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Challenges and Opportunities for Visual Analytics in Jurisprudence

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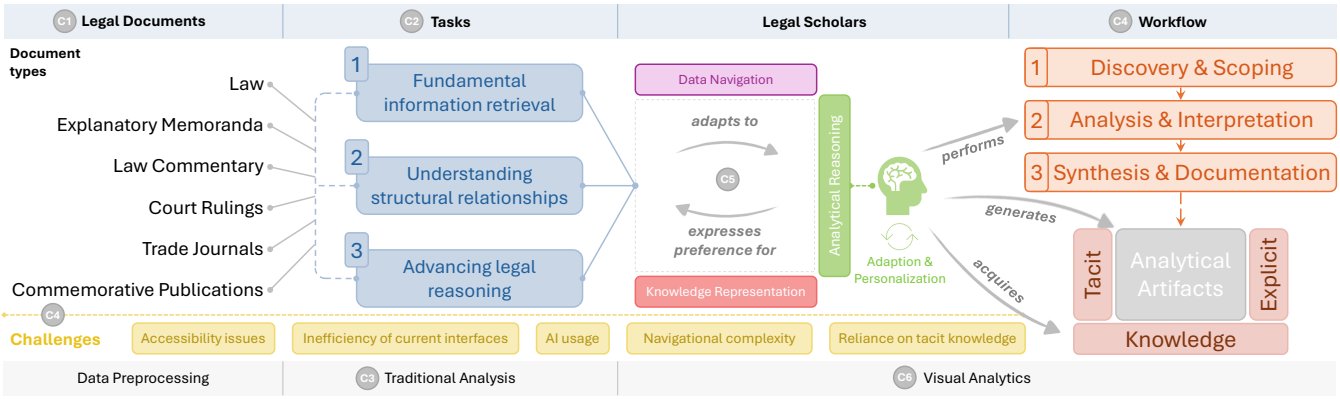

Figure 1: **The integration of jurisprudence and Visual Analytics (VA) for personalized legal exploration**: This approach processes diverse legal documents – including laws, explanatory memoranda, and court rulings – to support legal scholars in three key tasks: (1) fundamental information retrieval, (2) understanding structural relationships, and (3) advancing legal reasoning, while addressing several challenges. Through interviews with domain experts, we identify three workflow phases, namely (1) discovery & scoping, (2) analysis & interpretation, and (3) synthesis & documentation. Through them, scholars iteratively navigate through and generate analytical artifacts that capture tacit and explicit knowledge, fostering deeper comprehension of legal structures and reasoning, informing a VA design for legal.

Abstract

Exploring, analyzing, and interpreting law can be tedious and challenging, even for legal scholars, since legal texts contain domain-specific language, require knowledge of tacit legal concepts, and are sometimes intentionally ambiguous. In related, text-based domains, Visual Analytics (VA) and large language models (LLMs) have become essential for working with documents as they support data navigation, knowledge representation, and analytical reasoning. However, legal scholars must simultaneously manage hierarchical information sources, leverage implicit domain knowledge, and document complex reasoning processes, which are neither adequately accessible through existing VA designs nor sufficiently supported by current LLMs. To address the needs of legal scholars, we identify previously unexamined challenges and opportunities when applying VA to jurisprudence. We conducted semi-structured interviews with nine experts from the legal domain and found that they lacked the ability to articulate their tacit domain knowledge as explicit, machine-interpretable knowledge. Hence, we propose leveraging interactive visualization for this articulation, teaching the machine relevant semantic relationships between legal documents. These relationships inform the predictions of VA and LLMs, facilitating the navigation between the hierarchies of legal document collections. The enhanced navigation can uncover additional relevant legal documents, reinforcing the legal reasoning process by generating legal insights that reflect internalized, tacit domain knowledge. In summary, we provide a human-is-the-loop VA workflow for jurisprudence that recognizes tacit domain knowledge as essential for deriving legal insights. More broadly, we compare this workflow with related text-based research practices, revealing research gaps and guiding visualization researchers in knowledge-assisted VA for law and beyond.

CCS Concepts

• ***Applied computing*** → *Law;* • ***Human-centered computing*** → ***Visualization theory, concepts and paradigms;***

1. Introduction

Legal text data is vast [Fob24d; Fob24b; Fob21] and inherently structured [RFB22, pp. 92–93]. It combines *domain-specific language* [RFB22, p. 123] and *precise phraseology* with intentional *ambiguity*, at times [RFB22, p. 128]. This ambiguity allows for statutory interpretation [RFB22, p. 22], enabling laws to evolve alongside societal norms and values. For instance, in 2018, the German Federal Constitutional Court interpreted the protection of life and physical integrity according to Art. 2 Abs. 2 Satz 1 GG to include protection against the dangers of climate change [Bun21]. The legal text merely states that "[e]very person shall have the right to life and physical integrity. Freedom of the person shall be inviolable. [...]" This interpretation underscores that understanding legal norms alone is insufficient; comprehensive statutory interpretation also relies on an extensive understanding of **fundamental and specific legal principles** [RFB22, pp. 92–93, 460].

To navigate these challenges, legal scholars have developed **working methods to aid in the interpretation** of legal materials, including implicit structures, schema, and principles [RFB22, p. 450]. Visualizations can enhance these methods by improving comprehension and communicating mental models [Pas97; Bru14]. While many visualizations are hand-crafted, automating their creation is a growing focus in recent legal visualization research [GCHN15; LST22; RPNP23]. The increasing availability of machine-readable texts raises hope for better automatic generation of such visualizations [Vog24].

At the same time, the **digitization** of law is fraught with challenges. Substantial portions of legal documents, such as law commentaries, remain restricted by license models and are rarely publicly available. Moreover, some countries lag in legislative efforts to make legal documents available in structured, digital formats [Zan24]. In Germany, for example, less than 1% of associated legal texts are openly available [LTO]. Consequently, existing open German legal databases offer limited functionality to improve efficiency. Interfaces are primarily *keyword-based searches*, which often lack context-awareness and fail to account for implicit meanings or relationships [Ver; jur; Vog24]. This limits the accessibility of legal documents and hinders human-AI teaming.

To address these gaps, several **commercial applications** have emerged beyond the two primary commercial databases *beck-online* [Ver] and *juris* [jur], which feature only keyword-search and backlinks. *LEX AI* offers tools for monitoring regulatory changes and curating personalized feeds with AI-supported summaries and synopses of regulatory changes [LEX]. LeReTo KG enriche traditional documents like PDS with links to related materials [LeR]. Meanwhile, tools like *JURA KI Assistent* [RA-] and *Justin Legal* [Jus23] integrate recent LLM progress, mostly through the OpenAI API, to assist with tasks like legal drafting and management.

