On the Current State of Generative Artificial Intelligence: A Conceptual Model of Potentials and Challenges

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Abstract: Generative artificial intelligence (GenAI) is one of the most promising recent advances in digital technology. However, research often focuses on specific application scenarios, case studies and experiments. Overarching and comprehensive studies that consider potentials and challenges for the entire field of GenAI across domains are rather scarce. In this paper, the four domains of text, audio, image and code generation are examined by means of a systematic literature review. Opportunities for industry and society are discussed, with the aim of providing a conceptual model that enables a quick assessment of the current state-of-the-art and identifies applications for GenAI that are either not yet sufficiently researched and therefore invite further exploratory investigations, or are well researched and therefore represent recognized yet less experimental fields.

1 INTRODUCTION

The exponential rise in generated data, available computational power, and more advanced statistical techniques (Cobb 2023; Haertel et al. 2023; Vartiainen and Tedre 2023) have significantly increased the application of advanced machine learning (ML) (e.g., deep neural networks (DNN)) in various areas of the everyday life. Especially the fields of image analytics, video analytics (Daase et al. 2023), and language models have gained attraction in this regard (Liu et al. 2017). Recently, generative AI (GenAI) has gained severe prominence. Generative models pursue the objective of approximating training data sets' statistical distributions to generate new data points (François-Lavet et al. 2018). In this context, GenAI shifts the focus of AI from analytical expert systems as *decision-makers* to creators of new content that function similarly to *creative human collaborators* (Turchi et al. 2023). From a conceptual point of view, researchers see GenAI's potential between *factual knowledge* and *creative thinking* for partially rule-based activities (Kanbach et al. 2023). As integral technologies, GenAI includes inter alia natural language processing (NLP), image processing, and computer vision (Lv 2023), resulting in the four main output categories examined in this paper: text, image, audio, and programming code. To grasp the future impact of GenAI on the business sector, it is worth noting that Goldman Sachs estimates that AI in general could have an impact on up to 300 million jobs globally, while the major consulting company Accenture estimates that 40 percent of human workload will be affected by large language models (LLMs), one of the most prominent examples being GPT-4 (i.e., *Generative Pre-Trained Transformer*) and the chatbot ChatGPT that builds on it (Kanbach et al. 2023).

The present paper examines explicit use cases for GenAI from the four stated categories to provide a comprehensive overview of potentials and challenges in this area. Based on a systematic literature review (SLR), applications from different subcategories are evaluated and assessed, assuming that the future of GenAI will focus on exploring new application scenarios and integration with other technologies to

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increase its impact (Lv 2023). Furthermore, anticipated issues of GenAI such as bias, misinterpretation, societal impact, shifting responsibilities and roles of people in the workplace (Jiang et al. 2023; Kanbach et al. 2023; Vartiainen and Tedre 2023) are considered. As a result, a conceptual model of the fields of application of GenAI is presented to conclude the current state of research as it is reasonable based on the literature reviewed. The contribution of this paper is intended to help academics and practitioners to assess opportunities and obstacles in the highly dynamic and equally promising field of GenAI. In short, the research question (RQ) posed in this paper is as follows:

RQ: Which potentials and challenges of GenAI in industry and society can be identified in recent scientific studies and what is their expectable impact?

Following this introduction, the methodology of the SLR is described in Section 2. In Section 3, the identified fields of GenAI (i.e., text, audio, image, and code) are presented, including their very specific subcategories, industries, and use cases. Section 4 first assesses the overarching challenges and classifies the GenAI categories in the conceptual model as either well researched, moderately researched, or currently under-researched or less promising. The paper is concluded with an outlook on further research and limitations in Section 5.

2 METHODOLOGY

A systematic literature review (SLR) was conducted to answer the stated RQ. As the overall goal is to provide a comprehensive overview of the potentials and challenges of GenAI, the abstract and citation database Scopus was chosen as the primary literature source, since it refers to a large number of interdisciplinary articles from a variety of full text databases. For the automatic search for scientific articles in the first phase of the review, the search query was set to the inclusive phrase *"generative AI" AND <domain>*. As described in the introduction, the primary application domains of GenAI in the context of this paper are text, audio, image and code. In addition, the time frame was set to all years including 2023. A total of 228 articles were retrieved from the individual domains, 63 of which turned out to be duplicates. This left 165 articles after this phase.

In the second review stage, the abstracts were read to identify the overarching areas of application of GenAI in each article, whether the articles were written in English and if the quality of the publication could be considered sufficient (i.e. peer-reviewed in a reputable research publication). In this phase, 108 articles were rejected, while 57 remained.

In the third and final review phase, the remaining articles were read as a whole to extract the granular information on specific GenAI use cases, potentials, challenges, monetary value, and societal implications. Therefore, publications that did not provide sufficient detail on the implementation or operation of such systems were rejected. The industrial or societal value of GenAI's intervention needed to be made clear without relying solely on personal opinion or experience. Articles without sufficient scientific backing were also rejected, resulting in 12 articles being omitted and 45 remaining to form the final literature base. Figure 1 depicts the completed literature search process.

