioned solution were:

- Automatically provide textual representations of existing course material in PDF format
- Create well-structured texts with references to original slides (heading, slide number)

- Handle different types of visualisations

4.2 Technology Integration

Machine learning approaches have made documents accessible to visually impaired and blind users. Choi et al. (2019) built a browser extension using deep learning technology to provide textual descriptions of charts, including chart type and data tables. Lundgard and Satyanarayan (2021) propose a four-level semantic model for the usefulness of descriptions generated using natural language processing (NLP).

To meet the requirements described in the previous section, the use of large language models (LLMs), specifically the generative pre-trained transformers (GPT) provided by OpenAI, was explored to process these documents and generate screen-reader-accessible alternative texts in a separate file. While this approach is fast and scalable, there are several challenges:

1. **Accurate Text Generation.** The LLM must accurately interpret and convert the content of the original document into alternative text. This includes not just the textual content but also the correct and complete interpretation of charts, graphs and other non-textual elements.
2. **Contextual Understanding.** The LLM should not lose the document's context and subject matter in the generation process. This is crucial for ensuring that the alternative text accurately reflects the intended message and information of the original content.
3. **Avoid Hallucinations:** The LLM must not make up content not part of the document.
4. **Built for Use with Screen Readers.** The alternative text needs to be optimised for screen reader software. This involves structuring the text in an easily navigable and understandable way when read aloud by these tools.

The output format of choice is HTML to ensure compatibility with screen readers. This format facilitates the creation of a structured reading experience through language, header, and paragraph tags. Such structures allow visually impaired students to efficiently navigate the document using a screen reader, particularly if sections are demarcated with descriptive headers. For instance, a header using the <h1>-Tag like "Sequential Diagrams" is markedly more informative than a vague designation such as "Page 2". The tool was implemented as a web application using the Flask framework, Python and the OpenAI GPT-API.

The PDF documents were handled using the libraries *PyPDF2* and *pdf2image*. *PyPDF2*'s `PdfReader` class was instrumental in reading and manipulating the content of PDF files. Meanwhile, *pdf2image* allowed the conversion of PDF pages into images—a crucial step in processing the documents for the intended use case.

The proof-of-concept prototype TRAIL[1] integrates the GPT-4 Vision API to process images of the PDF slides. The Vision API is parameterised for low temperature to moderate the creativity level of GPT-4 during the generation process, ensuring the produced text remains closely aligned with the content and context of the original PDF document. The generated text is then compiled into an HTML document, optimised for compatibility with screen readers.

Specifically, the prototype disassembles the PDF, segregating each page into an individual image. Subsequently, each image is processed through the GPT-4 Vision API with a prompt to generate a detailed alternative text and an appropriate title for each page. Upon process completion, these responses are methodically assembled into an HTML document. This document is structured with a distinct header, representing each page of the original PDF, followed by the corresponding alternative text for the page as a paragraph, enhancing the navigability and accessibility of the content for visually impaired users. Mathematical formulas are written as LaTeX in the HTML file for correct parsing by screen readers. The processed HTML text for the exemplary slide from Fig. 1 is shown in Fig. 2, followed by the final LaTeX result.

Resulting LaTeX The slide is titled "Simple Case: Linear Regression With One Input" and is divided into two sections. On the left, there is a scatter plot with the x-axis labelled as 'x' and the y-axis labelled as 'y'. The plot shows numerous data points marked with blue 'x' symbols. A red dashed line passes through the data points, indicating the best-fitting line for the linear regression. Two annotations on the graph include "$\beta_0 = y$-intercept" at the point where the line crosses the y-axis and "$\beta_1 =$ slope" along the line, indicating the slope of the best-fitting line. The linear regression model is given by $y = \beta_0 + \beta_1 x$.

On the right side of the slide, there are several mathematical equations and definitions related to linear regression. The definition of residual e_i is provided as $e_i = y_i - (\beta_0 + \beta_1 x_i)$. The sum of squared residuals S is defined as $S =$

