Legal Protection Efforts and Policies to Combat Deepfake Porn Crimes with Artificial Intelligence (AI) in Indonesia

Ocktave Ferdinal[1] , **Herman Bakir[2]**
[1]Universitas Borobudur, Indonesia
[2]Universitas Borobudur, Indonesia

ABSTRACT

Background. The rapid development of artificial intelligence (AI)-based technologies, including deepfake, has introduced new challenges to the legal system. Deepfake porn, which manipulates digital content to create fake explicit materials, threatens privacy, dignity, and personal reputation. In Indonesia, existing laws related to pornography and electronic information are insufficient to address these crimes effectively, leaving victims vulnerable.

Purpose. This study aims to analyze the legal gaps in addressing AI-based cybercrimes, especially deepfake porn, and propose legal policies to provide better protection for individuals while balancing technological innovation.

Method. A qualitative approach was employed, combining doctrinal legal research with case analysis. Legal frameworks, including Indonesia's Law on Pornography and the Electronic Information and Transactions (ITE) Law, were reviewed alongside global legal precedents on AI misuse.

Results. The study reveals that existing laws are outdated in handling AI-driven crimes. There is an urgent need for specific regulations addressing the misuse of AI, particularly in creating and distributing deepfake content. Effective enforcement mechanisms and victim support systems are also lacking.

Conclusion. To combat deepfake porn crimes, Indonesia must establish specific legal frameworks regulating AI misuse and ensuring accountability. Clear definitions, strict penalties, and victim protection measures should be integral to these policies.

KEYWORDS

Deepfake Porn, Artificial Intelligence, Legal Protection, Cybercrime, Indonesian Law.

INTRODUCTION

The rapid development of Artificial Intelligence (AI) technology in recent years has had a significant impact on various sectors, from health, education, to the entertainment industry (Adir et al., 2020). One of the biggest breakthroughs in AI is the ability to produce content that is so realistic that it is hard to distinguish it from reality, including in the form of videos. Deepfake technology, one application of AI, allows the creation of videos that manipulate a person's face and voice to create scenes or conversations that appear real, even though they never happened. Using generative adversarial networks (GANs),

AI can analyze thousands of images and voices of a person to create a very convincing fake video (Ahmed et al., 2020). Although this technology has positive potential, such as in film and art, its ability to spread false information and deceive the public also opens up opportunities for abuse.

The misuse of deepfake technology, especially in the form of fake pornographic videos or deepfake porn, has caused serious social and legal impacts (Ameen et al., 2021). This crime often targets individuals personally, especially women, by manipulating their images and videos to be distributed without permission. This can damage reputations, destroy personal lives, and cause psychological trauma for victims. From a legal perspective, the existence of deepfake porn is a major challenge because it is difficult to distinguish between real and fake content, and there is no adequate regulation to combat the spread of this type of content (Ayoub Shaikh et al., 2022). In addition, AI also opens up the potential for other abuses, such as political manipulation, digital identity forgery, and attacks on individual privacy. Therefore, although AI has great potential for progress in various fields, its uncontrolled use can pose serious threats to security, privacy, and social justice.

Humans continue to strive to improve their abilities in various aspects of life, one of which is through technological advancement. Technology refers to rational methods or principles applied to create an object or system (Baduge et al., 2022). Technological advances have made significant contributions to improving various sectors of life, such as the economy, food, and computers. Along with the rapid development of technology, artificial intelligence (AI) has emerged as an intelligent system that increasingly dominates various fields. The emergence of AI proves that information technology in the digital era can have a positive impact on human life (Bohr & Memarzadeh, 2020). In Indonesia, the use of AI is increasing rapidly. In 2023, Indonesia will be ranked third in the world in terms of AI use, with 1.4 billion visits to AI-based applications, or 5.60% of total global traffic. This shows how important the role of AI is in supporting various community activities in Indonesia. AI can handle various types of tasks, including previously unimaginable tasks, and process big data quickly without space and time constraints.