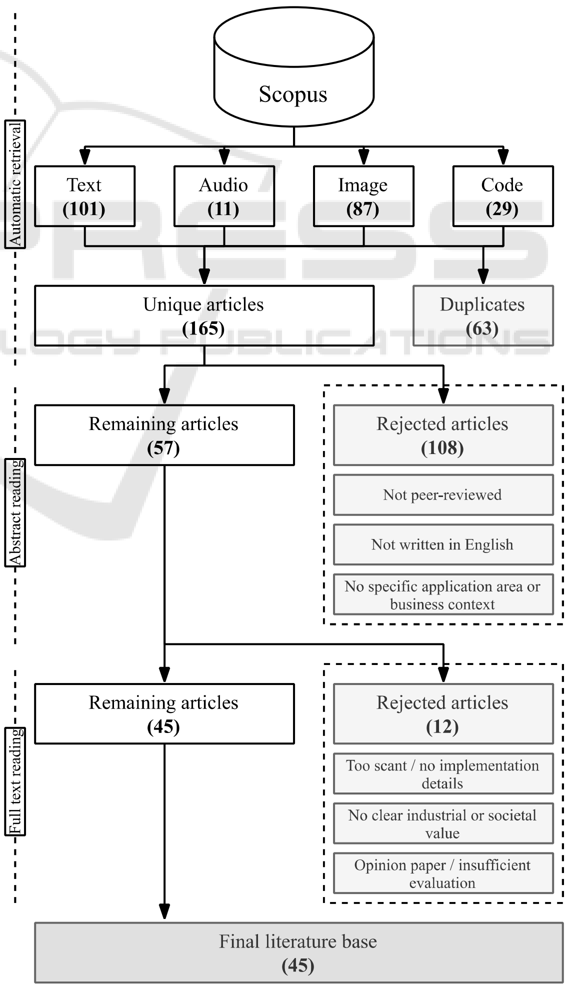

Figure 1: SLR search process.

3 FIELDS OF GENERATIVE AI

GenAI systems are capable of generating novel and creative content based on training data. The produced outputs can be categorized as text, audio, or image and video (Mannuru et al. 2023), each offering unique potentials but also posing significant challenges. Therefore, in the following, these aspects are discussed based on the retrieved articles from the SLR. The analysis is divided based on the above-mentioned categorization on GenAI output types. However, code is considered as a separate subsection since its applications are fundamentally different compared to the text category. Additionally, the use cases of image and video are subsumed under the same category.

3.1 Text

Almost half of the articles from the final literature base discuss GenAI use cases for text output. Accordingly, the opportunities are manifold. From providing quick access to a bandwidth of information for educational purposes to supporting and partially replacing human involvement in various business processes, the capabilities of GenAI seem sheer overwhelming. However, on the same note, numerous issues still have to be considered with GenAI usage, leading to partially low trust levels in the technology. Hence, complete detachment of human supervision is not recommended for the foreseeable future. Potentials and challenges of text-based application scenarios in public services, industry, sustainability, and art and media are outlined in detail below.

3.1.1 Public Services

The examined literature features numerous use cases for text-based GenAI for the public service sector (e.g., education, healthcare). K. Ali et al. (2023) and Panthier and Gatinel (2023) show the ability of ChatGPT to successfully pass exams in the healthcare domain. While both studies point out the predominantly high quality in the model's answers, ChatGPT was only able to process tasks based on text and could not answer questions containing figurative elements (K. Ali et al. 2023; Panthier and Gatinel 2023). Based on these findings, it can be concluded that GenAI will have a significant impact on assessment practices in higher education. In home examinations, ChatGPT excelled in terms of language and grammar, precision, completeness as well as partially in creativity (Farazouli et al. 2023). Still, the OpenAI chatbot still displays weaknesses in argumentation strategy, use of references and relevance to the topic of the course. Since these flaws could also be found in the answers of humans, teachers tend to more critical in grading texts of students (Farazouli et al. 2023).

Apart from that, the application possibilities of GenAI is assisting learners and teachers are vast. Content generation is mentioned (Yan et al. 2023) as a potential to create personified learning material depending on the respective pupil's skill level, leading to improved learning outcomes (Jauhiainen and Guerra 2023). GenAI can be utilized as additional (virtual) teaching support (Ooi et al. 2023; Yan et al. 2023) to achieve learning objectives such as acquiring proficiency in writing in a new language (Hwang and Nurtantyana 2022). Furthermore, these models can provide (personalized) feedback (Ooi et al. 2023; Yan et al. 2023) to derive suggestions for enhancement. For example, Siiman et al. (2023) use GenAI for analysis and evaluation of conversations performed in the context of problem-solving. Additionally, LLMs have been utilized to support research and academic writing (Ooi et al. 2023) by, for instance, producing text transcriptions for video content (Amarasinghe et al. 2023).