Despite these advancements, **scientific efforts** in legal tech have primarily focused on computational linguistics and text-based analysis [LWHM16; STL*22; VS22; CNAL23; BFMK24], leaving a gap in **Visual Analytics** (VA) tailored to legal workflows. Visualization and VA are critical for supporting knowledge work in fields such as digital humanities, healthcare, and jurisprudence [FWR*17]. Lettieri and Malandrino coined the term *Visual Legal Analytics* (VLA) and outlined challenges in applying VA to legal science, including the large volume of legal texts and the technical unfamiliarity of legal scholars [LM18]. In contrast, we understand the challenges of VLA as a mismatch between traditional VA models and the workflows of legal scholars.

Traditional VA models often view knowledge as a singular entity resulting from user interactions with visualizations [KAF*08; SSS*14]. In contrast, Knowledge-Assisted Visual Analytics (KAVA) distinguishes between explicit knowledge, which is interpretable by machines, and tacit knowledge, which arises from cognitive processing and is accessible only to humans [WJD*09; FWR*17]. KAVA emphasizes the symbiotic integration of tacit and explicit knowledge into VA, driving user interactions. In jurisprudence, tacit knowledge is indispensable for legal reasoning and generating insights. Hence, for VA to effectively support legal scholars, it must be tacit knowledge-assisted.

To address the unique needs of legal scholars, this work identifies previously unexamined opportunities but also challenges in applying VA to jurisprudence, using Germany as a representative example case, thereby making the following contributions:

- Identifying challenges in applying VA to jurisprudence through **semi-structured interviews** with nine legal experts,
- Proposing an **iterative VA workflow** to articulate tacit domain knowledge as explicit, machine-interpretable knowledge, facilitating predictions and navigation, and
- Proposing VA- and KAVA-based improvements to enhance traditional interfaces in a **case study** and generalize to new opportunities in related **text-based research practices**.

With these contributions, we provide a blueprint for a human-is-the-loop VA design that recognizes tacit domain knowledge as essential for deriving insights in jurisprudence and beyond, more generally guiding visualization researchers in knowledge-assisted VA.

2. Understanding Legal Research Pratice

Jurisprudence is a cornerstone of the legal domain, yet its complexity and reliance on vast information repositories pose significant challenges. Leveraging VA can offer novel ways to address these challenges, but a deep understanding of legal research practices is essential for effective application. Before turning to the role of VA in jurisprudence, we need to establish a common understanding of how legal scholars operate and which tasks are relevant to them. While there is extensive and foundational work on how jurisprudence operates [Bor12; Bru94; Fos10; Bun24], this paper contributes new insights by synthesizing existing knowledge and incorporating findings from the interviews with legal scholars.

2.1. Foundations and Background

Globally, there are primarily two competing legal systems: civil law and common law [Gle06]. The Anglo-American common law system relies on judicial precedents and case law, while the civil law system, rooted in codes and statutes, lends itself to more structured analysis. This distinction provides a foundational starting point for examining how VA can enhance legal research practices. For our initial analysis, we focus on the German legal system, leveraging the expertise of several domain experts available to support us in

this critical analysis. The structured nature of the German legal system, as an example of civil law, aligns well with the capabilities of VA to analyze and synthesize complex legal data.

2.2. How Legal Scholars Operate

The German civil law system builds upon a codified framework, anchored in the *Grundgesetz für die Bundesrepublik Deutschland* (Basic Law) and several codes, such as the *Bürgerliches Gesetzbuch* (Civil Code). These codes form the foundation of the legal system and are supplemented by an extensive array of additional legal sources. As of 2024, there are over 90,000 legal norms and regulations at the federal level, supplemented by numerous state and local statutes [MWO]. Beyond codified laws, the system includes other essential sources such as *explanatory memoranda*, *legal commentaries*, *court rulings*, and scholarly publications in *trade journals* and *commemorative volumes* [Bun24, p. 52]. Explanatory memoranda, published by the German parliament, elaborate on the legislative intent and provide interpretive guidance [Bun24, p. 55]. Legal commentaries, authored by scholars, interpret and analyze legal norms, while court rulings refine their application in practice [Bun24, p. 52]. However, access to these sources is often restricted. Legal commentaries are primarily available on proprietary platforms such as *beck-online* [Ver] and *juris* [jur], which impose licensing constraints. Similarly, court rulings – particularly from lower courts – are frequently inaccessible due to data protection regulations. While some publicly available datasets exist (refer to Table 1), they represent less than 1% of legal decisions [LTO; Vog24; Zan24].

Systematic Relationships — The interplay of these diverse legal sources constitutes the fabric of the German legal system [RFB22, p. 460]. Understanding individual components requires knowledge of their relationships within the broader system. These relationships are hierarchical and semantic, necessitating tacit knowledge to navigate their complexity effectively. While many professionals engage with this legal system, our work focuses on *jurisprudence*, the scientific debate and analysis of law. The workflows described here, however, also apply broadly to other legal professions. Applying legal sources follows a systematic process that relies on explicit procedures and a large amount of tacit domain knowledge [RFB22, p. 412]. Before applying legal norms, practitioners must first understand the sources that constitute the law. Then, the application process typically unfolds through a series of distinct steps [RFB22, p. 414]. First, practitioners establish the facts of the case, carefully analyzing the situation to identify relevant details. Next, they determine the applicable legal norms, leveraging their tacit domain knowledge to navigate the extensive and complex legal landscape. Experienced practitioners often intuitively classify the case within a specific legal area or discipline [RFB22, p. 413]. A particularly challenging aspect of this process involves identifying the legal norms relevant to the case. This task requires an understanding of the hierarchical and semantic relationships within the legal system [RFB22, p. 460]. Interpreting legal texts often depends on contextualizing a given norm within its broader legal framework, as its meaning and implications are frequently defined by its connections. Practitioners must continuously evaluate these relationships, considering both explicit legal provisions and implicit analogies or concepts derived from prior decisions or academic literature [RFB22, p. 413]. One of the main difficulties is that systematically identifying relevant norms is more complex. While some norms are established in legislation, others emerge from legal principles, judicial precedent, and scholarly interpretation. Determining these connections relies heavily on the practitioner's expertise and familiarity with the legal system. After identifying the relevant norms, practitioners assess whether the case fulfills the specific elements outlined by these norms. This process, known as *subsumption*, involves comparing the facts of the case with the requirements of the legal provisions [RFB22, p. 413]. If the elements are satisfied, the practitioner determines the legal consequences accordingly.