However, even though AI offers various positive benefits, the implementation of this technology still faces major challenges in terms of legal regulation (Briganti & Le Moine, 2020). The rapid development of digital technology requires adjustments to legal regulations to keep up with the pace of development. Crimes that occur in cyberspace, such as cybercrime, utilize computer technology and the internet as a medium to commit crimes. One example of a crime that utilizes AI is the creation of fake pornographic videos or deepfake porn, which is now a global phenomenon. Deepfake is an audio-visual manipulation technology that combines deep learning to create fake content with a high level of realism. The technology allows a person's face to be replaced with that of another person in a video, creating content that is very difficult to distinguish from the real thing. Deepfake porn, which is often used to spread fake pornographic content, poses a serious threat, especially to public figures and high-ranking individuals (Chen et al., 2020). The negative impacts include social unrest, the spread of hatred, and the potential for misuse in the form of propaganda or politics. As the use of this technology increases, it is possible that similar crimes can befall the general public, not just public figures or famous individuals. In the world of social media, criminals have a great opportunity to commit crimes that are difficult to reveal, especially in cases of cybercrime. This is due to the difficulties experienced by law enforcement officers in the process of providing evidence, especially in cases involving sophisticated technology such as deepfake. One of the main challenges in dealing with deepfake crimes is the difficulty in detecting the perpetrators, because they often use anonymous identities that are difficult to trace (Collins et al., 2021). In addition, victims of this crime often choose to remain silent or not report the incident,

thus exacerbating the difficulty in revealing the case. One example of a deepfake crime that occurred in Indonesia is the case of artist Nagita Slavina in 2022, where a 61-second indecent video allegedly resembling her was widely circulated. After being investigated, it turned out that the video was the result of engineering using deepfake technology. Other famous figures such as Donald Trump, Vladimir Putin, and Gal Gadot have also fallen victim to this phenomenon. Pornographic deepfake crimes more often target women, who are the main targets of gender-based violence in cyberspace, as recorded in a 2022 report by the National Commission on Violence Against Women.

Pornographic deepfake crimes are a serious problem in Indonesia because it is difficult to distinguish the authenticity of the content being distributed. Cases of cyber-based sexual violence using deepfake technology show how important it is to properly handle this crime (Gerke et al., 2020). According to the National Commission on Violence Against Women report, throughout 2022, more than a thousand cases of gender-based sexual violence were reported, with most of them involving cyber-crimes such as the distribution of pornographic videos or photos using deepfake techniques. This crime causes social unrest because its impact damages the victim's reputation and creates legal uncertainty (Himeur et al., 2021). Deepfake-based crimes create major challenges for the state in terms of protection and law enforcement because there are no regulations that specifically regulate this. Thus, the question arises whether existing laws are sufficient to provide effective protection or whether new laws need to be created that are more specific to deal with this type of crime.

Legal vacuum refers to a situation where there are no regulations or legal provisions that clearly regulate a particular action or phenomenon, which causes uncertainty in the application of the law (Huang et al., 2020). In the context of Artificial Intelligence (AI)-based pornographic deepfake crimes, a legal vacuum occurs because the development of this technology is very rapid while existing regulations have not been able to keep up with the impacts caused. Although several laws such as the ITE (Information and Electronic Transactions) Law in Indonesia have covered several aspects related to cybercrime, there are no regulations that specifically regulate the misuse of deepfake technology (Huynh-The et al., 2023). This causes difficulties in law enforcement because law enforcement officers do not have clear enough guidelines to prosecute perpetrators who use this technology to harm others, especially in terms of protecting victims and providing fair sanctions.

RESEARCH METHODOLOGY

The normative legal research method is an approach used to analyze legal problems based on applicable norms or laws (Hwang & Chien, 2022). In this study, the legislative approach is applied to explore and analyze existing regulations related to Artificial Intelligence (AI)-based pornography deepfake crimes, by reviewing whether the current applicable law is sufficient to address the phenomenon (Hwang et al., 2020). Meanwhile, the analytical approach is used to analyze and review the application of legal norms in practice and identify gaps or legal gaps that may exist, to provide more effective solutions in dealing with the problem (Jacovi et al., 2021). The combination of the legislative and analytical approaches allows the study to provide comprehensive recommendations related to the development of more specific regulations to address this technology-based crime.