Despite the apparent massive potential that GenAI offers for education, some drawbacks have to be taken into consideration. Through the potential processing of personal data, privacy and safety issues arise (Ooi et al. 2023). In addition, there is concern regarding the impacts of an increased psychological distance between teachers and students. The advancements in GenAI for education further spark debate regarding the originality of submissions and infusing the need to reevaluate forms of grading and examination. Another obstacle constitutes the potential bias in used data and algorithms since it could influence an individual's learning experience and outcomes (Ooi et al. 2023), contradicting the pursued aim of equality in education (Yan et al. 2023).

Moreover, several application possibilities of GenAI for healthcare were retrieved from the examined publications. Such models allow for the rapid provision of answers to medical questions and even the translation of such content (Ooi et al. 2023). Patients can further use AI to better understand and describe their experienced symptoms before seeing an actual doctor which can lead to more accurate diagnoses (Ooi et al. 2023). Furthermore, several application possibilities of GenAI for healthcare were retrieved from the examined publications. Such models allow for the rapid provision of answers to medical questions and even the translation of such content (Ooi et al. 2023). Patients can further use AI

to better understand and describe their experienced symptoms before seeing an actual doctor which can lead to more accurate diagnoses (Ooi et al. 2023). Similarly, Kanbach et al. (2023) describe the rise of AI-powered chatbots to increase accessibility to therapy, especially for mental health issues. However, these sophisticated capabilities pose significant requirements to the correctness and applicability of the results (Ooi et al. 2023) and for revised regulatory standards (responsibility of AI) (Mannuru et al. 2023). Additionally, the adequate personalized medical advice via GenAI necessitates multiple user interactions and using the right text prompts, which will pose a challenge for laypersons (Ooi et al. 2023). Accordingly, literature suggests using GenAI only as a supplement to traditional therapy (Kanbach et al. 2023).

Furthermore, the healthcare sector can benefit from the predictive capabilities of GenAI models for diagnosis and detection of diseases, for example, from medical images and records (Mannuru et al. 2023; Ooi et al. 2023). As a consequence, progression, monitoring, and potentially outcome of treatments could be enhanced (Mannuru et al. 2023). Nevertheless, ethical challenges like potential bias and privacy concerns (Mannuru et al. 2023; Ooi et al. 2023) pose danger to patients' acceptance and GenAI effectiveness in healthcare. Besides, such algorithms tend to overlook the social context in their analyses (Mannuru et al. 2023). Finally, the study of Karinshak et al. (2023) revealed that LLMs can also generate more effective public health messages (e.g., pro-vaccination messages) compared to human-initiated communication. Despite the positive implications of this discovery, a critical discourse with the potential exploits such as spreading misinformation and manipulating target groups is required (Karinshak et al. 2023).

3.1.2 Industry

In the SLR, several use cases were found where GenAI can offer support for various business process. For example, based on sentiments scores calculated by ChatGPT on corporate financial statements, the risk management capability and stock return of a company can be predicted (Chen et al. 2023). In general, GenAI possesses lots of potential for the finance sector such as the forecast of market trends, detection of investment prospects, fraud detection, and personalized financial advice (Kanbach et al. 2023; Ooi et al. 2023). With the LLMs' ability to process massive amount of demographic and browser history data, better understanding of customer behavior, leading to enhanced marketing strategies and more customer touchpoints (e.g., hyperpersonalization), is enabled (Ooi et al. 2023). Additionally, GenAI can be used in the product ideation process and provide better product descriptions. Therefore, this improved customer experience opens up new revenue streams for firms (Mannuru et al. 2023). Nevertheless, this new development in marketing strategies reduces the perceived empathy and emotion in service delivery ("dehumanization") (Ooi et al. 2023), which is especially fostered with the tendency to a future "overreliance on AI" (Mannuru et al. 2023).

Furthermore, Ooi et al. (2023) highlight additional application scenarios in manufacturing. GenAI is utilized for creating training programs of employees, reducing the need for humans for this task. Here, these models also gain attention for their capability to enhance predictive maintenance through sophisticated simulations and forecasts (anomaly detection) (Ooi et al. 2023). For its effectiveness, especially in manufacturing and finance, the availability and quality of training data is important but oftentimes constitutes an issue. Similarly, infrastructure requirements, potentially impacted by severe regulations, are significant and expensive. Despite GenAI's general ability to support decision-making in various business processes, certain considerations need to be made to ensure its actual applicability in practice. These include ethical concerns (e.g., bias), data privacy issues, hallucinations, and currently missing robust (international) regulations (Mannuru et al. 2023; Ooi et al. 2023). Apart from that, seeing the huge automation potential of GenAI, the fear of large-scale losses comes as little surprise.