Through this systematic yet highly knowledge-intensive process, practitioners bridge the gap between abstract legal principles and real-world cases, underscoring the critical role of domain expertise in legal reasoning.

2.3. Tasks

Legal scholars engage in various tasks that span multiple levels of complexity. Based on the literature, we categorize these tasks into *three primary levels*: fundamental information retrieval, understanding structural relationships, and advancing legal reasoning.

Fundamental Information Retrieval — Scholars focus on identifying and retrieving relevant legal sources at the foundational level. These tasks include filtering sources pertinent to a particular topic [RPNP23], understanding the hierarchical organization of these sources, and determining the location of specific legal norms within the broader legal corpus [LST22]. Efficient information retrieval serves as the groundwork for deeper analytical tasks.

Understanding Structural Relationships — Building on information retrieval, scholars analyze the structural relationships within legal texts. The analysis involves evaluating the chronological order of statutes [RPNP23] and interpreting both explicit and implicit relationships between legal norms [LAM17; RPNP23]. Grasping these relationships is critical for understanding how individual legal norms interact within the broader legal framework, enabling scholars to navigate the complexities of legal hierarchies effectively.

Advancing Legal Reasoning — At the highest level, legal reasoning tasks require synthesizing information to uncover patterns and identify conflicts across legal texts [GCHN15; MW21]. Scholars engage in activities such as detecting inconsistencies between norms, identifying legal precedents, and formulating arguments. Additionally, they analyze legal conflicts [BN19] and derive insights that inform decision-making processes.

Specialized Tasks — Beyond these general categories, certain tasks are unique to specific legal disciplines or application scenarios. Examples include *Policy Modeling* as analyzing the implications of proposed laws and policies [BN19], *resolving natural language queries* through interpreting and answering complex legal queries [LST22] or *comparative law analysis* which involves comparing legal systems or statutes across jurisdictions [LAM17].

Table 1: **A comparison of selected German legal document collections that are digitally available.**

Name [Reference]	Type			Availability	Size (in documents)	Data Formats
	Law	Commentary	Court Rulings			
openJur† [ope]	■	□	■	◐	> 600,000	HTML, PDF
Open Legal Data [OBO20]	■	□	■	●	308,229	HTML, JSON, XML
CDRS-BT [Fob21]	■	□	□	●	131,835	CSV, TXT, XML
CE-BGH [Fob23b]	□	□	■	●	77,892	CSV, GraphML, PDF, TXT
CE-BPatG [Fob24a]	□	□	■	●	30,866	CSV, PDF, TXT
CE-BVerwG [Fob24c]	□	□	■	●	27,200	CSV, PDF, TXT
CE-BFH [Fob23a]	□	□	■	●	10,310	CSV, HTML, PDF, TXT
CE-BVerfG [Fob24b]	□	□	■	●	8,949	CSV, GraphML, HTML, PDF, TXT
Gesetze im Internet [Buna]	■	□	□	●	6,800	EPUB, HTML, PDF, XML
C-DBR [Fob24d]	■	□	□	●	6,784	CSV, EPUB, PDF, TXT, XML
CE-BAG [Fob20]	□	□	■	●	5,625	CSV, PDF, TXT
Rechtssprechung im Internet [Bunb]	□	□	■	●	*N/A*	HTML, PDF, XML
OpinioIuris† [Sha]	■	■	■	◐	*N/A*	HTML, PDF
Landesrecht BW [Min]	■	□	■	◐	96,050	HTML, PDF
beck-online† [Ver]	■	■	■	○	> 55,000,000	HTML, PDF
juris† [jur]	■	■	■	○	> 680,000	HTML, PDF

The document types are marked with a filled square (■), while an empty square (□) signifies their absence. A filled circle (●) indicates document collections available in a structured, machine-readable format and eligible for automatic processing. In contrast, a half-filled circle (◐) designates the absence of one of these properties. Collections attributed with an empty circle (○) are unavailable in a structured, machine-readable format and not eligible for automatic processing. Datasets superscripted with a dagger (†) apply restrictive licensing prohibiting access to or processing their documents.

3. Subject Matter Expert Interviews

To deepen our understanding of the tasks performed by legal scholars and their associated challenges, we conducted semi-structured interviews with domain experts. These interviews provided valuable insights into established workflows and the technical requirements to support them effectively.

3.1. Participants

We interviewed nine subject matter experts from the legal domain, representing a diverse range of experiences. The participants, who did not receive any monetary compensation, included a professor of public law (E_1), seven doctoral and post-doctoral research associates specializing in various legal areas (E_{2-8}), and an undergraduate student of public management (E_9). Concerning their experience, E_1 has extensive experience in jurisprudence and legal practice. E_2, E_3, and E_4 focus on European, German federal, and state public law and have practical experience in legal institutions. E_5, E_6, E_7, and E_8 specialize in German administrative law, criminal law, private building law, and civil law, respectively. E_9 specializes in local politics and municipal law. This diversity ensured a comprehensive understanding of workflows across legal contexts.

3.2. Methodology

The semi-structured interviews, averaging one hour each, followed a protocol but allowed for follow-ups to capture detailed insights. We began by gathering information about the participants' *specializations and backgrounds*, asking them about their legal expertise, their professional and academic experiences. Next, we inquired about the *established workflows* for working with legal texts, including their tasks. We also encouraged participants to *compare their practices* in previous roles. Finally, we asked the experts to identify specific *obstacles* they faced, providing examples. Finally, we inquired about their *needs and expectations* for applications that could improve their workflows.

3.3. Results

The interviews revealed common workflows and recurring challenges faced by legal scholars:

Data Accessibility and Availability — Participants emphasized the importance of digitized legal texts in streamlining their work. For instance, E_2 noted that access to digital resources accelerates research, whereas manual retrieval of printed materials causes significant delays (E_5). However, the participants pointed out that the duopoly of *beck-online* [Ver] and *juris* [jur] restricts access to crucial documents. Further, lower court rulings, in particular, remain difficult to obtain due to data protection regulations [LTO].

Search Interface Limitations — The search functionalities of *beck-online* and *juris* emerged as a key challenge. Participants reported limited support for domain-specific language (E_4, E_6, E_7), a failure to identify legal concepts not explicitly mentioned in texts (E_3), and over-reliance on syntactic search, which does not accommodate conceptual or fuzzy queries (E_4). To mitigate these issues, E_4, E_5, and E_8 frequently use browser-based search within retrieved results, highlighting the inadequacy of built-in tools.

Navigating Hierarchical Structures — Participants often rely on manual methods to understand the relationships between legal documents. These methods include analyzing tables of contents and hierarchical document structures (E_7, E_9), exploring explanatory memoranda for context (E_4, E_7) and using hyperlink-based backlinks between related documents, or manually searching for connections when links were unavailable (E_8). These workflows demand significant manual effort, underscoring the need for tools that enable exploratory navigation of document hierarchies and relationships.