RESULT AND DISCUSSION
The Effectiveness of Current Legal Regulations in Indonesia in Handling Artificial Intelligence (AI)-Based Pornographic Deepfake Crimes

Rapid technological developments, especially in the field of artificial intelligence (AI), have had a significant impact on various aspects of life, including the digital world. One of the AI applications that is currently raising concerns is the use of deepfake technology, which allows the creation of fake videos or images with a very high level of authenticity . This technology, although it has positive potential, is also used for criminal purposes, one of which is in the creation of pornographic content that is detrimental to individuals, especially through pornographic deepfakes (Jung et al., 2021). In Indonesia, although there are several legal regulations governing cybercrime, including in the Electronic Information and Transactions Law (UU ITE), the existence of these regulations has not been fully effective in dealing with crimes involving AI technology such as pornographic deepfakes. [13] This raises questions about the extent to which existing regulations are able to protect victims and provide a deterrent effect on perpetrators, and whether there needs to be legal reform or adjustment to address this issue more effectively.

So far, attention in criminal law has often focused on perpetrators of crimes, while victims are often ignored. In many cases, after the perpetrator is sentenced, victims are considered to have obtained justice, even though in reality, restitution for the losses they have suffered is often not prioritized. However, in recent years, Indonesian criminal law has begun to pay more attention to victim protection. Crimes are not only seen as violations of state interests, but also as acts that harm individual victims. One proof of this transformation is the existence of the Witness and Victim Protection Law which provides legal protection for those who are victims of crimes, including crimes with serious impacts such as pornography.

Legal protection for victims, especially in cases of crimes such as artificial intelligence (AI)-based deepfake pornography, is very important. The state, through regulation and law enforcement, has a responsibility to protect the rights of victims, as stipulated in the principle of equality before the law. Victims of pornography crimes not only experience physical and psychological losses but also severe emotional impacts, including trauma and deep shame (Kaplan & Haenlein, 2020). Sometimes, victims experience re-victimization through cyberbullying, and some are even depressed to the point of having thoughts of ending their lives. Unfortunately, many people prioritize sensation or even spread the content without empathy for the victim.

Preventive legal protection aims to prevent violations or disputes by establishing clear regulations and regulating the behavior of citizens. The government can make policies in the form of laws and regulations that aim to prevent crimes and provide limitations on certain obligations. This preventive legal protection does not only focus on law enforcement after a violation occurs but rather emphasizes early prevention so that violations of the law do not occur (Kaur et al., 2023). In the context of artificial intelligence (AI)-based pornography deepfake crimes, the regulations that can be used to prevent violations are Law Number 11 of 2008 concerning Information and Electronic Transactions (ITE), Law Number 27 of 2022 concerning Personal Data Protection, and other regulations that regulate criminal acts related to the use of deepfake technology.

Meanwhile, repressive legal protection focuses more on efforts to impose sanctions on perpetrators of crimes as a form of retaliation for the losses experienced by victims. This form of protection includes the application of criminal sanctions such as fines or imprisonment for perpetrators of crimes. In the case of pornographic deepfake crimes, repressive measures also involve technical measures such as terminating access or "taking down" violating content, as well as the application of the right to be forgotten (Lalmuanawma et al., 2020). Protection through takedown is regulated in the Regulation of the Minister of Communication and Information (PERMENKOMINFO-PSE) Number 5 of 2020, which includes blocking or deleting detrimental content. Meanwhile, the right to be forgotten is regulated in the ITE Law and the Government

Regulation on Electronic System and Transaction Organizers (PP-PSTE), which allows victims to request the deletion of irrelevant and detrimental electronic information or documents, based on a court order.