According to the literature, GenAI offers capabilities to support tasks in the legal industry. Ioannidis et al. (2023) developed an AI tool that summarizes and categorizes regulatory information for clients. Lam et al. (2023) assessed the usefulness of LLMs for contract drafting to simplify the workflow of legal professionals. While the basic utility of the approaches could be confirmed, some major obstacles still need to be considered. First of all, significant testing before deployment is required since GenAI models are not immune to creating plausible sounding text that is wrong (Ioannidis et al. 2023). Because of the severe implications of potential errors in the law domain where accurate information is mandatory, this poses a massive risk. Thus, the used prompt setting is important (Lam et al. 2023). As a conclusion, also due to privacy and confidentiality doubts (Ioannidis et al. 2023), enhancements are still needed in this area (Lam et al. 2023).

Next, human resources (HR) profit from GenAI in various ways. Employee training initiatives can be improved (Mannuru et al. 2023; Ooi et al. 2023) as already seen in the educational sector. In general, GenAI shows potential to significantly change the job market. While new job types for working with GenAI are created (e.g., prompt engineering), demand for other positions involving automatable tasks (e.g., customer service) and even services with human expertise (e.g., programming) is reduced. Self-evidently, this sparks concerns regarding employment opportunities as well (Mannuru et al. 2023). Nevertheless, GenAI allows to support employees by delegating repetitive tasks. For example, Lukauskas et al. (2023) describe how LLMs can be utilized to extract skills demand from job profiles to improve the recruitment process. Furthermore, Ooi et al. (2023) outline several opportunities for using GenAI to enhance team collaboration such as establishing reminders for deliverables and overcoming resource allocation challenges. Despite the summarized advantages, the actual applicability is still hampered by obstacles in terms of significant data requirements to avoid bias, lack of explainability leading to low trust, and partially inaccurate as well as inappropriate responses (Ooi et al. 2023).

3.1.3 Sustainability

The relationship of GenAI and sustainability constitutes a double-edged sword. While certain techniques supporting the reduction of carbon emissions are facilitated, the needed compute intensity of these models pose considerable energy demands (Mannuru et al. 2023) which are not necessarily compatible with sustainability requirements. Accordingly, the environmental impact of GenAI across its entire lifecycle needs to be evaluated (Ooi et al. 2023). On this note, amongst, others, regulatory frameworks and developing a competent workforce in this domain are required for AI to make a positive impact in sustainability concerns.

The predictive capabilities of GenAI can be used for energy savings for various sectors by forecasts and resulting modifications to power management and resource distribution (Mannuru et al. 2023; Ooi et al. 2023). Moreover, AI can aid in the design optimization of existing or new (IT) systems with regards to efficiency, economic, and scalability metrics (Mannuru et al. 2023; Ooi et al. 2023). This can also include digital twin simulations that incorporate environmental characteristic. In the next step, necessary components can be compared regarding their ecological impact (e.g., Echochain AI) to achieve sustainable procurement (Ooi et al. 2023). This is also applicable for the end of the product lifecycle when the processing of data on (electronical) waste and the resulting insights can lessen the environmental impact. Finally, Villiers et al. (2023) examine the potential of AI-powered sustainability reporting due to high-speed analyzing abilities of large quantities of corporate data. However, the authors point out the risk of greenwashing, since some information (e.g., financial) are "easier to process" (Villiers et al. 2023).

3.1.4 Art and Media

Similar to the potential of GenAI in content generation for educational purposes, ChatGPT can assist journalists in writing as well, which is shown by Pavlik (2023). As a consequence, in the long run, this may constitute a threat to human professionals that could fall victim to cost savings in this industry. Despite the significant potential, reservations exist because of possible misuse to produce information with malicious intent or partial lack in range and depth of knowledge in GenAI models (Pavlik 2023). Additionally, the text generation ability of LLMs finds use in producing new cooking recipes. In conjunction with genetic algorithms, GenAI can be used to create the recipe text from encoded recipe solutions (Razzaq et al. 2023). However, the current approach does not account for the nutritional values of the food which is a notable limitation for being able to compose a conscious diet.

3.2 Audio

Based on the conducted SLR, audio is the least represented field of GenAI. Only three of the included publications specifically discuss the application of GenAI for audio-related use cases.

Lv (2023) discusses the role of GenAI in the metaverse. In this context, it is mentioned that GenAI can be utilized for speech synthesis and the generation of music. The Wavenet model constitutes one of the well-known examples and is allegedly able to "produce convincing synthetic voice and music" (Lv 2023).

Ocampo et al. (2023) also present an GenAI-driven method for the domain of art. The authors describe a GPT-3-powered data sonification approach that uses the most-read Wikipedia articles of a given day as data input. With this a basis, a set of requests is given to the model to perform a semantic mapping between the data interpretations and sound descriptions (Ocampo et al. 2023). Therefore, the authors show the general ability of GenAI to create prompt-specific outputs that can be used for the music creation process. Nevertheless, the experiments discovered some limitations with the interpretation capabilities of the used model. At times, the assigned labels did not reflect the input data accurately (Ocampo et al. 2023). The authors deduce that GPT-3's numerical reasoning abilities might negatively influence the results in this regard and that the prompting approach plays a significant factor in the quality of the results.