[1] https://github.com/AltarisV/TRAIL-PDF

```
<h1>Regression Analysis (Page 10)</h1>
<p>The slide is titled "Simple Case: Linear Regression With One Input" and is divided into two sections. On the left, there
The plot shows numerous data points marked with blue 'x' symbols. A red dashed line passes through the data points, indicat
Two annotations on the graph include "\(\beta_0 = y\)-intercept" at the point where the line crosses the y-axis, and "\(\be
<p>On the right side of the slide, there are several mathematical equations and definitions related to linear regression.
The definition of residual \(e_i\) is provided as \(e_i = y_i - (\beta_0 + \beta_1x_i)\). The sum of squared residuals \(S\
<p>The equations for solving for \(\beta_0\) and \(\beta_1\) are also provided.
For \(\beta_0\), the equation is \(\beta_0 = \frac{\sum_{i=1}^{n} y_i}{n} - \beta_1 \frac{\sum_{i=1}^{n} x_i}{n}\) which si
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Figure 2: HTML text for the slide shown in Fig. 1 generated with TRAIL.

$\sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n}(y_i - \beta_0 - \beta_1 x_i)^2$. Partial derivatives for S with respect to β_0 and β_1 are given as $\frac{\partial S}{\partial \beta_0} = -2\sum_{i=1}^{n}(y_i - \beta_0 - \beta_1 x_i) = 0$ and $\frac{\partial S}{\partial \beta_1} = -2\sum_{i=1}^{n} x_i(y_i - \beta_0 - \beta_1 x_i) = 0$, respectively.

The equations for solving for β_0 and β_1 are also provided. For β_0, the equation is $\beta_0 = \frac{\sum_{i=1}^{n} y_i}{n} - \beta_1 \frac{\sum_{i=1}^{n} x_i}{n}$ which simplifies to $\beta_0 = \bar{y} - \beta_1 \bar{x}$. For β_1, the equation is $\beta_1 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^{n}(x_i - \bar{x})^2}$, where $\bar{x}$ and $\bar{y}$ represent the mean values of x and y, respectively.

Figure 3: LaTeX for the slide shown in Fig. 1 generated with TRAIL

5 EVALUATION

The evaluation process focused on the effectiveness of GPT-4 for rendering educational materials in accessible formats. The approach was guided by iterative refinement and critical examination of the AI-generated outputs and consisted of a few main focus points:

1. **Human Oversight.** Human oversight was a vital part of the evaluation process to validate AI-generated outputs and correct significant errors. This step was essential in ensuring the quality and accuracy of the final accessible documents.
2. **Prompt Engineering.** The evaluation also focused on refining prompt engineering techniques to enhance the consistency and relevance of AI responses. We experimented with different prompt structures and formulations to optimise the AI's performance.
3. **User Feedback.** We gathered feedback from end-users, including lecturers and a blind student, to assess the usability and understandability of the produced accessible documents. This input was crucial in identifying areas for improvement and validating AI technologies in educational settings.

The tool underwent the testing and evaluation process using a variety of slides sourced from business computing classes. The interpretation was possible for conventional text slides and worked also for mathematical formulas and LaTeX expression. However, the technology had errors distinguishing relevant from irrelevant content, making human oversight necessary. The requirement for manual intervention to correct significant errors, such as incorrect semantic interpretations or inaccuracies in graph descriptions, remains paramount. Notably, the frequency and nature of these errors depend on the input material's quality, with common challenges arising from low-resolution images or misinterpreting fine details in diagrams used in the slides.

An illustrative instance of this was observed during our experiments with an image of quadratic equations employing the quadratic formula, a concept prevalent in German-speaking regions, titled ”PQ-Formel”. The AI's response to the GPT-API accurately recognised the formula's application in solving quadratic equations. However, the generated LaTeX code for the formulas was erroneous. Once we removed the title ”PQ-Formel” from the image, we got flawless explanations and LaTeX generation, albeit without any reference to the quadratic formula.

A second step was iteratively testing the tool with the blind student, which played a pivotal role in refining its effectiveness and accessibility. Immediate implementation of the feedback from the blind student was crucial to enhance the tool's performance and address usability concerns specific to visually impaired users. This process identified areas for improvement and made necessary adjustments to ensure that the tool could accurately interpret and present educational content in an accessible format.

Furthermore, an integral aspect of the evaluation methodology was the process of prompt engineering, which played a crucial role in reducing randomness and minimising errors in the responses generated by the GPT-API. Extensive experimentation with different structures and phrasings of prompts revealed significant variations in the results. These differences were often attributed to subtle changes or omitting certain prompt words.

For instance, the prompt snippet ”short and precise alternative text” was interpreted literally by the GPT model, typically yielding brief descriptions, often just one to two sentences long, for complex diagrams. However, modifying the snippet to ”precise alternative text" resulted in more comprehensive and clearer responses. This alteration also helped eliminate the tendency for extraneous elaboration, encountered in earlier tests with different formulations.

To further streamline the consistency of the AI responses, the GPT-API's temperature setting was adjusted to 0.2. This modification significantly reduced the range of variability in the responses, aligning them more closely with our specific requirements for alternative text generation (Open AI, n d).

To summarise, prioritising initial content generation, followed by evaluative revision, has proven to be a time-efficient approach, aligning with our primary objective of enhancing document accessibility for educational purposes. This was reaffirmed by the feedback from the student, who emphasised the importance of well-structured and complete content and was happy to learn with a document after such evaluative revision.