Restitution is an effort to compensate victims of a crime as a form of restitution for losses incurred due to the perpetrator's actions. The concept of restitution aims to return the victim to their original condition before the crime occurred, although in practice this is difficult to achieve. Protection through restitution includes the restoration of the victim's rights, including freedom, social status, family life, work, and the victim's assets. In the context of AI-based deepfake pornography crimes, victims can obtain restitution based on the provisions of Law Number 12 of 2022 concerning Criminal Acts of Sexual Violence (UU TPKS). Article 4 of the TPKS Law stipulates that non-physical sexual harassment, such as that which occurs in deepfake porn crimes, can also be subject to restitution as part of the restoration of the victim's rights (Loh et al., 2022). In addition to restitution, compensation is also a form of compensation provided by the state when the perpetrator is unable to provide full compensation to the victim. The state has a responsibility to protect citizens and ensure their welfare. In the case of AI-based deepfake porn, compensation can be provided if the perpetrator's assets that have been confiscated are not sufficient to cover the restitution costs set by the court. Article 35 of the TPKS Law stipulates that the state will provide compensation to victims by the court's decision if the convict's assets are insufficient to compensate for the losses suffered by the victim.

In addition to material protection, victims of crimes such as deepfake porn also need psychological support. Counseling is an effort to help victims overcome the psychological impact caused by criminal acts, which often disrupt the victim's mental and social life. In the TPKS Law, some provisions require social service providers to provide psychological support to victims of sexual violence. Article 41 stipulates that the Regional Technical Implementation Unit (UPTD) or related institutions must provide psychological services, while Article 68 guarantees the victim's right to receive medical, mental, and social recovery. The purpose of psychological support is to help victims overcome trauma and improve their overall quality of life.

Although various forms of legal protection such as restitution, compensation, and counseling have been regulated in legislation, the regulations are still ineffective in handling cases of crimes such as artificial intelligence (AI)-based deepfake porn (Maia et al., 2020). This is due to several factors, including a lack of comprehensive understanding of the complex nature of this crime, limited implementation of existing regulations, and slow response from law enforcement officers in dealing with perpetrators and providing maximum protection to victims. Existing regulations, although providing a clear legal framework, still face major challenges in terms of consistent implementation and supervision, so victims often do not get the justice they deserve.

Legal Void and Efforts to Combat AI-Based Pornographic Deepfake Crimes in Indonesia

In Indonesia, pornography is regulated by several laws and regulations, one of which is Law Number 44 of 2008 concerning Pornography. This law prohibits the distribution, creation, and circulation of pornographic material that can damage public morality and violate individual rights, especially victims. In addition, Indonesia also has Law Number 11 of 2008 which has been updated by Law Number 19 of 2016 concerning Electronic Information and Transactions (UU ITE), which regulates the misuse of information technology to commit crimes, including pornography (Manickam et al., 2022). However, although there are regulations prohibiting the distribution and distribution of pornographic material, existing laws do not fully cover new crimes that are developing, such as crimes that use AI technology to create pornographic deepfake content. This

legal gap creates difficulties in tackling technology-based crimes because the AI technology used to create such content has not been specifically regulated in existing laws.

The legal gap regarding AI-based pornographic deepfakes is visible in several aspects. One of them is the inability of Indonesian law to identify and handle crimes involving sophisticated technology, such as deepfakes. Pornographic deepfake content is created using artificial intelligence to change or manipulate images and videos to spread pornography or commit sexual harassment without the victim's consent. Existing regulations, such as the ITE Law or the Pornography Law, do not directly regulate the misuse of AI technology to create this type of content (Naik et al., 2022). As a result, law enforcement officers have difficulty detecting and prosecuting perpetrators who use this technology to damage a person's reputation and violate their privacy. In addition, Indonesian law tends to be hampered by the speed of technological development. While the law still regulates criminal acts based on clearly visible physical acts, AI technology is developing so rapidly that many crimes involving this technology are not covered by existing regulations.