Expectations for Enhanced Search Tools — Participants expressed a desire for search tools with advanced capabilities, such as fuzzy and semantic search similar to Google (E_6) or contextualization of results based on progressive query direction (E_6).

Views on AI/LLMs — Opinions on AI and LLMs vary: while E_6 rarely uses LLMs, E_7 and E_8 highlight concerns about transparency and reliability. However, some participants (E_8) use LLMs to filter search results retrieved from commercial platforms, suggesting cautious optimism about the potential of LLMs.

4. Adressing Challenges in Legal Research: A Three-Phase Workflow Design

Based on the semi-structured interviews with experts and the literature, we identify the challenges legal scholars face in analyzing and applying legal sources:

1. **Accessibility Issues:** Licensing restrictions and lack of digital availability limit access to essential legal commentaries and court rulings, particularly at lower court levels.
2. **AI Usage:** A cautious but growing interest in AI-based tools is contingent on their reliability and explainability.
3. **Navigational Complexity:** Lack of approaches to navigate relationships between legal texts to identify relevant norms
4. **Inefficiency of Current Interfaces:** Current platforms such as *beck-online* and *juris* prioritize syntactic search, which lacks semantic or contextual understanding.
5. **Reliance on Tacit Knowledge:** Scholars must draw on implicit domain expertise to interpret norms and identify relationships, a labor-intensive and error-prone process.

Apart from the licensing issues, these findings emphasize a need for more adequate support in the legal domain. VA offers ways to address these challenges through human-AI teaming by enabling semantic exploration and systematic analysis of legal texts.

4.1. Three-Phase Workflow

From the literature and interviews, we distill a *three-phase* workflow (WF_{P_1}- WF_{P_3}) frequently encountered by legal scholars (see also Figure 1). The phases – Discovery & Scoping, Analysis & Interpretation, and Synthesis & Documentation – illustrate the systematic but manual processes scholars currently follow. To illustrate, consider *Alice*, a legal scholar with extensive experience in German legislation. She is researching racial profiling in the context of the legal safeguards offered by German law against law enforcement from engaging in racial profiling. The following three sections describe the workflow's phases as executed *traditionally* without VA, outlining legal scholars' challenges.

4.1.1. WF_{P_1}: Discovery and Scoping

In the first phase of the workflow (WF_{P_1}), Alice identifies suitable legal texts and narrows them down to address her research problem. Familiar with *beck-online* [Ver], she begins by querying the platform's search interface. Given her expertise, Alice assumes that cases of racial profiling are particularly prevalent in operations conducted by the *Bundespolizei* (German Federal Police), whose responsibilities include securing German borders (§ 2 BPolG (Bundespolizeigesetz, i.e., Federal Police Act)), train stations (§ 3 BPolG), and airports (§ 4 BPolG). She starts with the search phrase *"Racial Profiling Bundespolizei"*. Her query yields only five matching documents, prompting Alice to broaden her search using the more general phrase *"Racial Profiling"*. While this query produces a significantly larger volume of results, it also introduces many irrelevant entries. Alice begins her review by examining the most relevant legal norms by *beck-online* for her search queries. These include Art. 3 GG (Grundgesetz, i.e., Basic Law), § 23 BPolG, and Art. 14 EMRK (Europäische Menschenrechtskonvention, i.e., European Convention on Human Rights). Although already familiar with these norms, Alice notes them for further reference.

Next, Alice evaluates the documents listed in the search results. The results are sorted by relevance, but the platform does not make the ranking criteria transparent, leaving Alice uncertain about the prioritization. She skims through the initial results and discovers that some relevant documents are inaccessible due to the limits of her subscription. Despite their potentially high relevance, Alice is forced to exclude these documents from her analysis. The first results predominantly include trade journal articles, court rulings, and commentaries rather than primary legal statutes. To supplement this, Alice manually expands her search to explanatory memoranda in other databases, such as the *Dokumentations- und Informationssystem für Parlamentsmaterialien* (DIP) [Deu]. Recognizing the importance of these documents for contextual analysis, she notes them for detailed inspection in WF_{P_2}.

4.1.2. WF_{P_2}: Analysis and Interpretation

In the second phase (WF_{P_2}), Alice analyzes the documents identified in the first phase WF_{P_1}. She focuses on connecting the legal norms highlighted by *beck-online* – such as Art. 3 GG, § 23 BPolG, and Art. 14 EMRK – with the content of the selected documents. *beck-online* allows Alice to preview these norms but does not support visualizing relationships between them. Alice draws on her expertise to recall that § 23 BPolG, which permits identity checks by the federal police, is conceptually linked to §§ 2-4 BPolG, which outline the responsibilities of the federal police. However, *beck-online* lacks tools to map or visualize such connections explicitly, requiring Alice to track the relationships as she progresses through her analysis mentally.

She begins by examining the first matching document from a trade journal. Due to its limited structural organization, Alice skims the text to identify relevant legal norms and notes them mentally. This process repeats for the remaining documents, including those accessed through supplemental searches in other databases. Alice consults their details whenever she encounters unfamiliar norms by following backlinks in the legal database. Through her analysis, Alice identifies arguments supporting her assumption that German law inadequately prevents racial profiling. However, eliciting these insights requires substantial manual effort as she digs through multiple documents. Alice also suspects that norms related to the state police laws (such as the *Polizeiaufgabengesetz* (Police Tasks Act) in Bavaria) might offer additional insights. However, she finds no references to these in her current search results, indicating a gap in the coverage.

4.1.3. WF_{P_3}: Synthesis and Documentation

In the final phase (WF_{P_3}), Alice synthesizes her findings and documents the outcomes of her analysis. She integrates her mental map of relationships between legal norms with the arguments and insights derived from the reviewed documents. Using a document editor of her choice, she organizes these findings into a coherent narrative, ensuring that references to relevant legal texts and scholarly arguments support her conclusions. Alice imports the key documents into her reference management software for citation and further reference. This phase remains labor-intensive due to the absence of automated insights from multiple sources that visualize the relationships between legal norms. Despite these limitations, Alice completes the synthesis and prepares to revisit it in subsequent iterations, aiming to address gaps identified in previous phases.

