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Future-Oriented Civil and Private Law: Integrating Artificial Intelligence (AI) and Machine Learning (ML) Technologies

ABSTRACT: *A recent study delved into the burgeoning fields of artificial intelligence (AI) and machine learning (ML) within civil and private law. The study, which focused on analyzing 140 academic papers published from 2017 to 2023 using software tools such as RStudio, VOSviewer, and Excel, revealed a significant rise in publications, particularly since 2020. Key research topics have examined the application of AI in decision-making on civil and private law, argument, persuasion and progress in the legal processing of natural language through deep learning techniques. The study also identified leading contributions from scientists in the US, Canada and the Netherlands. However, it also recognizes the need for further research to evaluate the effectiveness of various AI and ml methodologies in legal contexts. This in turn would support civil and private evidence -based rights in various sectors and geographical regions, which would increase their usability and integration.*

KEYWORDS: Artificial Intelligence, Machine Learning, Legal System, Bibliometric Study, Emerging Patterns, Areas of Research Interest.

JEL CLASSIFICATION CODES: N10, N50, N70

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INTRODUCTION

The application for artificial intelligence (AI) and machine learning (ML) in civil and private law brings exciting possibilities and complex challenges. These technologies can radically transform legal processes, improve decision -making and facilitate greater approach to justice. This is found at the work of Chalkidis & Kampas (2019). AI and ML can analyze large volumes of legal data, predict the results of cases and help in legal research, increasing the effectiveness and accuracy in the legal system (Branding et al., 2021). However, the use of AI in civil and private law raises serious related issues concerning ethics, regulation and possible bias in AI decisions on legal matters (Larsson, 2020). The first applications, such as Embeddings legal words, have shown a promise to process large collections of legal documents, but to create scalable and explained models, further development is needed (Chalkidis & Kampas, 2019; Branting et al., 2021).

Skirting of systems, such as hypothetics (hypo), created the shape of contemporary trajectories for AI in the law and touched the needs of ethical management in AI (Bench-Capon, 2017). The concept of the digital Code of Civil Procedure and the concept of AI as the law is evidenced by the developing landscape of legal practice at digital age (Engstrom, 2021; Verheij, 2020). In addition, the AI application in the area of law enforcement and its ability to classify and analyze legal norms further illustrates the enormous potential of AI to innovate legal areas (Rademacher, 2020; Walzl et al., 2019). However, the introduction of AI into civil and private law requires detailed discussions on ethical considerations, regulatory frames and responsible proposals in the implementation of the AI (Simshaw, 2018; Moodley et al., 2020). This represents a very promising trend on the interface between AI and right for effective, transparent and accessible justice (Villata et al., 2022; Greenleaf et al., 2018).

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Attention to ethical, regulatory and distorted concerns in this rapidly developing field is very important. In the field of civil and private law, interdisciplinary cooperation between legal experts and technologists is essential in unlocking all AI and ml options. With such cooperation, legal systems of controlled Ai-kars are considered to be fair, transparent and responsible-(Chalkidis & Kampas, 2019; Branting et al., 2021; Larsson, 2020). Key challenges include ensuring data privacy, mitigating algorithmic bias, and addressing the ethical implications of AI in legal decision-making. Overcoming these hurdles will enable the effective use of AI in streamlining legal processes and improving the outcomes of civil and private law. Using a bibliometric approach, this study analyzes the current state of AI and ML in civil and private law and bridges historical fragmentation in the field. The research aims at the following key questions:

- a) Evolution of Research: How has academic research on AI and ML in civil and private law evolved from the year 2017 to 2023? This analysis will track the development of the field over the past 6 years, identifying emerging themes and areas of focus.
- b) Publication Trends and Key Players: What are the major emerging publication volume and citation patterns, and who are the important contributors in the field of AI and ML in civil and private law, as brought out by the bibliometric analysis? This mapping of research output will then be used to identify prolific authors and institutions that determine the character of the field.
- c) Critical Gaps and Future Directions: What are the significant deficiencies in the current literature on AI and ML in civil and private law, and how may these deficiencies impact future developments? Identifying these significant gaps facilitates the advancement of future research initiatives, ensuring the continued evolution of the area.

This is a bibliometric analysis of the application of AI and ML integrations in civil and private law, considering 279 articles indexed on Web of Science (WoS) and Scopus from 2017 until the end of the year 2023. In this framework, seven thematic research clusters are spotted through citation, co-citation, co-authorship, trend, and keyword analysis: Artificial Intelligence and Civil and private law, Argumentation in Civil and private law Technologies, Digital Economy in Civil and private law Technologies, Persuasion in Civil and private law Technologies, Human Legal Language Technology, Legal Natural Language Deep Learning, and Proof in Civil and private law Technologies.

Through a comprehensive bibliometric approach, this research plunged light on the development of AI and ml in civil and private law with an emphasis on the main research trends, key players and critical gaps in the literature. This study is a step beyond the previous limited studies on the narrow aspects of civil and private law and also considers a number of traditional research methods. It provides a holistic view of this area by making valuable accessories related to the insight into legal culture, using AI in legal practice and the role and impact of social evidence in this area. These findings will have a useful basis for further research and applications in a rapidly developing field. The following sections are organized as follows: Section 2 describes data sources and methodology; Section 3 represents the findings of bibliometric analysis; And Section 4 summarizes the main findings and discusses their consequences for future research in AI and ML in civil and private law.

STRUCTURE OF METHODS

Data Gathering

Data collection channels

The additional strengths of the WOS and Scopus databases were supported by the following studies: Razzaque (2021), Shamdi et al. (2022), Lillywhite & Wolbring (2019), Al Qudah et al. (2023) and Al Qudah et al. (2024). This was the main reason for our decision to use these two data collection bases. First, WOS is one of the largest archives of reviewed academic publications in various areas of scientific knowledge. Due to the wide range of our investigation, this is very welcome. It provides scientists sophisticated search equipment along with a number of bibliometric analytical functions. Finally, WoS boasts a huge storage of reliable legal issues that guarantees the quality and relevance of resources for our research.

By contrast, Scopus provides a massive database of multidisciplinary research that includes valuable dimensions in our analysis through its extensive citation data and author profiling. While not as exclusively targeted toward legal research compared to WoS, the addition of Scopus would carry along greater diversity of sources and perspectives concerning the integration of AI and ML into civil and private law. Their integration will thus yield a more complete dataset and enhance the quality and breadth of the literature we

can draw upon. In other words, using both WoS and Scopus helps one to draw a more comprehensive, robust dataset for our research and stands to gain from the advantages of both these two platforms put together to support our study related to AI, ML, and law.

The procedure for choosing and improving keywords

First, we carried out a careful search of a set of specialized online dictionaries and glossaries related to AI and ML in civil and private law. This enabled us to identify keywords relevant to the subject matter (Al-Qudah, et al., 2022; Qudah et al., 2023; Momani et al., 2023; Aladayleh et al., 2023; Alqudah et al., 2023). This helped us to understand which keywords within this domain are used most often and which ones are of relevance. In the next stage, we employed a two-phase search strategy on both WoS and Scopus platforms deep within AI and ML terminology from the perspective of civil and private law. *Phase 1:* A first exploratory search using the keyword tools available on both databases. This enabled us to iterate our final search query within the various character limits set by each platform. We carefully went through Phase 2 and ensured the precision of each term to get as accurate results as possible. The two-tier approach ensured the inclusivity and accuracy of keyword selection, ranging widely across AI and ML terminologies relevant to civil and private law.

After the development of our research question, a search strategy was used following the description in Table 1 using title and keyword conditions in both WoS and Scopus. We filtered all the records to include only English language papers and reviews on AI and ML in civil and private law, which generated an initial dataset of 841 publications. Moreover, we focused our search even more closely on publications between 2017 and 2023. This period is supported by research from Simshaw (2018), where he states that before 2017, most research done on AI and ML applications in civil and private law was scant and a handful of studies. We also excluded non-law journals by applying filters based on the Social Sciences Citation Index (SSCI), Science Citation Index Expanded (SCI-EXPANDED), or Emerging Sources Citation Index (ESCI) on WoS' and Scopus' own indexing systems for law-related journals. Finally, each publication underwent a rigorous screening process to ensure its relevance to the subject matter. Manual screening procedures eliminated irrelevant publications.

Tab. 1: Query for the Ultimate Data Compilation.