The main challenge faced by law enforcement officers is the difficulty in identifying pornographic deepfake crimes. The process of creating deepfake content that changes a person's face to appear as if they are involved in pornographic activities, without their knowledge or permission, often makes it difficult for perpetrators to be tracked. The technology used to produce deepfakes is very sophisticated, and much of this content is distributed through digital platforms that are not easily monitored by authorities (Niu et al., 2022a) . Furthermore, while some technologies can be used to detect image or video manipulation, software limitations and the difficulty in identifying perpetrators who often use anonymity in cyberspace make law enforcement very difficult. Thus, existing laws and regulations, while trying to cover the misuse of technology, are not effective enough in dealing with the rapid development of deepfake and AI technologies that are increasingly being misused to commit pornography-based crimes.

The absence of adequate legal frameworks is evident in the inability of Indonesian law to provide sufficient protection for victims of AI-generated deepfake pornography. The existing legal provisions fail to comprehensively address the necessary aspects required to combat this emerging crime, including the restoration of victims' rights and the enforcement of justice. For instance, when victims of deepfake pornography attempt to remove harmful content, the current legal procedures are neither sufficiently clear nor effective in safeguarding such rights(Niu et al., 2022b). Moreover, existing regulations do not adequately establish the responsibilities of digital platforms in addressing harmful deepfake content, particularly given the volume of content uploaded without appropriate oversight. Consequently, to combat this technology-driven crime, a more comprehensive and responsive regulatory framework is required to keep pace with rapid technological advancements.

Deepfake technology is a tangible manifestation of the rapid progress in artificial intelligence (AI). A significant consequence of this technology is its capacity to produce fabricated pornographic content, often referred to as "deepfake porn." By leveraging AI, deepfake technology can generate manipulated videos or images that falsely depict individuals engaged in sexual acts, even though no such acts occurred in reality (Pan & Zhang, 2021). This type of content has become an increasingly alarming form of cybercrime, as it exploits individuals without their consent and damages their reputations. A 2019 study by Deeptrace revealed that approximately 96% of videos created using deepfake technology pertain to pornographic material. The proliferation of such content poses a growing threat, particularly given the rapid advancements in technology and the ease of internet access that facilitates the dissemination of harmful materials.

The urgency of establishing specific legal provisions to address AI-based deepfake pornography in Indonesia becomes increasingly evident in light of the rising use of the internet and technological sophistication. Although Indonesia has enacted the Electronic Information and Transactions Law (UU ITE) and the Pornography Law, these regulations are insufficient to address the challenges posed by deepfake technology (Pelau et al., 2021). Existing laws do not specifically regulate AI technology or its negative implications, including its misuse in creating fabricated pornographic content. Therefore, the Indonesian government must develop regulations that not only govern the use of this technology but also address the various legal issues arising from its misuse, such as cybercrimes and violations of individual privacy rights.

In responding to the rapid advancements in AI technology, Indonesia can draw inspiration from countries like the European Union (EU) and the United States, which have already implemented regulatory measures for AI usage. The EU, for example, classifies AI systems based on their risk levels, ranging from unacceptable risk systems to lower-risk systems. High-risk AI systems, such as those used for assessing individual performance or monitoring sensitive data, are permitted but subject to stringent requirements to mitigate negative impacts (Soori et al., 2023). In the context of generative AI, such as that used to create deepfakes, clear transparency requirements are essential to ensure that users are aware of AI-generated content and to prevent the technology's use in creating illegal materials. This approach could serve as a model for Indonesia in formulating appropriate regulations to govern AI usage, particularly regarding AI-based cybercrimes like deepfake pornography.