5. Visual Analytics for Jurisprudence

The identified three-phase workflow consists of discovery & scoping, analysis & interpretation, and synthesis & documentation (refer to subsection 4.1). This structure aligns with common practices in jurisprudence and other text-based research domains. For example, TIAN, LI, and YUAN propose *LitVis*, a VA system for literature exploration and management, which follows a corresponding three-phase workflow [TLY23]. Their framework supports tasks such as scientific survey writing, which shares key abstract tasks with jurisprudence. In the first phase, "*data collection*," practitioners conduct literature searches to scope their survey. This is followed by "*literature management*," for paper identification. Finally, during "*literature exploration*," relationships are identified, topics are prioritized, and papers are classified. This analogy underscores the broader relevance of our workflow across domains. Similar parallels can be drawn with systems such as *KAMAS* [WRTA17] and *VIStory* [ZDCC21], which adapt similar workflows for malware analysis and interactive storytelling, respectively. PIROLLI and CARD further abstract these processes as part of the sense-making loop [PC05], which is rooted in cognitive psychology. Their model divides the workflow into two interdependent loops: the browsing loop and the sense-making loop, consisting of 16 steps, mitigating cognitive biases and supporting complex reasoning.

Integrating VA in Browsing and Sense-Making Loops — In the browsing loop, PIROLLI and CARD recommend the principle of "*[o]verview first, zoom and filter, then details-on-demand*" [Shn96]. VA systems can leverage this approach by highlighting documents relevant to analysts' tasks pre-attentively. Such features reduce the time required to sift through large document collections while amplifying the utility of experts' tacit domain knowledge. For example, analysts can quickly reject irrelevant items, minimizing unnecessary drill-downs.

VA systems can expand analysts' working memory in the sense-making loop by externalizing evidence, relationships, and insights. The expansion reduces cognitive load and counteracts biases inherent in human reasoning, such as confirmation bias [TK74]. However, poorly designed systems can exacerbate these biases, potentially hindering users instead of supporting them. Thus, careful attention must be paid to system design, evaluation, and iterative refinement.

A Case Study on Integrating VA and Jurisprudence — Based on these observations, we identify three key areas of VA that hold significant benefits for jurisprudence: (1) *data navigation*: for effective exploration of document collections, (2) *knowledge representation*: for integrating domain knowledge with explicit knowledge from legal entities, and (3) *analytical reasoning*: to synthesize findings while mitigating cognitive biases. In Figure 2, we **critically discuss** the visual components of an exemplary *traditional user interface* (UI) of a commonly used German legal database, featuring a keyword-based search (refer to section 3) and propose, based on the literature and our findings, enhancements leveraging VA techniques. This forms the basis for the future development of such approaches.

The **traditional UI** in Figure 2 consists of three parts: (1) the hierarchy of the inspected law for data navigation, (2) the display of the legal norm's contents, and (3) a list of related legal documents. On the left-hand side, the UI (1) visualizes the hierarchy of the *Bundespolizeigesetz* (Federal Police Act) using a collapsable tree structure. It contains the law's hierarchical structure labeled by its section titles. Users can navigate the law through interaction with the structure, moving between legal norms. To drive data navigation in jurisprudence through VA, we identify two exemplary existing VA techniques (Treemap and Icicle Plots) proposed in the literature. The UI (2) renders the selected legal norm's contents at the center, representing explicit knowledge. The rendering highlights the keywords from the query in the contents verbatim. For explicitly referenced legal entities, the user interface backlinks to their documents, simultaneously displaying a preview on hover. To enable legal scholars to introduce their tacit knowledge, we reference two exemplary approaches from VA that offer additional, corresponding user interactions (spatial layouts and Concept Map). On the right-hand side, the legal database (3) lists legal documents related to the currently displayed document, like legal norms, law commentary, and court rulings. We suggest two existing VA techniques that leverage common methods for visualizing relationships between documents, which the literature proposes for such scenarios. For the three key areas of VA discussed above, we analyze the deficiencies, explore the state-of-the-art literature, and distill possible improvements in jurisprudence through VA while discussing the intersection's challenges.

5.1. Data Navigation

In VA, data navigation concerns the exploration of and the movement in information spaces [SV08]. For jurisprudence, this translates to the exploration of and the movement in hierarchically structured legal document collections. The traditional UI of legal databases (refer to Figure 2) provides a collapsable tree-based list of the hierarchy. However, this still exposes the legal scholar to the lack of semantic context during navigation. Since law structures can be nested several levels deep [Bun24, p. 152], their tree structure can become cumbersome. Moreover, the tree-based list does not enable the simultaneous navigation of multiple hierarchies as it is often necessary in jurisprudence.

Hence, MERKL and SCHWEIGHOFER introduced the concept of navigating such corpora using a *Hierarchical Feature Map* [MS97], a **Treemap** variant, which organizes clusters across layers rep-