Search query	Findings
All = (("machine learning" OR "deep learning" OR "support vector machine" OR "artificial neural network" OR "supervised learning" OR "random forest" OR "reinforcement learning" OR "text processing" OR "AI" OR "ML" OR "artificial intelligence") AND ("civil and private law" OR "private law" OR "legal technology" OR "AI in law" OR "legal machine learning" OR "law automation" OR "legal AI applications" OR "legal analytics" OR "AI in judicial systems" OR "AI in legal research" OR "future law technologies"))	841 publications initially identified, restricted to online English sources in accounting and finance
Restrict the investigation to articles published from 2017 to 2023 and include journals indexed in SSCI, SCI-EXPANDED, or ESCI	Reduced to 387 articles after refining the timeframe and focusing on indexed journals
Remove publications unrelated to accounting and finance through manual screening to ensure a comprehensive study	To ensure a comprehensive study focused on the intersection of accounting and finance, a manual screening of the initial dataset was conducted to remove publications unrelated to the field. After this rigorous screening process, the final dataset comprised 279 relevant publications
	These publications were divided as follows: 140 articles from the WoS database and 139 articles from the Scopus database

WoS: Web of Science

During this research, we used careful data preparation techniques. To ensure the relevance of selected literature, we have set clear criteria for the inclusion and exclusion of specialized bibliometric methods. After the strict screening process, we identified and selected 279 articles and reviews for further analysis. Renowned academic magazines have published all these publications that focused on AI and ML in civil and private law. Our decision to investigate AI and ML within civil and private law stems from increasing recognition of the importance of civil and private law since the mid -20th century. Selected keywords further emphasize the critical role of analysis of the legal systems controlled by AI in understanding and solving current problems with civil and private law.

Instruments of Study

This study was based on a very healthy three -stage methodology that asked the AI and ML in civil and private law. The first level began to analyze the performance, from which the most famous scientists who shaped the fields through their leading contributions in the literature were introduced. The second level was a citation analysis, which provided a more detailed view of the influence controlled by different research entities such as publications, authors and even countries. Finally, we performed a network analysis using advanced software such as VosViewer and Rstudio with Bibliometrix package. This network analysis consisted of coexistence of keywords, factorial analysis, trends analysis, co -authorship network and bibliographic bonds. According to Van Eck and Waltman (2010, 2017), such tools have made it possible to create the order of the most important contributors to the field. Bibliometric tests were carried out using a friendly interface offered by Bibliometrix Rstudio (Van Eck and Waltman 2010, 2011, 2013, 2017; Waltman et al., 2010). This research therefore took advantage of the combination of established bibliometric techniques and advanced software as tools to understand the intellectual landscape within AI and ml in civil and private law.

RESULTS AND DISCUSSION

Performance Assessment and Overview

A surge of interest has built up in recent scholarship on the integration of AI and ML into civil and private law. In this respect, Table 1 reflects both the WoS and Scopus databases for the period 2017–2023 as shown in table 2. In this analysis, 279 publications from 45 sources were used and included prestigious journals such as Artificial Intelligence and Law and University of Pennsylvania Law Review. Despite this growing interest, the annual growth rate is negative at –18.42%, with 3.12 years being the average age of the documents. These are a set of varied publications written by 195 different authors. The key focuses are: deep learning applied to legal cases, scalability of legal prediction models, ethics of the deployment of AI, and civil and private law from guidelines of AI ethics. The average number of citations per document is 6.34, indicating how important this set of documents is to the scholarly community.

Figure 1 further supports the emerging interest in incorporating AI and ML into civil and private law. The literature around this topic has increased considerably over recent years, as represented by the graphic. In 2023, there were 55 major publications, which demonstrated the field's strong growth. Representative works for this year include Bhattacharya et al. (2023), which researched deep learning techniques on the analysis of legal documents; Branting et al. (2021), which researched scalable and explainable legal prediction models; and Chalkidis & Kampas (2019), which provided early discussions on AI and ML adoption in legal word embeddings. The upward trajectory is crystal clear: from just seven publications in 2018 to 53 in 2022, this evidences that the research activity kept increasing over the last couple of years.

Figure 2 presents a view of those countries that are most productive and highly influential in terms of AI, ML, and law research. The USA, with an overall output of 44 publications and 137 citations, heads the list. Closely following this ranking are the Netherlands with 21 publications and 28 citations, Canada with 19 publications and six citations, and the UK with 17 publications and 78 citations. The most active countries are Germany and Poland, with 16 and 14 publications, respectively. Italy and China stand out for their impact with 13 and 12 publications, respectively. Russia and Ukraine complete the list.

Analysis of the publications shows different levels of international collaboration in research on AI and law. Although the USA leads with 23 articles, 95.7% of these publications are single-country papers (SCPs).. It represents a very small portion (4.3%) of Multi-Country Papers (MCPs) (publications with researchers from other countries) as shown in figure 3. Similar is the case

Tab: 2. Key Data from the WoS and Scopus Databases.

Category	Data	Description
Timespan	2017–2023	The timeframe during which the data was collected and analyzed
Sources (journals, books, etc.)	45	The number of different sources from which the documents were obtained, including journals, books, and other publications
Documents	279	The total number of documents analyzed in the study, including articles, book chapters, early access papers, and reviews
Annual growth rate %	–18.42	The annual growth rate percentage indicates a decrease in the number of documents over time, expressed as a negative value
Document average age	3.12	The average age of the documents in years, indicating how recently they were published
Average citations per doc	6.34	The average number of citations each document received, providing insight into their impact and influence within the scholarly community
References	5890	The total number of references cited across all documents, demonstrating the breadth of sources consulted and referenced in the study
Keywords plus (ID)	135	The number of unique additional keywords or terms identified beyond the author's keywords, providing additional context or specificity to the documents
Author's keywords (DE)	310	The number of unique keywords or terms provided by the authors themselves to describe the content of their documents
Authors	195	The total number of unique authors contributing to the documents analyzed in the study
Authors of single-authored docs	40	The number of authors who contributed to documents that were single authored, indicating individual scholarly contributions
Single-authored docs	55	The number of documents that were authored by a single author, excluding co-authored works
Co-authors per doc	2.5	The average number of co-authors per document, representing collaborative efforts in scholarly writing
International co-authorships %	23.12	The percentage of co-authorships involving authors from different countries, showcasing international collaboration in research
Document types		
Article	149	The number of documents categorized as articles, typically representing original research or analysis
Article, book chapter	50	The number of documents categorized as both articles and book chapters, indicating dual publication formats
Article, early access	10	The number of documents categorized as articles available through early access, allowing readers to access content before formal publication
Review	15	The number of documents categorized as reviews, providing critical assessments of existing literature or research in the field

WoS: Web of Science

with Germany and UK in that UK stands higher at 55.6% of international collaboration through MCPs. Furthermore, valuable contributions come from the Netherlands, Russia, Canada, and China, all at different levels of international collaboration in their respective outputs. Even smaller contributors like Poland, Ukraine, and Australia show interest in this area, further indicating the trend of global interest in research at the intersection of AI and law.

Figure 4 shows the trends of publication and citation activity of influential authors in this area over time. The circle size represents annual publication rates. Larger circles represent a researcher who published more that year. Darker circle colors indicate higher citation rates for the representative publications. These are, among others, Branting (2021) with a high citation rate: 52 citations (total citations per year: 13) and Bench-Capon (2022), a very productive author with several publications: five papers, 20 citations, and an average of 6.667 citations per year. This enables us to pinpoint important contributions such as Chalkidis and Kampas (2019) on deep learning applications in law and Branting et al. (2021) on scalable legal predictions. Influential works by

Fig. 1: Development of corporate civil and private law literature using artificial intelligence and machine learning.