Additionally, Indonesia's legal framework for AI should encompass provisions to address the misuse of this technology. Crimes leveraging deepfake technology to create fabricated pornographic content or exploit individuals without their consent are on the rise. Given the challenges many countries face in addressing AI-based cybercrimes, the implementation of strict regulations and clear sanctions is urgently needed. While the UU ITE already addresses certain forms of cybercrime, it does not specifically regulate AI and its potential for misuse (Talaviya et al., 2020). Therefore, specific regulations are required to govern the utilization of AI across various sectors, including personal data security and the prevention of technology misuse for criminal purposes, such as deepfake pornography. By enacting clearer and more stringent regulations, Indonesia can enhance its ability to combat technology-driven crimes and provide better protection for its citizens.

As a further step, Indonesia must craft regulations that balance technological advancements with legal protections for individuals. While the development of AI technology offers numerous benefits, clear and firm regulations are necessary to ensure its usage does not infringe on individual rights or cause significant harm to society (Ullah et al., 2020). Future legislation should not only address the general use of AI but also facilitate beneficial technological advancements while safeguarding individual privacy and security. Strict sanctions for the misuse of AI technology should also be considered to create a strong deterrent effect against perpetrators. Consequently, although the challenges facing the government are substantial, the establishment of precise and responsive regulations tailored to the advancements in AI technology is critical to protecting society from the adverse effects of AI-based cybercrimes.

CONCLUSION

Artificial intelligence (AI)--b deepfake technology has had a significant impact, especially in the context of creating fake pornographic content that threatens individuals' privacy and reputation. Although Indonesia has several regulations governing criminal acts related to pornography and electronic information, the existing regulations are not sufficient to address AI-based crimes such as

deepfake porn. Therefore, it is important for Indonesia to immediately formulate a specific law governing the use of AI, taking into account its negative impacts, such as the exploitation of individuals through the creation of harmful fake content. Clear regulations and strict sanctions are needed to address this challenge, while still providing space for beneficial technological innovation. Thus, the establishment of regulations that are responsive to the development of AI technology will increase legal protection for the community and strengthen law enforcement against cybercrime which continues to grow.

AUTHORS' CONTRIBUTION

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.
Author 2: Conceptualization; Data curation; In-vestigation.

REFERENCES

Adir, O., Poley, M., Chen, G., Froim, S., Krinsky, N., Shklover, J., Shainsky-Roitman, J., Lammers, T., & Schroeder, A. (2020). Integrating Artificial Intelligence and Nanotechnology for Precision Cancer Medicine. *Advanced Materials*, *32*(13), 1901989. https://doi.org/10.1002/adma.201901989

Ahmed, Z., Mohamed, K., Zeeshan, S., & Dong, X. (2020). Artificial intelligence with multi-functional machine learning platform development for better healthcare and precision medicine. *Database*, *2020*, baaa010. https://doi.org/10.1093/database/baaa010

Ameen, N., Tarhini, A., Reppel, A., & Anand, A. (2021). Customer experiences in the age of artificial intelligence. *Computers in Human Behavior*, *114*, 106548. https://doi.org/10.1016/j.chb.2020.106548

Ayoub Shaikh, T., Rasool, T., & Rasheed Lone, F. (2022). Towards leveraging the role of machine learning and artificial intelligence in precision agriculture and smart farming. *Computers and Electronics in Agriculture*, *198*, 107119. https://doi.org/10.1016/j.compag.2022.107119

Baduge, S. K., Thilakarathna, S., Perera, J. S., Arashpour, M., Sharafi, P., Teodosio, B., Shringi, A., & Mendis, P. (2022). Artificial intelligence and smart vision for building and construction 4.0: Machine and deep learning methods and applications. *Automation in Construction*, *141*, 104440. https://doi.org/10.1016/j.autcon.2022.104440

Bohr, A., & Memarzadeh, K. (2020). The rise of artificial intelligence in healthcare applications. In *Artificial Intelligence in Healthcare* (pp. 25–60). Elsevier. https://doi.org/10.1016/B978-0-12-818438-7.00002-2

Briganti, G., & Le Moine, O. (2020). Artificial Intelligence in Medicine: Today and Tomorrow. *Frontiers in Medicine*, *7*, 27. https://doi.org/10.3389/fmed.2020.00027