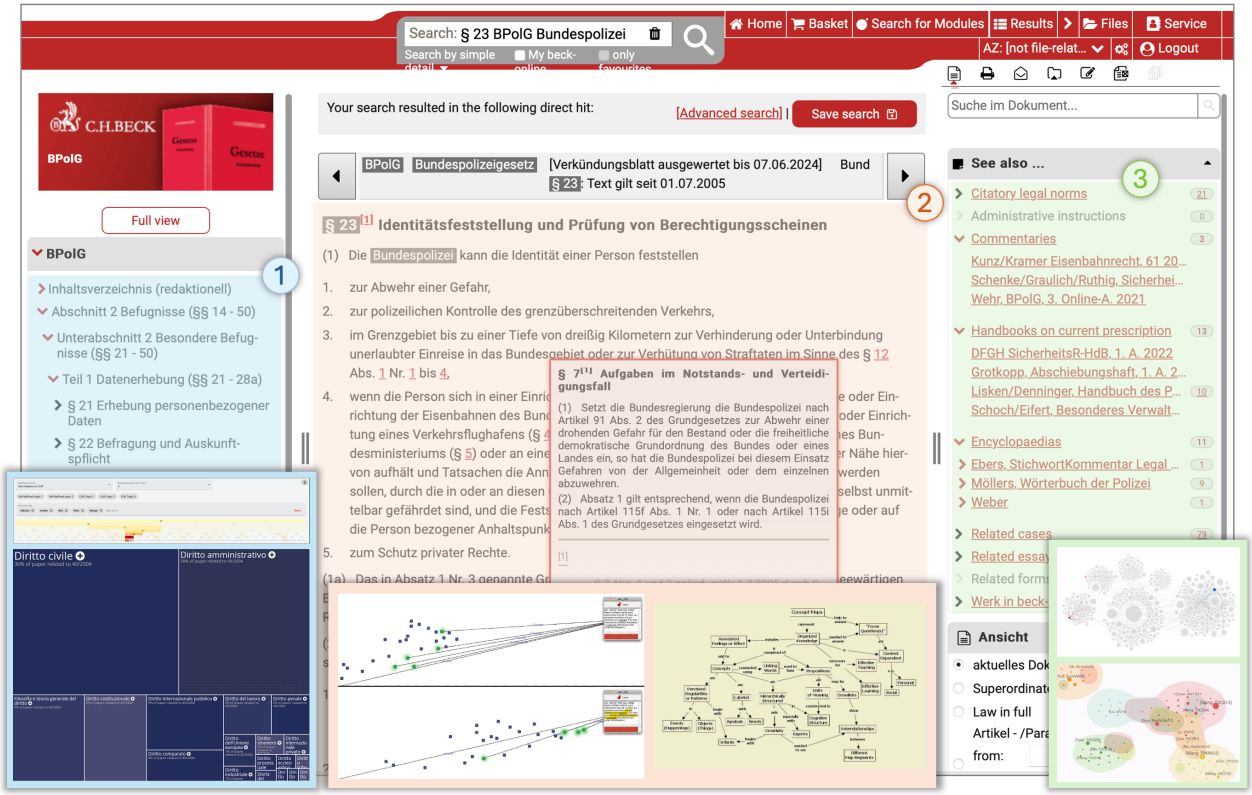

Figure 2: **An annotated screenshot of a legal database's user interface that displays the results for a search query.** On the left-hand side, the user interface (1) displays the hierarchical structure of the *Bundespolizeigesetz* (Federal Police Act). At the center, the database (2) renders the selected legal norm's text with keywords from the query highlighted. On the right-hand side, the user interface (3) lists related documents such as legal norms and law commentaries.

resenting the hierarchy. Each layer corresponds to a hierarchical level, with subsequent layers revealing sub-clusters. Despite their improvement, the static, semi-automatically generated maps require manual input for cluster titles, limiting scalability. With the *Legal Doctrine Semantic Navigator*, LETTIERI, ALTAMURA, and MALANDRINO started employing Treemaps [JS91] for navigating hierarchical legal documents through drill-down and roll-up operations [LAM17]. Later, some of the authors also introduced the *sliding Treemap*. This variation enables the navigation of rulings by the European Court of Justice and other legal documents on mobile devices [LGMZ20]. Treemaps combined with interactive drill-downs can display several paths simultaneously in one or multiple hierarchies. In addition, they can visually encode guidance by enlarging documents of higher relevance [LAM17] (refer to the visualization augmented to the lower left corner of Figure 2), for example.

Besides Treemaps, **Icicle Plots** [KL83] have emerged as an alternative visualization method for hierarchical data. For example, digital humanities employ these plots during document comparison [TSR*24]. KIM, DRAKE, ENDERT, and PARK use an Icicle Plot to visualize a hierarchy of topics during their interactive modelling [KDEP20], while TYTARENKO, SHAO, RUTAR, et al. also visualize a hierarchy of topics to compare documents [TSR*24] (refer to the visualization augmented to the lower left corner of Figure 2). Contrary to Treemaps, Icicle Plots statically display hierarchies at once. They do not require an interactive drill-down to uncover a path in the hierarchy. Using visual highlighting, an Icicle Plot can inform legal scholars at a glance [TSR*24].

We **suggest** combining their advantages. Since Icicle Plots are limited in scalability, we intend to use a dynamic display to visualize the currently selected path in the hierarchy with less horizontal space. To compensate for the lack of overview, we imagine leveraging a variant of the Treemap that does not rely on interactive drill-down operations but displays nested layers of the hierarchy at once. In supporting data navigation, their combination would support legal scholars during the first workflow phase (refer to WF_{P_1}), discovering and scoping legal document collections.

5.2. Knowledge Representation

The interactions with visualizations for data navigation heavily depend on the user's prior knowledge [WJD*09]. In VA, knowledge is commonly represented as a singular entity the user gains during the analysis [KAF*08; SSS*14]. However, this view is too simplistic and does not accurately reflect the knowledge-generation process. Hence, there is work proposing a more granular distinction

of knowledge as explicit and tacit [WJD*09]. In jurisprudence, explicit knowledge can appear as relationships between legal documents La Cava, Simeri, and Tagarelli, where one norm references another legal norm, establishing a relationship.

The **traditional UI** of legal databases displays these relationships as backlinks, with a popup and metadata. The tree-based list of the law's hierarchy to the left and the list of related legal documents on the right also express explicit knowledge contained in legal documents. Meanwhile, legal scholars' tacit knowledge includes legal norms' application and is not articulated but internalized as part of legal scholarship [RFB22], and therefore is not reflected, which is especially important for legal reasoning, i.e., analysis and interpretation (refer to subsubsection 4.1.2).

In the **literature**, Gomez-Nieto, Casaca, Hartmann, and Nonato present several types of visualizations like a stacked graph and geographic maps to visualize the metadata of legal documents [GCHN15]. Similarly, Resck, Ponciano, Nonato, and Poco visualize the structure of legal documents by semantically separating them into paragraphs [RPNP23]. Focused on the content, Bokwon Lee, Lee, Kyumin Lee, et al. statically analyze the complexity by visualizing explicit references between its articles [BLK*18]. Outside of jurisprudence, explicit knowledge of text-based documents is visualized in the context of discussion forum posts [JWXZ18] and document comparison [TSR*24], for instance. However, neither these examples nor those discussed from jurisprudence allow users to articulate their tacit knowledge, which is enabled by approaches for KAVA [FWR*17] instead. For instance, Wagner, Rind, Thür, and Aigner allow experts for cybersecurity to classify behavioral rules of software for identifying malware [WRTA17], while Mistelbauer, Bouzari, Schernthaner, et al. enhance medical visualizations by ranking views based on the experience of medical experts [MBS*12]. Endert, Fiaux, and North define several of such semantic interactions that support analytical reasoning for text analytics [EFN12]. The authors also provide an implementation, letting users determine the importance of phrases through text highlighting. Accordingly, documents containing the exact phrase become closer in a spatial layout (refer to Figure 2). Drawing on these semantic interactions, we find *Concept Map*, a diagram of concepts connected by labeled arcs that describes the tacit knowledge [CCH*05], to the right of the spatial document layout.

Translating **VA solutions** to jurisprudence, we observe that visually layouting legal concepts in a map is an established approach [BN19][GF19, p. 48]. As such, concept maps can benefit VA for jurisprudence in converting legal scholars' domain knowledge to explicit knowledge through semantic interactions. This conversion also enhances the effectiveness of LLMs. With *KMTLabeler*, Wang, Ouyang, Wu, et al. propose a labeling tool for medical texts integrating VA with LLMs [WOW*24]. This tool allows experts to express their domain knowledge by adjusting keyword weights and defining labeling rules. The resulting explicit knowledge is incorporated into the embedding generation of the LLM and used to improve the labeling of the medical texts. We can also connect the knowledge representation to legal reasoning since *Concept Map* resembles a network. Both support the latter two phases of the jurisprudence workflow (see WF_{P_2} and WF_{P_3}).