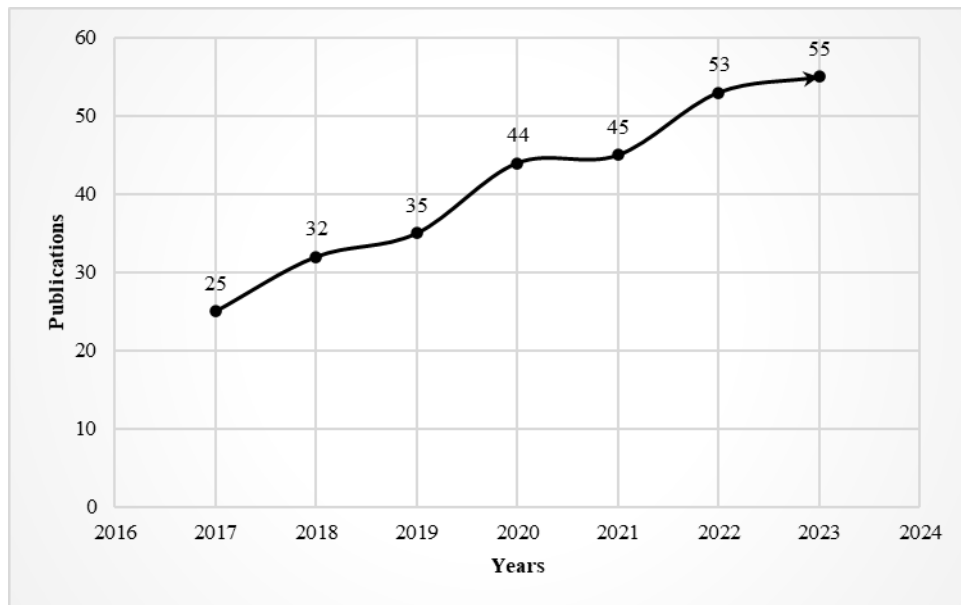
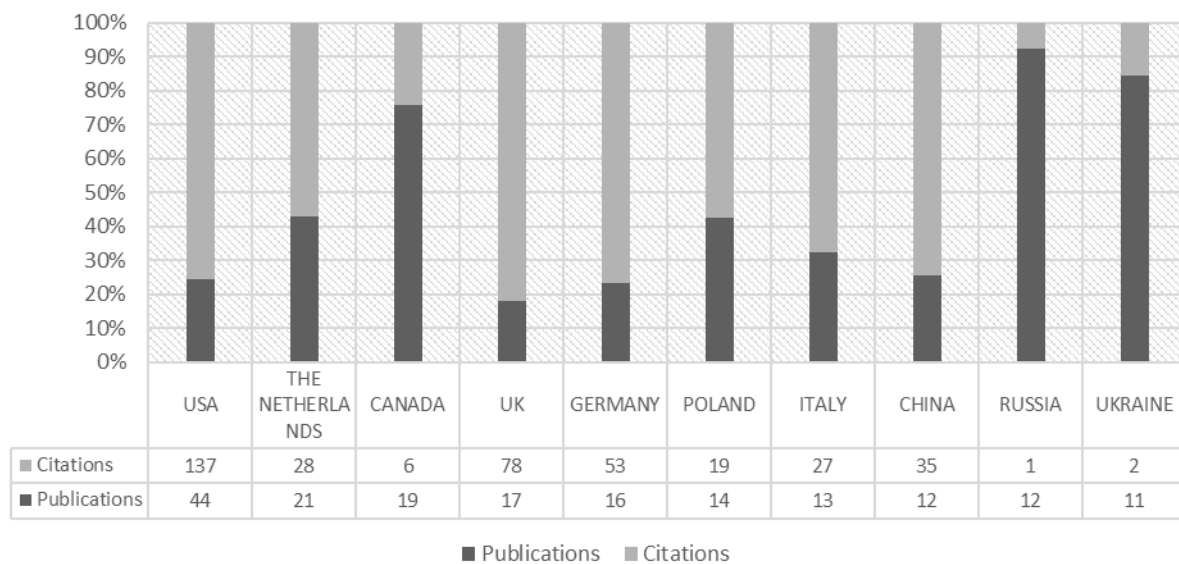


Fig. 2: The most productive and impactful countries.



Bench-Capon (2017) and Verheij (2020) also point out the evolution of the integration of AI into the legal frameworks. Data to that effect reinforces the increasing impact of AI in both legal scholarship and practice.

Fig. 3: Publishers associated with the corresponding country's research output.

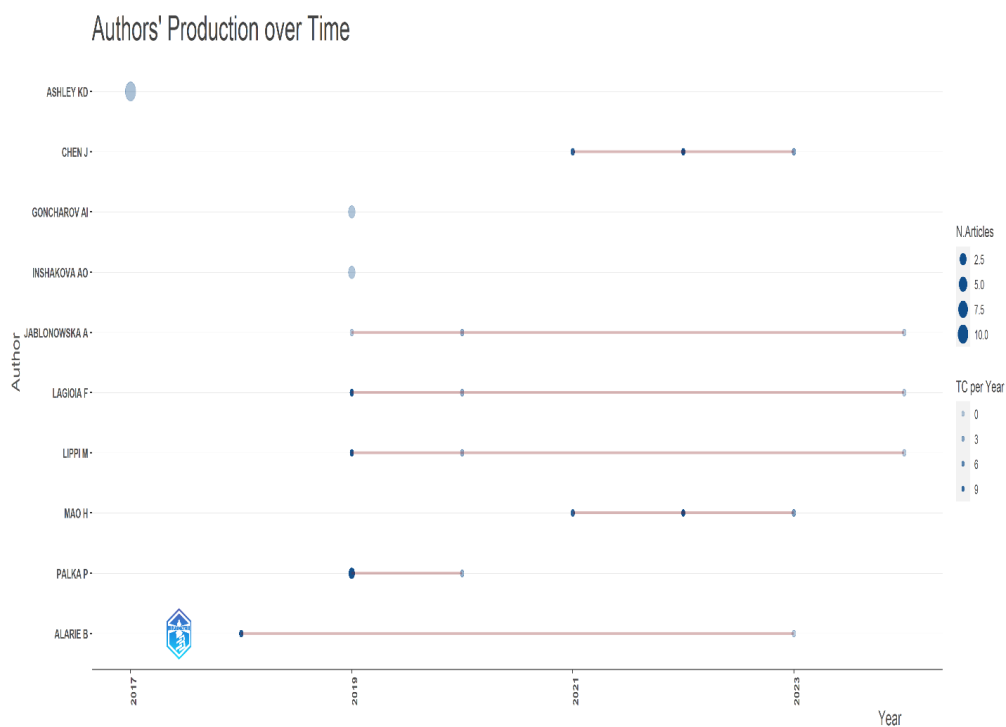
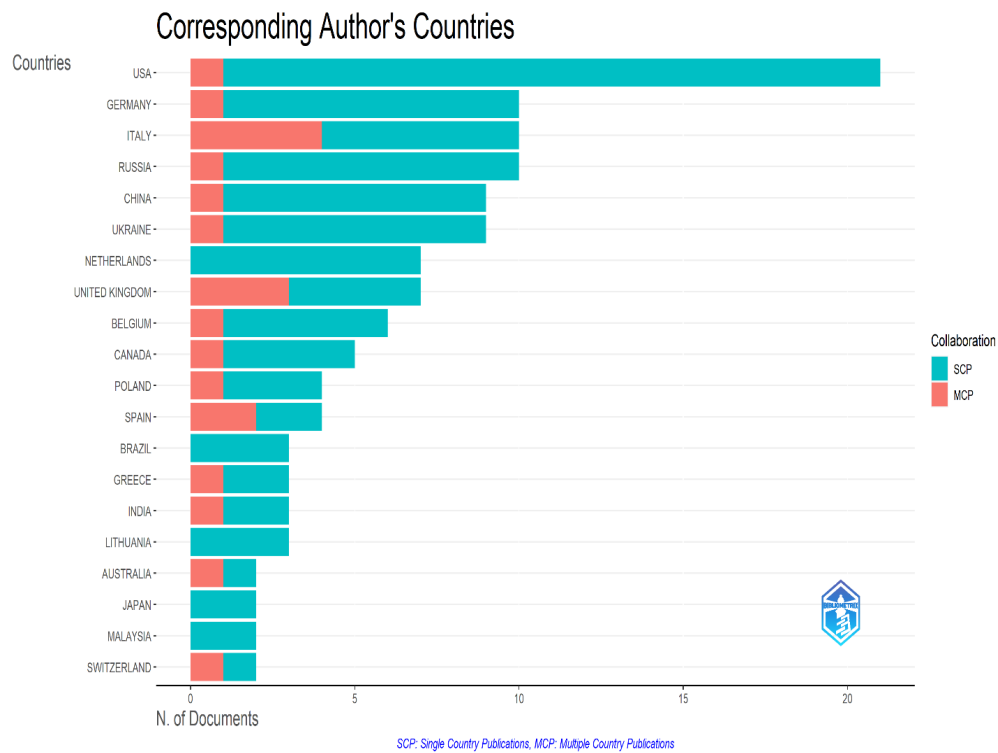


Fig. 4: The publication and citation rates of the top authors over time.