Chen, X., Xie, H., Zou, D., & Hwang, G.-J. (2020). Application and theory gaps during the rise of Artificial Intelligence in Education. *Computers and Education: Artificial Intelligence*, *1*, 100002. https://doi.org/10.1016/j.caeai.2020.100002

Collins, G. S., Dhiman, P., Andaur Navarro, C. L., Ma, J., Hooft, L., Reitsma, J. B., Logullo, P., Beam, A. L., Peng, L., Van Calster, B., Van Smeden, M., Riley, R. D., & Moons, K. G. (2021). Protocol for development of a reporting guideline (TRIPOD-AI) and risk of bias tool (PROBAST-AI) for diagnostic and prognostic prediction model studies based on artificial intelligence. *BMJ Open*, *11*(7), e048008. https://doi.org/10.1136/bmjopen-2020-048008

Gerke, S., Minssen, T., & Cohen, G. (2020). Ethical and legal challenges of artificial intelligence-driven healthcare. In *Artificial Intelligence in Healthcare* (pp. 295–336). Elsevier. https://doi.org/10.1016/B978-0-12-818438-7.00012-5

Himeur, Y., Ghanem, K., Alsalemi, A., Bensaali, F., & Amira, A. (2021). Artificial intelligence based anomaly detection of energy consumption in buildings: A review, current trends and new perspectives. *Applied Energy*, *287*, 116601. https://doi.org/10.1016/j.apenergy.2021.116601

Huang, S., Yang, J., Fong, S., & Zhao, Q. (2020). Artificial intelligence in cancer diagnosis and prognosis: Opportunities and challenges. *Cancer Letters*, *471*, 61–71. https://doi.org/10.1016/j.canlet.2019.12.007

Huynh-The, T., Pham, Q.-V., Pham, X.-Q., Nguyen, T. T., Han, Z., & Kim, D.-S. (2023). Artificial intelligence for the metaverse: A survey. *Engineering Applications of Artificial Intelligence*, *117*, 105581. https://doi.org/10.1016/j.engappai.2022.105581

Hwang, G.-J., & Chien, S.-Y. (2022). Definition, roles, and potential research issues of the metaverse in education: An artificial intelligence perspective. *Computers and Education: Artificial Intelligence*, *3*, 100082. https://doi.org/10.1016/j.caeai.2022.100082

Hwang, G.-J., Xie, H., Wah, B. W., & Gašević, D. (2020). Vision, challenges, roles and research issues of Artificial Intelligence in Education. *Computers and Education: Artificial Intelligence*, *1*, 100001. https://doi.org/10.1016/j.caeai.2020.100001

Jacovi, A., Marasović, A., Miller, T., & Goldberg, Y. (2021). Formalizing Trust in Artificial Intelligence: Prerequisites, Causes and Goals of Human Trust in AI. *Proceedings of the 2021 ACM Conference on Fairness, Accountability, and Transparency*, 624–635. https://doi.org/10.1145/3442188.3445923

Jung, J., Maeda, M., Chang, A., Bhandari, M., Ashapure, A., & Landivar-Bowles, J. (2021). The potential of remote sensing and artificial intelligence as tools to improve the resilience of agriculture production systems. *Current Opinion in Biotechnology*, *70*, 15–22. https://doi.org/10.1016/j.copbio.2020.09.003

Kaplan, A., & Haenlein, M. (2020). Rulers of the world, unite! The challenges and opportunities of artificial intelligence. *Business Horizons*, *63*(1), 37–50. https://doi.org/10.1016/j.bushor.2019.09.003

Kaur, D., Uslu, S., Rittichier, K. J., & Durresi, A. (2023). Trustworthy Artificial Intelligence: A Review. *ACM Computing Surveys*, *55*(2), 1–38. https://doi.org/10.1145/3491209