Additionally, Mannuru et al. (2023) found that accents in audio stream can be modified for better understandability and high-quality speech for people with disabilities related to communication skills can be generated (Houde et al. 2020; Qadir 2022). However, misusing GenAI for creating content with malicious intents (e.g., deep fakes) constitutes a specific danger in this regard (Tacheva and Ramasubramanian 2023).

Although the literature features some great potentials for audio content generation with GenAI, the coverage remains sparse in comparison to the other categories. Especially surprising is the absence of concrete use cases related to the conservation of voice of deceased (voice) actors in the examined portion of the scientific body of knowledge.

3.3 Image

The creation of images with the help of GenAI usually requires input data in the form of text or other images, whereas the output quality largely depends on the quality of that input (Fernberg et al. 2023). While the capabilities to generate high-fidelity images with appropriate descriptive prompts are already quite sophisticated (Chang et al. 2023), the underlying creativity cannot be expected to be taken away from humans (Hoggenmueller et al. 2023; Vartiainen and Tedre 2023), although the advantages that humans have are becoming less significant with the rapid improvements in the AI domain (Seneviratne et al. 2022). However, the roles of developers and *prompt engineers* might shift towards reviewing, refining, and evaluating the results rather than creating all output by themselves.

Throughout the literature reviewed, researchers tend to view GenAI for images as a digitized colleague in a human-machine partnership rather than a mere tool. Especially when it comes to designing digital content, products, sketches, fashion, or entire story-boards (Chang et al. 2023; Hoggenmueller et al. 2023; Lv 2023), GenAI oftentimes exceeds the expectations placed on a software tool. Consistent with the vision of GenAI as a digital co-creator, the technology also partially relieves humans of the necessity to understand the underlying mechanisms and instead lets them describe what they need before the orders are executed (Vartiainen and Tedre 2023). The most frequently mentioned models for generating images include DALL-E, Stable Diffusion, MidJourney, Parti and Imagen (Chang et al. 2023; Hoggenmueller et al. 2023; Hong et al. 2023; Lv 2023; Turchi et al. 2023).

3.3.1 Product Design

The design and development of physical products is one of the main application areas of AI-based image generation. For example, fashion is a domain in which a large number of preliminary conceptual preparation might be necessary before a decision on the final design of a collection is made. GenAI can help to transfer a certain style from a manual sketch to an aesthetic realistic clothing image in a fast manner with a quality comparable to human designers (Wu et al. 2023). However, as usual for sophisticated ML models, this approach potentially requires a substantial amount of training data, meaning preparatory human labor. A similar use case for GenAI in this domain is image inpainting. Existing clothing images can be manipulated in an image-to-image generation process, in which parts of clothes are overwritten with new content (Muhammad et al. 2023). Newly designed outfits could be tried on digitally as part of an existing catalog.

Although fashion companies in particular rely heavily on creative minds to come up with revolutionary designs while breaking away from outdated ideas, this is not only posing a problem in this sector. Robotics can be identified as an area in which the issue of design fixation, meaning the adherence to well-established conceptions, is widely prevalent (Hoggenmueller et al. 2023). When creating new robot designs, GenAI could help to overcome simple notions of anthropomorphic or zoomorphic depictions of robots by incorporating other elements from the training phase into the creation process.

While the visual design of physical systems might be a secondary task in engineering, the actual functioning of entire electrical assemblies can also be supported by GenAI for images. In one of the most topical branches of automotive engineering, *e-*

mobility, a recent study investigated the capabilities of *generative adversarial networks* (GANs) for the preliminary design of dynamic inductive charging stations (Curtis et al. 2023). With this technology, cars do not need to stop for charging if the coil is integrated into the road on which a car with corresponding electrical systems is moving. This approach shows that the inclusion of technical requirements such as safety, energy consumption, and flexibility is a possible option.

Lastly, hand crafting is identified as an area for GenAI in the domain of product design. When regarding crafting as a four-phase process consisting of ideation, design, making, and reflective evaluation (Vartiainen and Tedre 2023), artificially generated images can especially benefit the first and partially the second stage. As the intended design becomes more and more complex in the course of its finalization, the level of detail of ideas can increasingly no longer be converted into adequate prompts. Verheijden and Funk (2023) call this circumstance the *crooked bow tie effect*, since one side (i.e., the input) in its extent can only be transformed into something smaller that does not sufficiently represent the given input. However, in the initial phases of craft product design, visualization is seen as an important means of communication and feedback and thus constitutes an additional use case for GenAI for images.