Fig. 5: Citation analysis.

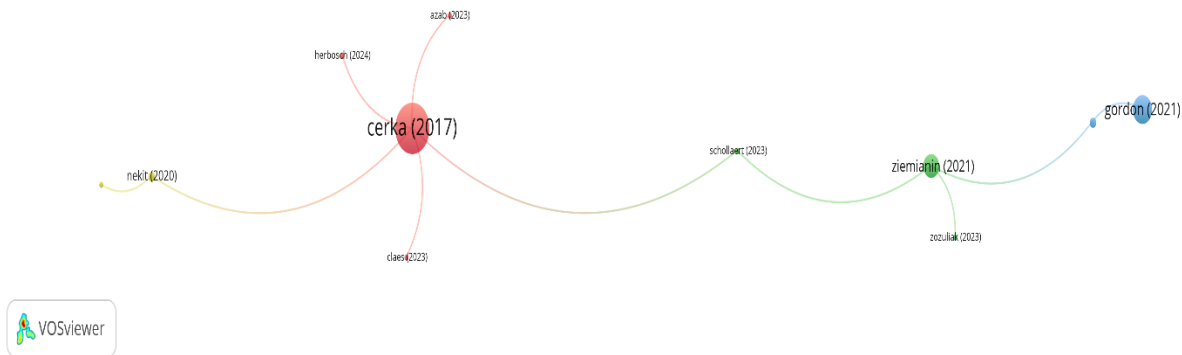
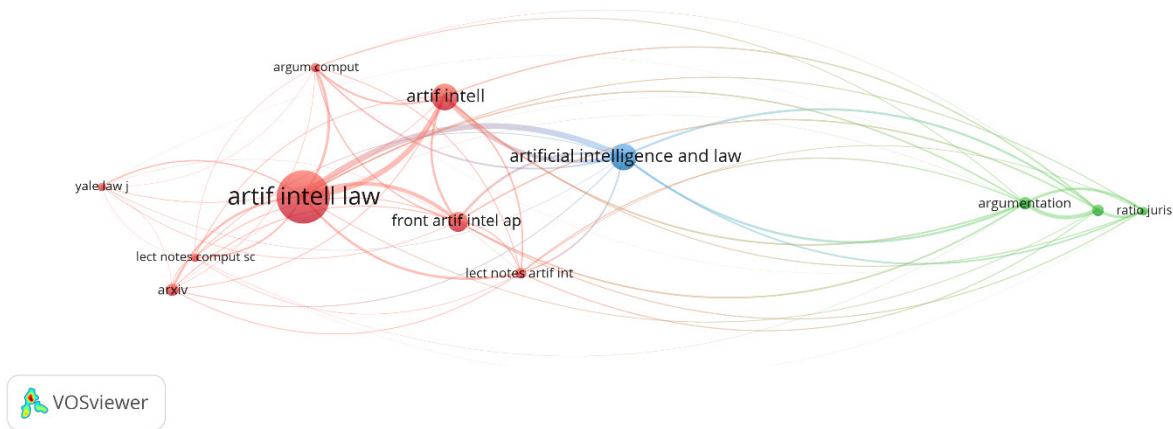


Fig. 6: Co-citation patterns.



Citation Analysis

Figure 5 and Appendix I present the most cited papers on work that deals with how AI and ML are changing civil and private law. Overall, 140 publications, representing data from 2017 to 2023, address topics such as legal word embeddings (Chalkidis & Kampas, 2019) and scalable legal prediction models (Branting et al., 2021). The USA dominates this research landscape, but the UK leads in international collaboration, with 55.6% of its publications involving multiple countries. The leading authors are Branting (2021) based on citations, while Bench-Capon (2022) is more prolific. Influential works explore AI's role in legal practice – Engstrom (2021), Verheij (2020) – and grapple with ethical considerations: Simshaw (2018), Larsson (2020). The research deals with the steadily high influence of AI on civil and private law, defines further research into its potential, and points out ethical consequences.

Network Visualization

This section focuses on the network of relationships among researchers in the areas of AI and civil and private law. The frequency at which researchers cite others characterizes the domains of cooperation and intellectual interchanging. Figure 6 shows a mapping of such co-citation patterns. The more interconnected the sources, the closer the link between the scholars who published them. Out of 3,837 sources examined, 12 significant links were identified to show a high level of interconnectedness among journals within this setting. This was in agreement with our earlier observations of good citation practices within the scholarly community. It demonstrated an established network, wherein researchers cite and build on other people's research.

Fig. 7: Top-cited co-authorship patterns.

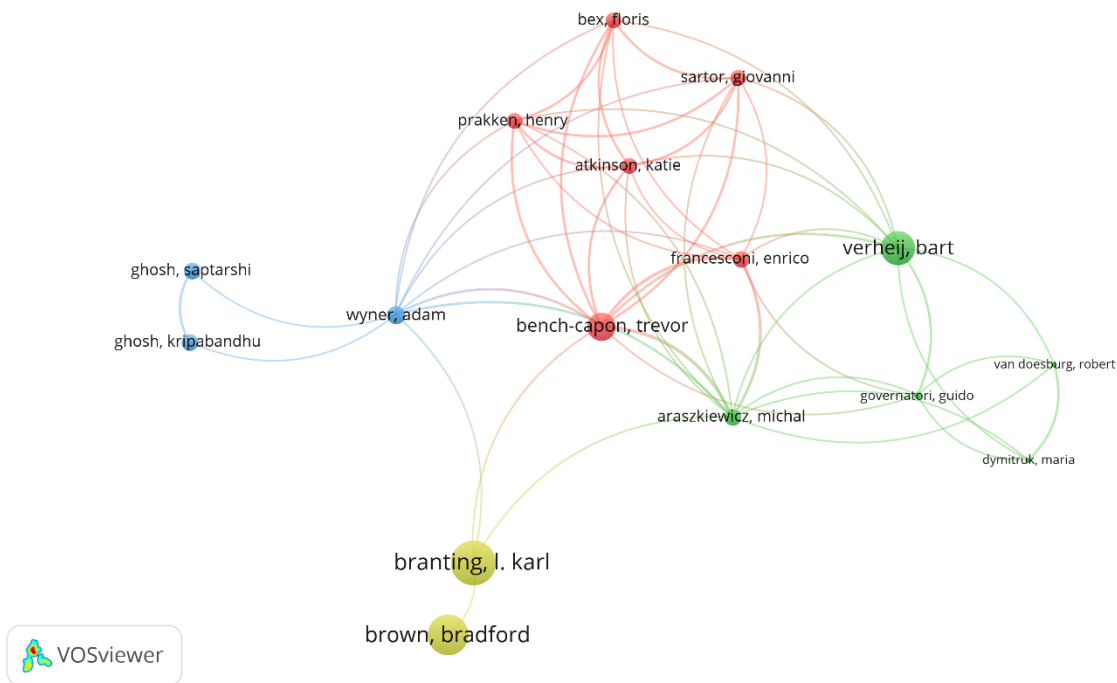
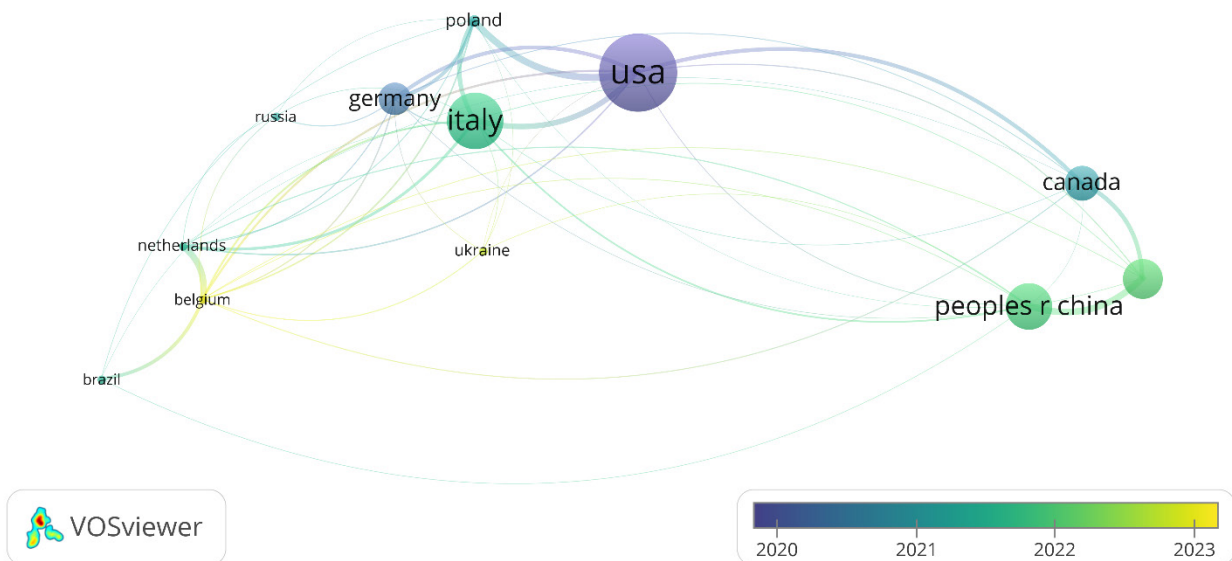


Fig. 8: Distribution map.