Lalmuanawma, S., Hussain, J., & Chhakchhuak, L. (2020). Applications of machine learning and artificial intelligence for Covid-19 (SARS-CoV-2) pandemic: A review. *Chaos, Solitons & Fractals*, *139*, 110059. https://doi.org/10.1016/j.chaos.2020.110059

Loh, H. W., Ooi, C. P., Seoni, S., Barua, P. D., Molinari, F., & Acharya, U. R. (2022). Application of explainable artificial intelligence for healthcare: A systematic review of the last decade (2011–2022). *Computer Methods and Programs in Biomedicine*, *226*, 107161. https://doi.org/10.1016/j.cmpb.2022.107161

Maia, E. H. B., Assis, L. C., De Oliveira, T. A., Da Silva, A. M., & Taranto, A. G. (2020). Structure-Based Virtual Screening: From Classical to Artificial Intelligence. *Frontiers in Chemistry*, *8*, 343. https://doi.org/10.3389/fchem.2020.00343

Manickam, P., Mariappan, S. A., Murugesan, S. M., Hansda, S., Kaushik, A., Shinde, R., & Thipperudraswamy, S. P. (2022). Artificial Intelligence (AI) and Internet of Medical Things (IoMT) Assisted Biomedical Systems for Intelligent Healthcare. *Biosensors*, *12*(8), 562. https://doi.org/10.3390/bios12080562

Naik, N., Hameed, B. M. Z., Shetty, D. K., Swain, D., Shah, M., Paul, R., Aggarwal, K., Ibrahim, S., Patil, V., Smriti, K., Shetty, S., Rai, B. P., Chlosta, P., & Somani, B. K. (2022). Legal and

Ethical Consideration in Artificial Intelligence in Healthcare: Who Takes Responsibility? *Frontiers in Surgery*, *9*, 862322. https://doi.org/10.3389/fsurg.2022.862322

Niu, H., Li, H., Gao, S., Li, Y., Wei, X., Chen, Y., Yue, W., Zhou, W., & Shen, G. (2022a). Perception-to-Cognition Tactile Sensing Based on Artificial-Intelligence-Motivated Human Full-Skin Bionic Electronic Skin. *Advanced Materials*, *34*(31), 2202622. https://doi.org/10.1002/adma.202202622

Niu, H., Li, H., Gao, S., Li, Y., Wei, X., Chen, Y., Yue, W., Zhou, W., & Shen, G. (2022b). Perception-to-Cognition Tactile Sensing Based on Artificial-Intelligence-Motivated Human Full-Skin Bionic Electronic Skin. *Advanced Materials*, *34*(31), 2202622. https://doi.org/10.1002/adma.202202622

Pan, Y., & Zhang, L. (2021). Roles of artificial intelligence in construction engineering and management: A critical review and future trends. *Automation in Construction*, *122*, 103517. https://doi.org/10.1016/j.autcon.2020.103517

Pelau, C., Dabija, D.-C., & Ene, I. (2021). What makes an AI device human-like? The role of interaction quality, empathy and perceived psychological anthropomorphic characteristics in the acceptance of artificial intelligence in the service industry. *Computers in Human Behavior*, *122*, 106855. https://doi.org/10.1016/j.chb.2021.106855

Soori, M., Arezoo, B., & Dastres, R. (2023). Artificial intelligence, machine learning and deep learning in advanced robotics, a review. *Cognitive Robotics*, *3*, 54–70. https://doi.org/10.1016/j.cogr.2023.04.001

Talaviya, T., Shah, D., Patel, N., Yagnik, H., & Shah, M. (2020). Implementation of artificial intelligence in agriculture for optimisation of irrigation and application of pesticides and herbicides. *Artificial Intelligence in Agriculture*, *4*, 58–73. https://doi.org/10.1016/j.aiia.2020.04.002

Ullah, Z., Al-Turjman, F., Mostarda, L., & Gagliardi, R. (2020). Applications of Artificial Intelligence and Machine learning in smart cities. *Computer Communications*, *154*, 313–323. https://doi.org/10.1016/j.comcom.2020.02.069