3.3.2 Construction

Similar to engineering, the field of construction often necessitates the integration of functional requirements into design processes. For example, urban design requires the consideration of complex concepts such as health and safety (Seneviratne et al. 2022). When developing GANs with the goal of generating images of meaningful urban and landscape compositions from descriptive texts, engineers need to be skilled in *prompt engineering* (Dortheimer et al. 2023), so that the model can be trained to visually link specific terms with logical consequences. For instance, in their study, Seneviratne et al. (2022) associated terms like *healthy* with green environments and *safe* with clean paint on completed constructions. In contrast to the creation of still images, another use case for GenAI is related to the preparation of interactive 3D scenes in virtual reality. Bussell et al. (2023) conducted a study in which participants used GenAI to first create conceptual designs of construction projects, which were then modeled and integrated into an explorable virtual world.

One step further, studies in architecture view GenAI as part of a multistep workflow from early inspirations to the enhancement of final renderings (Dortheimer et al. 2023). When creating vivid representations of buildings, landscapes or community spaces, modern approaches often use 3D models for further inspection. In addition to direct image generation, this also offers potential for GenAI, as the models must be provided with textures in the 3D software and the renderings need to be post-processed, for example by adding context, light and weather effects (Dortheimer et al. 2023; Turchi et al. 2023). In the ideation phase, GenAI for images can also be used to overcome the aforementioned problem of design fixation in the field of architecture (Dortheimer et al. 2023; Hoggenmueller et al. 2023).

Concluding the discussion of the different levels of detail in construction, the final area of application identified here for GenAI revolves around interior and asset design. In general, work in this sector consists of three phases: ideation, schematic drafting and layout planning (He et al. 2023), with the last phase being similar to the arrangement of elements in landscape and urban development at a reduced scale. Interior designers need to build up asset libraries, including materials, textures, or even representations of people for more realistic visualizations (Fernberg et al. 2023). While GenAI for images (e.g., through GANs) can drastically increase productivity when creating images of everyday things, limitations become clear when the integration of implicit factors is necessary, such as certain cultural styles and aesthetics (He et al. 2023). Thus, human intervention for the final composition of design alternatives is still currently essential. For the future, not only in the field of interior design, researchers see the expansion of image generators to include linguistic models, more sophisticated inpainting functions and the extension to participatory process models as possible directions (Fernberg et al. 2023).

3.3.3 Art and Media

As a basic example of what GenAI is capable of, pure images resembling paintings or photographs can be generated by models that mimic the artistic style of different artists or have been trained to create novel stylistic compositions themselves (Chang et al. 2023). In the literature, the connection between *art* and AI has recently led to intense discussions about whether something that is considered to be art can be created by AI at all and, if so, who owns the copyright to it. Jiang et al. (2023) argue that the creation of art is an endeavor unique to humans, as it is based on aesthetical and cultural experience, while ML models, once trained, are fixed on whatever was part of the training data. In a similar sense, Chang et al. (2023) discuss the question of whether GenAI can be considered an artist or merely a tool for actual artists. This in turn leads to the important question of who should be credited for the images produced with AI models: the one who developed the GenAI platform or the one who created the prompt that leads to a particular image. Furthermore, if the model imitates an artistic style, the question arises as to whether there is a copyright violation against the inventor of a style (Vartiainen and Tedre 2023; Verheijden and Funk 2023), and how a *style* could be patented in such a scenario in the first place.

Enjoyable art products for recreational purposes include goods from the fields of entertainment and games. Applications for GenAI from the construction domain, such as assisting in the development of 3D assets, can also accelerate the creation of consistent scenes from descriptive prompts by providing structures, materials, and textures for games or the metaverse (Lv 2023). For simple games based on images, such as spot-the-difference, GenAI can be used to generate the essential game content directly and with debatable quality (Hong et al. 2023). In contrast, for more complex and extensive games, GenAI can support subtasks of development, such as providing maps, character designs, and equipment based on images or, more broadly, dialogs, emotions of non-playable characters, behaviors, and other gameplay elements (Lv 2023).

3.3.4 Public Services

GenAI for images can also be employed for tasks in domains that do not have a direct monetary value but might benefit communities in other regards. Under the umbrella term of *public services*, this includes applications in education, science, and healthcare.

In education, two directions can be identified. First, it is argued that students need to be educated on how GenAI works, how it can be used, and how to distinguish content that was created by GenAI from human-made productions (S. Ali et al. 2021). Especially the last aspect is of topical interest, as researchers and society are observing an increase in so-called deep fakes, misinformation, and the use of GenAI for malicious purposes. The second avenue in education is the use of GenAI itself during lessons and training programs. A study by Vartiainen and Tedre (2023) investigated how the ideation process in crafting education could be enhanced by means of text-to-image generative approaches. However, the authors remark that the lack of materiality (i.e., haptics) cannot be compensated by GenAI.

In archaeology, a subcategory of science, Cobb (2023) investigated whether images can be generated which reconstruct archaeological elements. However, the quality was not considered sufficient, as science requires a high level of factual knowledge, experience and understanding, for example when depicting ancient writings or architectural plans. Nevertheless, the author recognizes a potential for GenAI when it comes to 3D reconstructions of ancient artifacts and places. On the other hand, Cobb (2023) notes that archaeology is not a very profitable field, which makes it questionable whether GenAI is worth an investment.