6 DISCUSSION

AI holds considerable promise in enhancing the accessibility of educational materials for visually impaired students. As highlighted earlier, a crucial element of accessible documents is providing alternative text for graphical content. Utilising common language models like Chat-GPT offers a viable solution for generating comprehensive image descriptions (Johnson et al., 2023).

Moreover, AI can generate detailed descriptions for complex diagrams and structured textual content (He and Deng, 2017; Bernardi et al., 2016). This functionality aids in parsing information presented visually and gives visually impaired students a more comprehensive understanding of the material.

Engaging with content in code snippets or tables poses a challenge for those with visual impairments. Optical character recognition (OCR) within AI systems can be a valuable technology (Sheela et al., 2023). Converting code and tabular data into accessible formats can be an assistive tool.

Other approaches focused on accessible slide-creation solutions where visually impaired users could complete slide reading and authoring tasks independently through a multimodal interaction board (Zhang et al., 2023). The developed A11yBoard was an extension for Google Slides and gave visually impaired users an inclusive interface to navigate and modify slides themselves.

Similar to our findings, Glazko et al. (2023) valued generative AI technology as a useful tool but found it required "significant human involvement and iteration, rather than an out-of-the-box end-to-end solution for [their] access needs" .

6.1 Learnings

AI technologies have demonstrated significant efficacy in rendering previously inaccessible documents usable for educational purposes. Advanced iterations of GPT, such as GPT-4, exhibit remarkable proficiency in extracting and elucidating information from conventional university lecture slides. This capability extends to interpreting and generating mathematical formulas and LaTeX expressions facilitated by the extensive training data used for these models.

During the material assessment, it also became apparent that each course brings different requirements to accessibility. Many mathematical formulas were printed as an image instead of markdown or LaTeX and were therefore impossible for screen readers to interpret. Diagrams to depict business cases in business process modelling notation (BPMN) were saved as screenshots. The same applied to accounting classes where t-accounts or booking rates were pictured. Most of these cases were unique to business computing classes but showcased the need for further material evaluation in other study programs.

Nonetheless, the journey towards full automation in document accessibility remains incomplete. Current large language models, including GPT-4, are not infallible and exhibit limitations, particularly in image comprehension. The ability of these AI models to distinguish between relevant and irrelevant content is still being refined, necessitating human oversight during the conversion process.

One key learning from this case study is the realisation that, in many cases, it is more efficient to recreate slides entirely with accessibility in mind rather than attempting to retrofit existing slides to meet accessibility standards. This highlights the importance of incorporating accessibility principles from the outset of slide creation, ensuring that educational materials are inherently accessible to all users.

6.2 Limitations

Our study was bound in its focus on converting a limited number of existing slides into an accessible format. The tool's evaluation was restricted to business computing classes and limited in broader applicability across different educational settings and disciplines. Further research should be done to evaluate TRAIL's effectiveness in other study fields.

Additionally, the development and evaluation process involved only one blind student, and while their insights have been instrumental, they may not fully capture the diverse needs and perspectives of the broader blind community. We acknowledge the necessity for further testing and validation across various contexts and with a more representative sample of blind users.

6.3 Future Work

Moving forward, further development should address the previously mentioned limitations by expanding the tool's applicability to diverse academic contexts and a broader sample group of visually impaired students. Engaging with a larger blind community from different academic disciplines will ensure the tool's functionalities align with varied preferences and requirements.

Furthermore, integrating options for direct user feedback on the generated slides as part of the tool's functionality would help iterative improvements based on user interactions and experiences.

By addressing these areas, researchers can contribute to advancing accessible technologies for visually impaired individuals in educational settings, enhancing effectiveness, usability, and inclusivity for a broader audience.

7 CONCLUSION

This paper discussed the possibilities of AI for generating accessible learning material. Despite legal requirements for accessibility, visually impaired students still encounter barriers in many aspects of higher education, particularly regarding access to adapted course material. These deficits were highlighted with the enrolment of a fully blind student in one of our study programs. This formed the basis of a comprehensive case study in which the complexities of adapting existing course materials for blind students were investigated. The exploration introduced a promising solution: leveraging generative AI technology to streamline the creation of accessible educational materials. The introduction and evaluation of the TRAIL tool exemplified the potential of AI in generating textual descriptions of lecture slides, thereby enhancing accessibility and creating a more inclusive learning environment. Moving forward, continued research and innovation in AI-driven accessibility solutions hold the key to overcoming barriers and ensuring equitable educational opportunities for all students, regardless of disabilities.

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