Tab. 3: Most Used Keywords.

Keywords	Cluster color	Total link strength	Occurrences
1 Artificial intelligence	Blue	23	17
2 Law	Blue	36	11
3 Argumentation	Green	33	7
4 Legal	Light Blue	20	7
5 Machine learning	Purple	22	7
6 AI and law	red	20	6
7 Big data	Blue	10	6
8 Legal technology	Blue	8	6
9 Legal reasoning	red	20	5
10 Natural language processing	Light Blue	12	5
11 AI	red	7	4
12 Knowledge	Green	21	4
13 Artificial intelligence and law	Purple	5	3
14 Persuasion	Yellow	12	3
15 Proof	Orange	13	3

We extend our analysis to collaborative patterns of scholars in this area of AI and civil and private law. Figure 7 shows the co-authorship pattern and displays only 16 links for the 185 authors identified; this would indicate a limited collaboration degree among researchers. This could become one of the viable ways of future development: increasing the level of collaboration and knowledge flow between the institutions active in this type of research. In addition, further collaboration can lead to more in-depth and influential studies on AI and ML integration into civil and private law.

Statistical Distribution by Countries

Our analysis also explored collaborative patterns between countries in AI and civil and private law research (Figure 8). This revealed some particularly strong research partnerships. Notably, the USA, England, and Luxembourg appear to be collaborating extensively on projects that explore AI and ML applications in civil and private law (Aladayleh et al., 2023). Furthermore, there are also signs of German–Polish collaboration and the involvement of scholars based in the USA with this joint effort. This illustrates well that the challenges and opportunities arising from AI and ML for the area of civil and private law are indeed global.

Analysis of Keywords and Cartography

We used VOSviewer software to analyze the keywords involved in research – a powerful network analysis tool that confirmed some of the selections we had initially made as shown in table 3. Figure 9 shows that there are clear clusters apparent in the research landscape, mapping key themes. The purple cluster is the most significant and includes some of the pivotal topics such as ML, AI, and law. Broader themes in corporate governance include legal technology, legal reasoning, and natural language processing, which also connect with those core concepts. Other applications, such as time series prediction and clustering, further show the practical integration of AI and ML. Curiously, algorithmic trading forms a separate cluster, indicating that research in this field was focused at an earlier stage than for other topics examined in the present study. Overall, clustering analysis underlines that AI and ML methodologies are finding their role in civil and private law, which is increasingly applied and integrated into different legal contexts.

Fig. 9: Keyword co-occurrence.

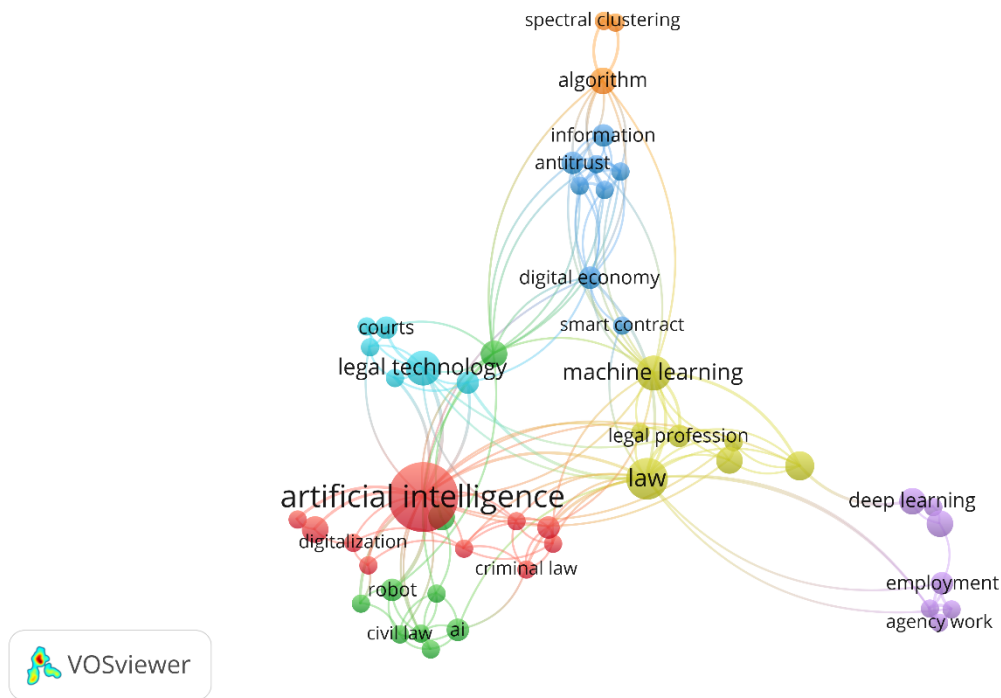


Fig. 10: Visualizing keyword overlap.

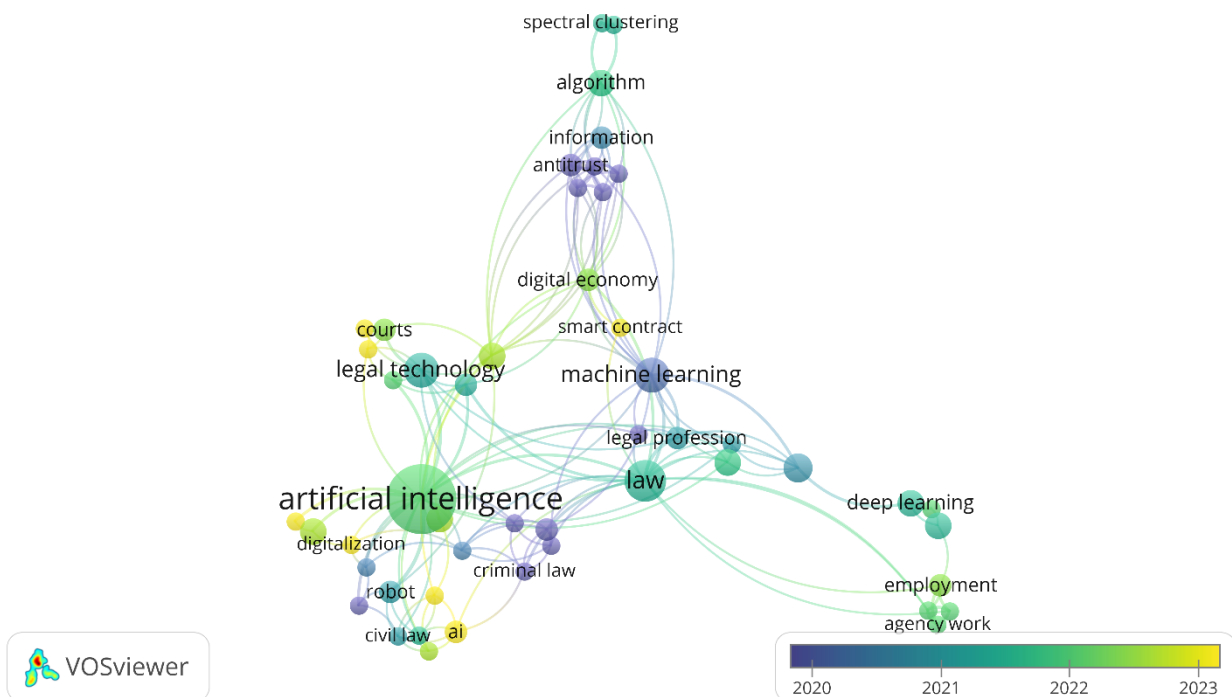


Fig. 11: Trilateral visualization.