5.3. Analytical Reasoning

The **traditional UI** of legal databases only lists groups of legal documents related to the currently displayed document. There are no means by which legal scholars can add evidence of their insights to that list. In VA, analytical reasoning is a knowledge-generation process that can have systematic aspects but is also serendipitous [SV08]. Users must be aware of the evidence found throughout this process to increase the chance of insights. A prominent approach to capture such evidence is analytical provenance as suggested by Pirolli and Card for their sense-making loop [PC05]. For that, Pérez-Messina, Ceneda, Schetinger, and Miksch suggest organizing analytical artifacts like annotations and their relationships [SV08; PCSM24].

In related, text-based research practice, **Overview** allows investigative journalists to create tags that attach their findings to clusters [BISM14]. Tian, Li, and Yuan add to this, allowing users to interactively adapt clusters of literature, adding comments about their understanding of topics [TLY23] (refer to the lower visualization augmented to the right-hand side of Figure 2). With *ForceSPIRE*, Endert, Fiaux, and North address visual text analytics in general, allowing experts to create text highlights that constitute a spatial layout of document relationships [EFN12].

Conveying the **relationships** within and between such clusters is central for analytical reasoning, so networks are frequently employed as visualization methods. Lettieri, Altamura, and Malandrino introduce the *Norm Graph Navigator*, allowing interactive exploration of legal relationships [LAM17]. More recently, La Cava, Simeri, and Tagarelli integrate natural language querying into network navigation, enabling users to filter nodes efficiently [LST22] (refer to Figure 2). Since analytical artifacts externalize tacit knowledge as explicit [WJD*09], they can act as a countermeasure to the confirmation bias in hypothesis generation [PC05] and enable collaboration [PCSM24], which can reinforce diverse opinions in legal decision-making. Being persisted [PCSM24], these artifacts can help users recall and replicate insights [RESC16]. Analytical **provenance** additionally fosters transparency, which is particularly important in the legal domain, where the validity and reliability of insights must be meticulously documented. Integrating these aspects, for example, through 2D clusterings for overview, graph networks for relations, and provenance trees for documentation, shows the great potential of VA for jurisprudence.

6. Emergent Challenges for Visual Analytics Design

While numerous approaches exist for data navigation in the legal domain, knowledge representation and analytical reasoning are often left to analysts to perform manually, as we have seen in the previous case study. We have analyzed several examples of existing VA techniques to address these shortcomings in section 5. Crucially, no existing solution, to the best of our knowledge, integrates all three key areas of VA into a unified framework to exploit their synergetic effects. In the following, we explore the *opportunities and challenges* of developing such an integrated approach, building upon the proposed solutions.

6.1. Addressing Jurisprudence

Traditionally, German legal scholars predominantly use simple keyword-based search bars, which serve as the prevalent UI paradigm [Ver; jur]. However, this poses several challenges to legal scholars, hindering effective workflow support. While familiar, the paradigm limits scholars to primitive input, lacking the expressiveness required in the legal domain. Hence, we propose to combine existing visualization techniques into a novel VA workflow (see Figure 1) for jurisprudence. As part of the initial workflow phase (refer to WF_{P_1}), the scholar scopes their research by verbally articulating goals in an NLI using plain text instead of keywords. The system processes the verbalized analysis goal and recognizes references to legal entities such as laws, legal norms, and court rulings. We imagine an overview displaying clusters of legal concepts and individual documents relevant to the query, enabling scholars to leverage their domain expertise to refine the selection. For its implementation, the overview leverages a network visualization augmented with colored shapes that indicate clusters. For details, a scholar can preview individual documents on-demand during selection, highlighting explanations for their relevance.

After refining the scoping, legal scholars transition to the second workflow phase (refer to WF_{P_1}). In VA, the UI transitions into a detailed view upon selecting a cluster or document of interest. For this, we propose to combine a Treemap on the left-hand side with an Icicle Plot on the right-hand side. The former displays the legal documents of the scope with their hierarchy, enabling swift navigation. Meanwhile, the Icicle Plot provides the contextualized path of the selected document in its hierarchy. Together, these visualizations address the legal domain's unique requirement for **simultaneous navigation across multiple hierarchies**.

During the analysis & interpretation, legal reasoning takes place, which must utilize the scholar's domain knowledge. While the proposed VA techniques can initially visualize the explicit knowledge from the legal documents, they cannot draw on that tacit domain knowledge. Hence, at any point during the workflow, if users identify a document relevant to their query that is missing from the current selection, they can establish a relationship to include it. The Treemap and Icicle Plot visualizations support this interaction by integrating empty cells with suggestive icons as visual placeholders. We exploit this integration to augment embeddings resulting from an LLM with the expert's domain knowledge, personalizing the VA workflow. Further, we draw tacit knowledge from its externalization through analytical artifacts.

Besides the Treemap and the Icicle Plot, we propose to add a concept map to the top side of the suggested user interface. The map allows users to synthesize and document evidence acquired throughout the legal reasoning process, forming a crucial part of the third workflow phase (refer to WF_{P_3}). Scholars capture and connect relevant artifacts within the concept map to organize their legal insights. Nodes represent primitive artifacts resembling individual legal entities, such as legal norms or court rulings. In contrast, compound artifacts describe the links that relate multiple primitives, representing causal connections in the legal realm. For instance, in analyzing racial profiling by the German Federal Police (refer to subsection 4.1), a scholar might document that the police are responsible for securing train stations (§ 3 BPolG) and are permitted to identify individuals if necessary for fulfilling their duties (§ 23 BPolG). However, this authority must be balanced against the third-party effect of the German Basic Law (Art. 3 GG), which ensures equality and non-discrimination.

While the concept map is an isolated visualization so far, we propose an augmented merge with the network visualization used during (refer to WF_{P_1}), as scholars need to transition from the detailed view back to the overview and vice-versa. This augmentation is novel since existing works in jurisprudence and related text-based research disciplines do not consider the proposed **unified design**.