One particular use case found in healthcare for GenAI for images does not rely on text-to-image or image-to-image concepts as before, but on the reconstruction of images from neural activity (Ozcelik and VanRullen 2023). Although the research is still at an early stage, the authors have obtained overall satisfactory results when using *functional magnetic resonance imaging* (fMRI) data as input for image reconstruction and suggested that this idea could be further developed to better understand, for example, the sensory and semantic system or the functioning of the visual cortex.

3.4 Code

GenAI for code offers multiple use cases that shift the roles of human developers, from generating entirely new code to translating from one language to another and documenting its functionality in a meaningful way (Kanbach et al. 2023). However, the extent to which GenAI can actually improve certain KPIs such as productivity, code quality, and program correctness is disputed in the literature (Weisz et al. 2022). Thus, automation is still limited, and human workers will most likely still be needed in development processes in the near future.

While the generation of code can be driven by developers' ideas and the general desire to create something new, the reasons for translating existing code can depend on external modernization pressure. Use cases include, for example, preparing applications for migration to cloud computing environments or transitioning from legacy languages to more current frameworks (Weisz et al. 2021). Studies suggest that developers value code quality and correctness higher than a boost in productivity, whereby the generative capabilities of GenAI for code are already quite advanced (Cámara et al. 2023; Weisz et al. 2022). In contrast to natural language, code follows stricter rules, making errors more critical, and only distinguishes the results into code that can be compiled and code that causes errors (Weisz et al. 2021). As a hybrid use case, GenAI can be applied to document the semantic functionalities of code, as was attempted by Muller et al. (2021).

In another stage of the software development cycle, when the system is planned and designed, GenAI can also be employed for software modeling. Cámara et al. (2023) found that ChatGPT currently has limited capabilities in this regard, as while the syntax of software models is largely sound, the semantics are sometimes not. The authors see opportunities when interfaces for LLMs are provided so that experts can customize the models.

Lastly, an early study by Nelson et al. (2023) explored how ChatGPT could be used to generate 3D models for computer-aided design (CAD) software, bringing together the potential of GenAI for visual creation and coding. The models are usually stored in formats that include the positions of the vertices, the edges or the sequential manufacturing processes. As 3D printers become more popular and 3D models in specific formats are needed to produce results, this could be a promising research direction.

4 CONCEPTUAL MODEL

While the presented application domains of GenAI share general advantages, such as supporting human decision making, requiring little technical knowledge and being available at low cost (Kanbach et al. 2023), serious challenges could be identified from the literature that are prevalent in all areas. Since generative models are dependent on the quality and statistical distributions of the training data, the learning process can be influenced by biases if the data used suffers from corresponding structures. This can be caused either by misinterpretation, when the data unintentionally fuels stereotypes, or by under- and over-representation, when certain phenomena are not represented in the training data in adequate numbers (Vartiainen and Tedre 2023).

Related to issues of ethics, challenges posed by GenAI onto engineers and researchers reach from trust, transparency, and explainability to fears of misuse, deep fakes, and autonomously acting malicious machines. In their study, S. Ali et al. (2021) call for more education on such topics, as generative models are becoming increasingly powerful and produce hyper-realistic results that may become indistinguishable to the average user. Particularly affected domains are image, when untrue circumstances are shown or an artist's style is imitated for images with malicious messages (Vartiainen and Tedre 2023), and audio, when the voices of politicians, for example, are faked.

From a legal perspective, copyright issues are frequently addressed in the literature, particularly in art-related publications. One point of contention is the question of who deserves the credit for the generated works: the generative model and its developers or the person who provided the prompt that leads to the result (Chang et al. 2023). Furthermore, if GenAI is imitating the style of an established artist, the question arises as to whether there should be some kind of financial compensation if it is decided that the copying is legal at all (Jiang et al. 2023; Vartiainen and Tedre 2023; Verheijden and Funk 2023).

Less financially attractive areas, on the other hand, suffer from the challenge of whether an investment in GenAI would be worthwhile. For example, a science such as archaeology is heavily based on factual knowledge and does not generate large profits (Cobb 2023). Similarly, in healthcare, efforts such as reconstructing images from neural activity may not directly lead to major financial gains, but are a hot topic in medicine nonetheless (Ozcelik and VanRullen 2023).

What all areas of GenAI utilization have in common is the expectation that the roles of humans in the workforce and society will shift, as the new evolutionary stage of AI requires less expertise on the fundamental usage level and still allows to easily generate new content (Kanbach et al. 2023). The conceptual model in Figure 2 illustrates all the use cases discussed within the four areas of text, image, audio, and code generation. However, it is not claimed that the model covers all existing applications of GenAI, as the area under investigation is developing dynamically. The color coding is divided into three groups of characteristics. Based on the literature findings, green is associated with well-researched areas for which studies with working use cases, a comprehensible financial value and a low but manageable level of challenges could be found. The second variant, yellow, is intended for areas that are considered more experimental, with working examples and a justifiable financial impact. However, this category includes areas where major technical and legal challenges remain to be overcome, as outlined in the corresponding section. Finally, areas that have not been sufficiently researched but still provide some conceptual ideas are highlighted in red. In this category, the financial impact compared to the necessary investment is lower than in the other areas, while the challenges and requirements are higher.