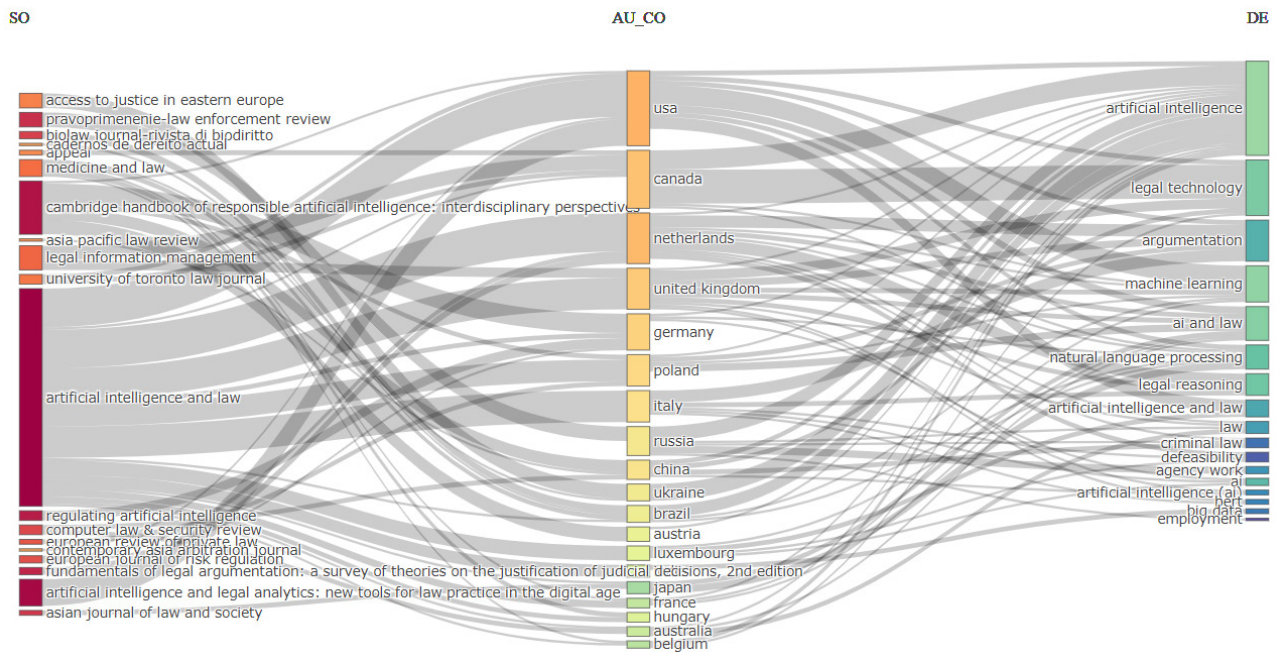


Figure 10 presents the emerging frontiers in corporate governance research. Yellow highlighted areas represent newly explored themes, demonstrating how interest in sustainability and autonomy has grown in this area. This also describes a trend observed in most other aspects of modern civil and private law practices due to the pace of influence set by AI/ML. The figure illustrates the changing landscape where AI/ML is increasingly becoming embedded and important in the development of new approaches to corporate governance.

Our analysis extends beyond the typical two-dimensional visualizations. Figure 11 provides a one-of-a-kind three-dimensional perspective on 20 pivotal sources in this field. This view allows us to examine the relationships between journals (positioned on the left axis), the countries where the research originates (middle axis), and the keywords used in the publications (right axis). This visualization reveals the USA, Canada, and the Netherlands as leading contributors to research in AI and civil and private law. Interestingly, “Artificial Intelligence and Law” emerges as the most frequently referenced publication, solidifying its position as a highly influential journal in the field.

Evaluating Content and Bibliographical Relationship

The chosen cluster titles effectively capture the essence of each research theme within the identified groups. These concise titles act as summaries of the dominant topics, offering a clear and focused lens through which to understand the content of each research area. By analyzing the keywords that frequently appear together (co-occurrence), researchers were able to group related studies and assign them descriptive titles that reflect their core themes.

Cluster 1 (red): AI and legal frameworks

The rapidly growing area of civil and private law has seen great developments, but significant hurdles persist in the attempt to integrate AI and ML. Deep learning techniques and extensive legal databases have allowed recent improvements in legal prediction models; these have been implemented by developing legal word embeddings (Chalkidis & Kampas, 2019). Still, making those models

scalable and explainable remains a long-standing challenge. Branting et al. (2021) raise the need for strong frameworks that ensure accuracy and transparency in legal decision-making. Ethical issues are still high, with debates on the ethical effects of AI-powered legal practices. These further underscore the calls for clear guidelines and mechanisms for oversight (Simshaw, 2018). In this respect, governance and regulatory frameworks are quite essential to the effect that AI imposes on the conducts of legal proceedings. In this respect, Larsson (2020) explains that ethical principles guide AI applications in civil and private laws to maintain a proper balance between innovation and accountability. Verheij (2020) discusses how AI shapes legal norms and how frameworks should ensure that technological advances in such technologies bely within set legal principles. Despite these efforts, integrating AI into the application of civil and private law practices effectively remains challenging to achieve in practice (Engstrom, 2021). Refining and validating AI systems for legal use is difficult due to complexities in interpreting legal texts and categorizing legal norms with AI models (Waltl et al., 2019; Tagarelli & Simeri, 2022).

Cluster 2 (green): legal argumentation tech

Cluster 2 represents a dynamic area on the penetration of artificial intelligence and civil/private law, but also represents a large number of challenges. Research emphasizes progress in the use of AI for legal forecasts and arguments using techniques such as deep learning and insertion of a legal word (Chalkidis & Kampas, 2019), but there is a question about the scalability and explaining of these models. Branting et al. (2021) emphasize that robust frameworks are needed to ensure accuracy and transparency in decision-making in the environment of civil and private law. Ethical considerations are no less important because the introduction of AI into legal practice depends on well-defined leadership and supervision to avoid bias and to ensure justice (Simshaw, 2018; Abdo et al., 2023; Abdo et al., 2021; alqudah et al. Management and regulatory framework play a key role, and scientists advocate the development of ethical instructions to effectively control AI applications (Larsson, 2020). In addition, the interpretation of legal texts and classification of legal standards using AI models (Waltl et al., 2019; Tagarelli & simeri, 2022) represents challenges that require further improvement and verification. This leaves a larger gap in understanding the wider result of AI on legal arguments in civil and private law. Further research will be required to develop holistic frames that align technological progress to established legal principles (Engstrom, 2021; Verheij, 2020).

Cluster 3 (blue): digital economy and law tech

Cluster 3 emphasizes critical gaps in the field of research and orientation, reflecting the developing relationship between AI and private law. The scholars examined the Framework of Administration for AI (Larsson, 2020; Engstrom, 2021), emphasizing ethical instructions and regulatory structures in civil and private law. Research of scalable and explained legal prediction models (Branting et al., 2021; Gowder, 2018) increases transparency in the legal decision-making of controlled AI. In addition, deep learning application (Chalkidis & Kampas, 2019; Qudah et al., 2021; Wang, 2020) improve legal text analysis and predictive analysis. Ethical concerns remain central, especially in terms of legal decisions and responsibility controlled by AI (Simshaw, 2018). The discussion of the civic legal personality AI (Ziemianin, 2021; Qudah et al., 2021; Garingan & Pickard, 2021) question traditional legal frameworks and question the status and rights of autonomous systems. The impact of AI applies to family law (Gingras & Morrison, 2021), while predictive analysts form legal administration (Lazaro & Riszi, 2023). In addition to the AI family law, the Consumer Protection Act and the Act on Mental Property significantly affect. AI controlled client services and algorithmic decisions are evoked by concerns about the rights and transparency of consumers (Micklitz et al., 2022). In the Mental Property Act, the AI-generated content is questioned by traditional copyrights, especially in Europe, where legal debates continue over the potential AI (Hilty & Richter, 2023). Transformative AI roles in private law require interdisciplinary cooperation between legal scientists, politicians and AI scientists. Recent legislative development, in particular the Act on Artificial Intelligence (Regulation (EU) 2024/1689), further emphasizes the need for legal adaptation. This regulation provides harmonized rules for AI, affecting several private legal domains and forming an ongoing legal discourse on AI administration.