Implementing the proposed VA workflow **faces challenges**. The suggested visualization techniques for VA may suffer from issues with visual scalability. For vast legal datasets, networks, Treemaps, and Icicle Plots are of limited use. However, since these datasets are hierarchically structured, we can progressively unveil parts of the hierarchy to limit the information these visualization techniques need to convey. Further, leveraging progress in natural language understanding remains difficult: legal text data contains domain-specific language [RFB22, p. 123], specific phraseology, and is intentionally ambiguous at times [RFB22, p. 128]. This design allows for statutory interpretation [RFB22, p. 22] and evolves with social norms and society but is challenging for LLMs. Although they are trained on vast datasets, **Large Language Models** still struggle to apply these nuances of legal reasoning, in particular open foundation models. For example, we found that Llama 3.1 70B still confuses § 212 StGB (Strafgesetzbuch, i.e., criminal code), which defines homicide for murder (§ 211 StGB). However, by definition of the criminal code, they are two strictly separate criminal offenses. Further, hallucinations, particularly during the subsumption phase, are critical as LLMs struggle with completeness. Hence, it is necessary to either improve the base models or perform extensive fine-tuning of foundational LLMs to fit the specific language of the legal domain and overcome contemporary shortcomings.

6.2. Implications for Visual Analytics Design

Due to the lingering challenges in navigation, understanding, and reasoning, we advocate for a human-*is*-the-loop design [EHR*14], which positions the VA system as an integral part of the scholar's workflow. This view contrasts designs that rely on the common human-in-the-loop [KAF*08; SSS*14] approach. While the latter assumes the domain expert to become a part of their VA system, the former prerequisites the VA system to become part of the domain expert and their workflow instead. To achieve this, the VA design process requires a user-centered approach that fits the workflows of the domain expert, supporting them throughout the sense-making loop [PC05; EHR*14]. Therefore, we conclude the following **key techniques** from natural-language processing and visualization that enable a methodology transfer [MSK*19] from jurisprudence to other domains:

- **Natural language inference**: enable users to articulate their domain knowledge by inferring verbalization mental models
- **User-driven exploration**: interfaces should put users into the driver's seat to steer the navigation through information spaces
- **Semantic contextualization**: contextualize information spaces with inferred domain concepts to support analytical reasoning

- **Unified close and distant reading**: interfaces should unify close and distant reading to support analysis
- **Provenance tracking**: interfaces should support users in their analytical reasoning, keeping track of intermediate insights and supporting knowledge-generation processes

The natural language inference leverages domain-specific LLMs to deduce domain concepts from verbalized mental models. The inference seeds the user-driven exploration matching these mental models. Users are in charge of steering the navigation through information spaces. Since the interface semantically contextualizes the information spaces, the navigation happens through analogies from the domain that appear familiar to the users, easing the visual navigation of their mental models. Through unified close and distant reading, users leverage the benefits of inspecting documents in detail while being aware of the exploration's context through distant reading. Provenance tracking supports processes to capture intermediate insights and support knowledge-generation processes during analytical reasoning and synthesis of findings.

6.3. Future Work and Generalization

Our work leveraged expertise from nine domain experts, but we firmly focused on the German civil law system. While the civil law system works similarly, countries sometimes have substantial differences regarding style, structure, and methodology. For example, EU legislation and German law differ in the way the goals are stayed beforehand in the former (missing from the actual law in the latter), its teleological compared to its systematic interpretation, and the blending of some case law aspects into EU legislation as a supranational legal system. Future work should explore the particularities of extending our approach to **other legislative systems** and, in particular, to case law, with more considerable differences.

Unfortunately, open legal datasets necessary for training and fine-tuning are limited and need more diversity. While several German legal datasets include basic law and some court rulings (refer to Table 1), law commentary, interpretation, and the vast majority of legal cases and statements of claims are rarely available. However, access to law commentary is fundamental for the legal reasoning process [RFB22, p. 254]. In the future, more work must be done to offer more structured **open legal data**. One way forward here can be open data initiatives, justice system digitalization, or the scanning of older literature and its automatic LLM-based transformation to form legal archives.

While we have presented the textual analysis with a strong focus on juridprudence, some methods and solutions exhibit substantial overlap with workflows in related, text-based research domains [ZDCC21; TLY23]. These workflows share core elements of data navigation, knowledge representation, and analytical reasoning, as outlined in section 5. Consequently, our VA workflow (refer to subsection 6.1) can be **transfered** onto these usage scenarios, albeit with domain-specific adaptations. For example, the types of analytical artifacts must align with the target discipline. In the context of scientific literature, scholars writing a survey about visualization types might use the workflow to stash evidence regarding papers covering specific visualization techniques. In this case, a primitive artifact could represent an individual visualization figure, while a compound artifact could encapsulate a collection of papers discussing the same visualization type. This adaptability stems from the workflow's abstraction into the broader sense-making loop [PC05], as described by Pirolli and Card. Implementations of this loop are evident in various domains, including healthcare [FWR*17] and sports [CPG*16]. While the workflows in these domains differ in specific details, they share commonalities in the way data navigation, knowledge representation, and analytical reasoning are approached. For instance, the VA system proposed by Chung, Parry, Griffiths, et al. for analyzing rugby performance [CPG*16] uses a projection of game events to facilitate data navigation. This approach parallels the projection of medical texts employed by *KMTLabeler* [WOW*24]. Additionally, both systems enable domain experts to incorporate their tacit knowledge through weight modifications during analysis [CPG*16; WOW*24].

Thus, our VA workflow can provide a guiding framework for visualization researchers across diverse domains, where **tacit knowledge** remains a driving force for analytical reasoning and decision-making. Several KAVA systems externalize tacit domain knowledge as explicit rules, often as tables [CPG*16]. While functional, these representations may appear overly generic and disconnected from the specific workflows of individual domains. Therefore, future research should prioritize the development of **domain-specific metaphors** for externalizing tacit knowledge [WJD*09].

7. Conclusion

In this paper, we explore the integration of Visual Analytics (VA) into jurisprudence, addressing the unique challenges posed by legal texts' complex and hierarchical nature. Through semi-structured interviews with legal experts, we identify a typical workflow in jurisprudence and analyze its commonalities with workflows in other disciplines. This analysis reveals an abstraction in the sense-making loop, emphasizing the need for VA systems that integrate data navigation, knowledge representation, and analytical reasoning within a cohesive design. To address these gaps, we propose a human-is-the-loop VA workflow that leverages legal scholars' tacit knowledge, enhancing their ability to navigate, interpret, and reason with legal documents. We critically discuss the necessary transformations from a traditional UI commonly employed to a VA-based interface, alongside its challenges. Our proposed approach facilitates informed legal reasoning by combining human expertise with machine intelligence. It provides a scalable framework for other text-intensive domains and the blueprint for future development of such systems. Our findings extend beyond jurisprudence, offering valuable insights into the design of VA systems for fields such as healthcare, scientific research, and sports analytics. This work lays a foundation for future advancements in knowledge-assisted VA systems by addressing the interplay between tacit knowledge and sense-making processes.

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