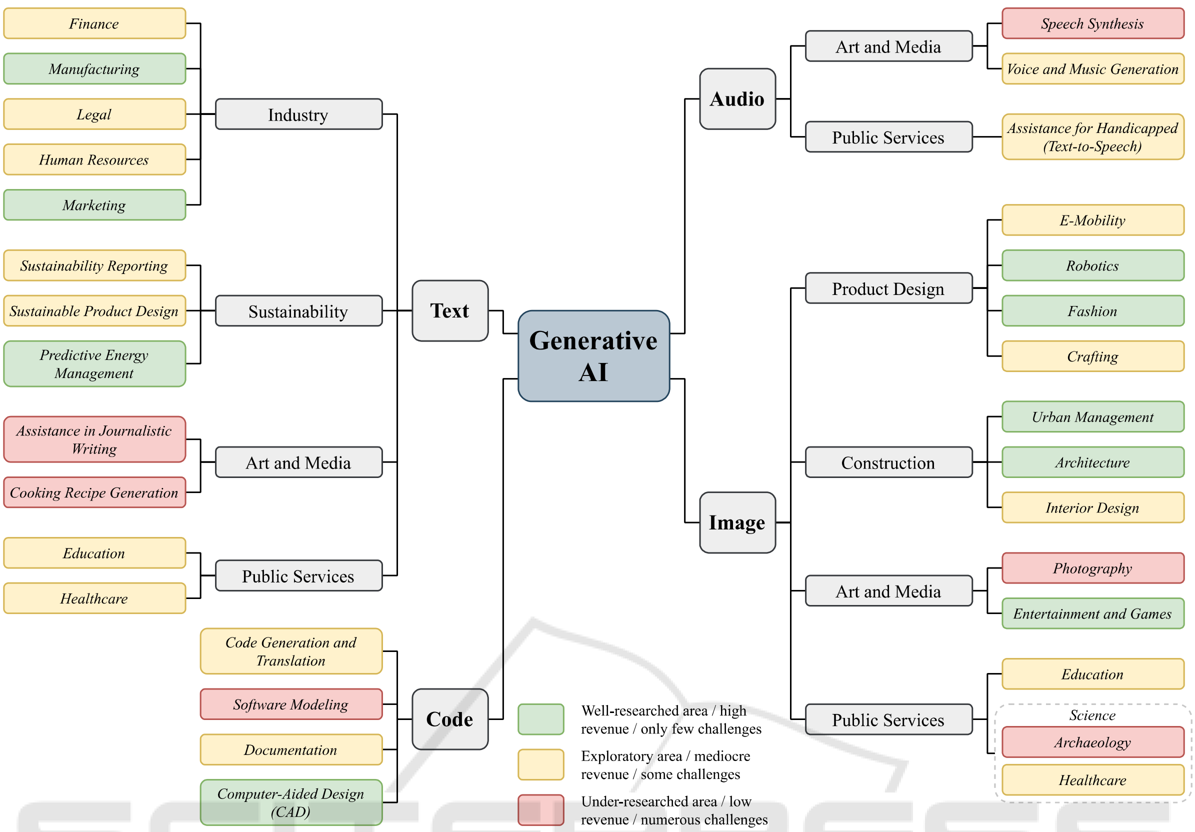

Figure 2: Conceptual model for GenAI potentials and challenges.

5 CONCLUSION

GenAI applications have recently gained significant attention because of the massive opportunities for industry and society. Accordingly, it is expected that GenAI will severely impact numerous areas of life in the future. Nevertheless, the benefits of this new phenomenon are accompanied by noteworthy obstacles that should be taken into consideration (e.g., bias, accuracy of results, potential misuse). Hence, in this work, the current state-of-the-art of GenAI in the scientific literature is examined, focusing on potentials and challenges. Based on the generated types of content, the analysis is divided in the four categories text, audio, image, and code. We derive a conceptual model for GenAI application areas that consolidates and assesses the findings from the literature. One notable observation is that the view of AI is shifting with the advance of GenAI, as AI is no longer seen as a mere decision-making tool, but as a kind of human-like collaborator in creative tasks (Turchi et al. 2023). The results of the study could be extended by considering further scientific literature databases and including forward and backward searches. Furthermore, specific emphasis could be put on the potential of hybrid GenAI outputs (e.g., text combined with video, or generated audio in a virtual environment created by GenAI) as additional promising developments might become visible, especially in the context of the metaverse (Lv 2023). In conclusion, the full potential of GenAI for cross-domain applications will still require considerable research efforts in the foreseeable future.

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