Cluster 4 (yellow): persuasion techniques in legal tech

Cluster 4 reveals crucial research gaps and future directions on the current debate of integrating AI into civil and private law. As much as AI may be an assured pointer to bright future developments in legal contexts, there are also ethical and operational challenges unique to civil and private law (Simshaw, 2018; He, 2019). Pioneering research has identified deep learning, in terms of adapting legal word embeddings previously trained on vast datasets, as a means to enhance decision-making in civil and private law (Chalkidis & Kampas, 2019). This seminal work further emphasizes the need for strong structures to ensure equity and accountability within AI-powered legal systems, with particular respect to civil and private law. In addition, legal prediction models, scalable and explainable, A feature highlighted by Branting et al. (2021) is the importance of adding plausibility to AI decisions, which is essential for upholding the rule of law and promoting ethical conduct in civil and private legal practices. Ethical issues concerning the use of AI in legal practice by Simshaw (2018) are paramount and demand the creation of guidelines that shall govern its use and protect legal integrity. Innovative approaches such as unsupervised law article mining (Tagarelli & Simeri, 2022) offer new avenues for efficiently extracting and utilizing legal knowledge, enhancing legal technologies' persuasive capabilities within civil and private law. These approaches also necessitate interdisciplinary collaboration among legal scholars, AI experts, ethicists, and policymakers. Such collaboration is crucial to navigating the complexities of effectively integrating AI into civil and private law.

Cluster 5 (purple): human language and legal tech

The purple cluster covers an up-and-coming area in which the latest developments in AI are changing the practices of the legal profession, but simultaneously and importantly points to some lacuna that are worthy of further investigation. The early works focused on the adaptation of deep learning techniques to legal contexts, training legal word embeddings on large legal databases (Chalkidis & Kampas, 2019; Kowalski & Datoo, 2022). These innovations represent the potential to identify valuable insights from datasets and enhance processes of legal decision-making. However, scalability and explainability of AI-driven legal prediction models remain among the most challenging issues for the time being (Atkinson et al., 2020). Transparency and interpretability of these models constitute an important requirement of legal compliance and ethical standards within judicial systems (Branting et al., 2021; Künnapas, 2021). Governance frameworks and ethical guidelines are also key to the successful integration of AI into the realm of law. Scholars argue for strong ethical guidelines for the responsible deployment of the emerging technologies AI represents. These guides must take into consideration pressing issues on fairness, accountability, and integrity within the legal order (Larsson, 2020; Simshaw, 2018). Meanwhile, unsupervised mining of law articles constitutes but one example of emerging capabilities related to automating and optimizing legal knowledge. However, overcoming technical and regulatory hurdles necessitates interdisciplinary collaboration between legal scholars, AI experts, ethicists, and policymakers (Tagarelli & Simeri, 2022; Engstrom, 2021).

Cluster 6 (light blue): deep learning for legal text

Light Blue Cluster: This is a field that has witnessed several great success in applying deep learning techniques in legal contexts. Pioneering works, such as Chalkidis and Kampas (2019), focused their efforts on developing legal words that were trained on the basis of relatively large data sets. This pioneering effort has laid the foundations for adapting the deep learning techniques to analyze legal texts, as discussed by Francesconi (2022) and Barys lit (2022). However, the fields still show critical gaps and challenges that require further investigation in Chatziathanasia (2022). How Branting et al. (2021) Note, scalability and interpretability remain key concerns in legal AI. Scalable and interpreted legal prediction models are of fundamental importance for ensuring practical AI applications in legal decisions. This requires overcoming technical difficulties without trading in the AI transparency and responsibility. An ethical consideration is another very important aspect presented by Larsson (2020) and Simshaw (2018). Strong ethical frames should be baked in the development and use of AI in legal systems for justice, responsibility and transparency. Indeed, such framework provides instructions for ethical application of AI; They also work in public and gain more confidence in various AI legal applications. In addition, interdisciplinary cooperation - as Tagarelli and Simeri (2022) emphasized - moreover, bridge the gap between technological progress and regulatory framework. It can also articulate regulatory challenges and gently fine-tune the AI models so that models more efficiently process legal complexity and find innovative applications to strengthen legal practice in terms of efficiency and justice.

Cluster 7 (orange): legal proof and technology

The orange cluster deals with the exciting area of AI and civil and private law. This area seeks to transform legal procedures by using technological innovations to improve the practice of law and decision-making. As such, Mandal et al. (2022) and Governor et al. (2022) noted that significant progress was made, especially pioneers in the techniques of deep learning and the words insertion of the law (Chalkidis and Kampas, 2019). This timely development made it possible to analyze and interpret legal texts powered by artificial intelligence, which gives a significant change in the milestone in civil and private law technology. However, there are still challenges: for example, Branting et al. (2021) point out that the legal forecast needs AI models that are scalable and explained. This is necessary to ensure transparency and reliability within the process of civil and private legal decisions. In addition, Bench-Capon (2017) and Larsson (2020) emphasize the importance of administration frames and ethical instructions in terms of AI deployment in a legal context. This ongoing debate signals the need to balance technological progress with ethical considerations of civil and private law. Simshaw (2018) expresses ethical interest in legal artificial intelligence, including requirements for strong frameworks that adhere to justice and responsibility in the processes of the law. Verheij (2020) and Rigoni (2018) argue for the integration of AI into established legal principles of civil and private law. This is a key step towards harmonizing technological progress with the main legal standards.

Key Insights, Bridging Gaps, and New Directions in AI and ML Research in Civil and private law

This study builds on the works of Khan et al. (2020) and Paltrinieri et al. (2023), determination of the importance of bibliometric and content analysis with regard to the identification of emerging trends from this very dynamic area of AI and ML in civil and private law. These research questions, as shown in Table 4, are an important contribution to scientific debate and expand the reach beyond what AI/ml/ml applications are currently being discussed in legal contexts. Research supports critical questions about future research directions, requires responsible investigation and measurement procedures, and visit thresholds in this area.

This research also serves to identify persistent research gaps that require further investigation. Particularly, the integration of AI/ML into legal practices, including the challenges of scalability, transparency, and ethical concerns, forms a general theme underlying many clusters of research, such as in legal natural language deep learning in Cluster 6, legal prediction models in Cluster 3, and the use of AI in governance frameworks in Cluster 5. These areas indicate the need for both interdisciplinary collaborations to ensure that the development of technologies is in line with ethical guidance, legal standards, and socially acceptable values. These findings are set to inform future studies on AI and the law and will encourage the development of stronger and more scalable legal prediction models. By engaging with the issues arising from uncertainty regarding the impact AI/ML will have on contemporary civil and private law, this research lays the foundation for more informed decision-making processes, better regulatory regimes, and a more profound insight into challenges the legal profession as well as society as such will face in the future. Through these efforts, scholars will be better prepared to contribute to the effective integration of AI into legal systems while maintaining fairness, accountability, and transparency.

Research of European technologies of civil and private law, especially the AI and ML-based ones, is doing well. Deep learning techniques have contributed to this development by being used for legal applications. For example, inserting legal words significantly improved the performance of legal forecasts (Chalkidis & Kampas, 2019). This is the basis for a deeper analysis and interpretation of the content of legal texts to further increase efficiency and efficiency in the decision-making process in European legal systems. Calls are constantly published in European and private law in terms of scalability and explaining the AI models. Other scholars such as Branting et al. (2021), emphasize that strong structures must be introduced for AI systems in order for AI systems not only accurate but also transparent, throwing light on some distortion and ethical consequences resulting from AI into legal practice. Ethical considerations also focus on the need for clear administration and regulatory framework, especially in the European context, to manage the responsible use of AI technologies in civil and private law. This is a shared Simshaw (2018) view.

The recently adopted Act on Artificial Intelligence, Regulation (EU) 2024/1689, is helpful in determining harmonized rules for AI throughout the EU, and therefore has consequences for private law. It is a regulation that has undergone a very long process of legislation, reflecting increased awareness of the need for comprehensive AI management. Its impact is huge in private law because it provides a regulatory framework for the responsible use of AI systems in the legal area. The law deals with questions such as transparency, responsibility and safety that are critical when AI technologies are applied in legal contexts. More structured approaches

Tab. 4: Key Insights, New Directions, and Bridging Gaps.

Cluster	Key findings	Challenges	Research gaps	Future research directions
Red	Deep learning and legal word embeddings for legal prediction	Scalability and explainability of AI models, ethical considerations, and need for clear guidelines	Limited research on integrating AI with legal reasoning and argumentation, lack of studies on the impact of AI on access to justice	Refining AI models for civil and private law applications, enhancing interpretability and robustness, developing ethical frameworks
Green	Similar findings to Red regarding deep learning and legal embeddings	Similar challenges to Red regarding scalability, explainability, ethics, and governance	Need for research on generating persuasive legal arguments, limited understanding of potential biases in AI-driven legal argumentation	Similar future research directions to Red, understanding broader impact of AI on legal argumentation, methods for evaluating persuasiveness of AI-generated legal arguments
Blue	Importance of governance frameworks for AI in legal contexts	Need for scalable and explainable legal prediction models, ethical considerations surrounding AI in legal professions	Gap in research on the impact of AI on the legal profession, lack of studies on legal implications of autonomous AI systems	Interdisciplinary collaboration for navigating AI integration in civil and private law, research on AI's civil legal personality and its legal implications, exploring AI for family law and predictive analytics in legal governance, incorporation of AI in consumer protection law, addressing challenges related to consumer rights, contracts, and dispute resolution, examination of intellectual property law, especially concerning AI authorship and intellectual property rights in the context of AI-created works (a growing debate in Europe)
Yellow	Deep learning for legal decision-making processes	Importance of ethical considerations and robust frameworks	Overcoming technical and regulatory hurdles for unsupervised law article mining, limited understanding of tailoring legal arguments to specific audiences	Exploring interdisciplinary collaboration for effective AI integration, methods for unsupervised legal knowledge extraction, research on personalizing legal arguments for different audiences
Purple	Deep learning techniques for legal text analysis	Importance of ethical guidelines and overcoming regulatory hurdles	Challenges in adapting Natural Language Processing (NLP) techniques to legal language, lack of research on AI's impact on legal writing and communication	Developing NLP techniques for handling legal complexities, research on improving clarity and efficiency of legal writing with AI
Light blue	Pioneering work on legal word embeddings for deep learning analysis of legal texts	Scalability, explainability, and ethical considerations	Limited research on integrating AI with legal reasoning and case law analysis, lack of standardized datasets for training and testing AI models in civil and private law	Fostering interdisciplinary collaborations for regulatory framework development, enhancing scalability and interpretability in legal AI models

AI: artificial intelligence

to the integration of AI into European legal systems, in particular those that ensure compliance with stipulated standards and principles in private law, appear from a more detailed examination of the impact of the law on literature.

Bedding gaps in AI/ml research and practical legal applications throughout Europe will require considerable efforts. Scientists have noticed the potential transformation effect of AI technology on legal administration and decision -making (Engstrom, 2021). However, trouble -free AI integration into European legal systems faces practical challenges, such as how AI models can interpret legal texts and classify legal norms specific to European civil and private law (Waltl et al., 2019; Tagarelli & Simeri, 2022). Understanding the nuances of legal texts across various jurisdictions, languages and legal traditions represent another layer of complexity. Future research should focus on improving AI systems to deal with the complexity of legal matters and at the same time to reconcile European legal principles and frames (Verheij, 2020). This research agenda should be formed by examining the social and organizational effects that AI adopts within European civil and private law. Thus, interdisciplinary cooperation between the sector of legal, AI and political sectors will be decisive in the proceedings of innovation to create justice and efficiency of European legal practices in the AI legal landscape.

The future of AI and ML in European civil and private law is very promising. Among the key trends you can notice the development of more interpreted and scalated models of legal forecasts of controlled AI. Branting et al. (2021) show how further improvements in deep learning methods, especially those that have a legal word and natural language processing, provide even more opportunities for such models. Research must also be directed to the development of complex ethical instructions for the use of AI in European law practices to ensure that such integration is non -discriminatory and responsible, as suggested by Larsson (2020). In addition, the legal environment in Europe, including complicated rules, such as the general data protection regulation or GDPR, should also be taken into account in the application of AI in civil and private law. Therefore, any AI application will have to meet local and Pan-Eu standards of privacy. Finally, highly complex problems require interdisciplinary cooperation between lawyers, scientists AI, ethicists and politicians. Optimization of AI within European civil and private law requires innovative solutions to streamline the procedures and at the same time to maintain the integrity of legal systems in Europe before a demanding landscape of developing technology.

CONCLUSION

This paper has explored research into AI and ML within civil and private law by bibliometric analysis. Analysis of 279 papers published over the period 2017–2023 in the WoS database shows that there is a remarkable increase in publications, especially from the year 2020 onward. The following research themes were developed in relation to the influence of AI on civil and private law, as well as on argumentation, persuasion, and deep learning applied in legal natural language processing. Surprisingly, the leading contributions to this area came essentially from the USA, Canada, and the Netherlands.

Looking into the future, the support of the interdisciplinary approach between legal scientists, scientists AI, ethics and politicians became critically important. In this way, the emerging challenges and opportunities concerning AI and ML applications can be solved more efficiently in civil and private law. Strong mechanisms of transparency, responsibility and ethical instructions must be introduced as steps to alleviate potential distortion in order to ensure fair and only law -powered legal practices. In addition, it will also encourage international research cooperation to share knowledge and begin to harmonize legal standards across different jurisdictions, leading to the creation of more holistic and general AI applications. Future research will focus on fine fine -tuning algorithms to make AI more interpreted and more scalable in the legal framework. This includes the development of AI models that can interpret and apply legal texts and align with existing legal standards and principles. It remains essential remains essential, such as its impact on the dynamics of legal professions and public law. In addition, expanding research on comparative studies across different legal systems would provide valuable knowledge of the universal applicability of AI technologies in legal practice and theory. The result of such an effort may be more informed of the creation of policy and the much needable AI integration into the framework of civil and private law around the world.

Limitations should be acknowledged herein. First, this study exclusively uses the WoS database for review and analysis, which may limit the number of publications that are reviewed. Regarding this, future literature reviews can be more inclusive by adding other databases like Elsevier-Scopus, PubMed, and Cochrane. This broader approach would give a far complete and more varied look at the research landscape in AI and ML within civil and private law, adding depth to the validity and robustness of any future findings.

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Appendix I. Top Citations on Artificial Intelligence and Machine Learning in Civil and private law.

Authors	Title	Year	Source title	ISSN	Impact factor	Volume	Issue	Page start	Page end	Page count	Citations	Affiliations	Countries	Publisher
Chalkidis & Kampas	Deep learning in law: early adaptation and legal word embeddings trained on large corpora	2019	Artificial Intelligence and Law	0924-8463	1.233	27	2	171	198	27	79	National Kapodistrian University of Athens	Greece	Springer
Branting et al.	Scalable and explainable legal prediction	2021	Artificial Intelligence and Law	0924-8463	1.233	29	-	213	238	25	52	MITRE Corporation	USA	Springer
Bench-Capon	HYPO's legacy: introduction to the virtual special issue	2017	Artificial Intelligence and Law	0924-8463	1.233	25	-	205	250	45	37	University of Liverpool	UK	Springer
Larsson	On the governance of artificial intelligence through ethics guidelines	2020	Asian Journal of Law and Society	2052-9015	0.873	7	3	437	451	14	35	Lund University	Sweden	Cambridge University Press
Engstrom	Digital Civil Procedure	2021	University of Pennsylvania Law Review	0041-9907	2.107	169	8	2243	2286	43	24	Stanford University	USA	University of Pennsylvania
Verheij	Artificial intelligence as law: Presidential address to the seventeenth international conference on AI and law	2020	Artificial Intelligence and Law	0924-8463	1.233	28	2	181	206	25	24	University of Groningen	The Netherlands	Springer
Rigoni	Representing dimensions within the reason model of precedent	2018	Artificial Intelligence and Law	0924-8463	1.233	26	-	1	22	21	23	European University Institute	Italy	Springer
Tagarelli & Simeri	Unsupervised law article mining based on deep pre-trained language representation models with application to the Italian civil code	2022	Artificial Intelligence and Law	0924-8463	1.233	30	3	417	473	56	20	University of Calabria	Italy	Springer
Simshaw	Ethical issues in robo-lawyering: The need for guidance on developing and using artificial intelligence in the practice of law	2018	Hastings Law Journal	0017-8322	1.25	70	-	173	211	38	16	University of California	USA	University of California
Waltl et al.	Semantic types of legal norms in German laws: classification and analysis using local linear explanations	2019	Artificial Intelligence and Law	0924-8463	1.233	27	1	43	71	28	16	Technical University of Munich	Germany	Springer