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A survey on business process view integration: past, present and future applications to blockchain

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Abstract

Purpose – The complexity of business environments often causes organizations to produce several inconsistent views of the same business process (BP), leading to fragmentation. BP view integration attempts to produce an integrated view from different views of the same model, facilitating the management of BP models.

Design/methodology/approach – To study the trends of BP view integration, the authors conduct an extensive and systematic literature review to summarize findings since the 1970s. With a starting corpus of 918 documents, this survey draws up a systematic inventory of solutions used in academia and industry. By narrowing it down to 71 articles, the authors discuss in-depth 17 BP integration techniques papers, classifying each solution according to 9 criteria.

Findings – The authors' study shows that most view-integration methods (11) utilize annotation-based matching, based on formal merging rules. While most solutions are formalized, only approximately half are validated with a real-world use case scenario. View integration can be applied to areas other than database schema integration and BP view integration.

Practical implications – By summarizing existing knowledge up to June 2021, the authors explore possible future research directions. The authors highlight the application of view integration to the blockchain research area, where stakeholders can have different views on the same blockchain. The authors expect that this study contributes to interdisciplinary research across view integration, namely to the context of blockchain.

Originality/value – This survey serves to pave the way for future trends, where the authors highlight the application of view integration to blockchain research.

Keywords Business process, View integration, Blockchain

Paper type Literature review

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1. Introduction

A BP is a collection of activities (or tasks), representing a well-defined procedure that aims to achieve a specific organizational goal (Aguilar-Savén, 2004). BPs are core assets of organizations, as they shape the functioning and efficiency of the same organizations.

BP models represent BPs and aim at facilitating communication between stakeholders (Indulska *et al.*, 2009), serving as the initial point to guide business decisions. BP models can be *instantiated*, allowing for customization. BP models are difficult to manage, sometimes accounting for several thousand models, especially if there are variations or different *views* of a given process. Such views naturally emerge because of the different responsibilities or roles assigned to each stakeholder. To manage such complexity, analysts can leverage *BP management* (BPM) techniques (Song *et al.*, 2011; Van Der Aalst *et al.*, 2003).

BPM provides tools and methods to design, optimize and maintain BPs. BPM typically requires five steps: process identification, process discovery, process analysis, process redesign and process implementation, monitoring and controlling. These five steps output BPs that can be represented as different *views*, e.g. organizational, stakeholder, information and application. Thus, one may have several views on the same BP. BPs are represented with *BP modeling languages* (BPMLs), such as *event-driven process chains* (EPCs) and *BP modeling notation* (BPMN). Figure 1 represents two different views of a BP: collecting evidence for semi-automated audits using blockchain (Belchior *et al.*, 2019, 2020a).

EPCs are a representation of BPs flow charts (Gottschalk *et al.*, 2008). An EPC has three node types: events, functions and logical connectors. Events are passive elements that constitute pre-requisites for the execution of functions. Logical connectors determine the process behavior, e.g. by associating two events or functions (via a directed arc). Connector types include XOR, $\wedge$ (and) and $\vee$ (or).

Although EPCs are much used, the industry standard for representing BPs is BPMN (vom Brocke and Rosemann, 2015; White, 2017). BPMN aims to support BPM by providing a notation that can represent complex business semantics. BPMN defines flow nodes (events, activities and gateways), connecting (sequences, messages and associations) and swimlanes and artifacts.

Process variability studies the representation of different variations of the same BP (La Rosa *et al.*, 2017). Process variability management is the set of processes dealing with the families of BPs rooted on the source BP. One of the main challenges is to *merge* different process variants into a consolidate version – view integration. *BP view integration* (BPVI), is the discipline that studies the consolidation of different views regarding a BP (Dijkman, 2008; Tran *et al.*, 2010; van Dongen *et al.*, 2013), a yet unsolved problem.

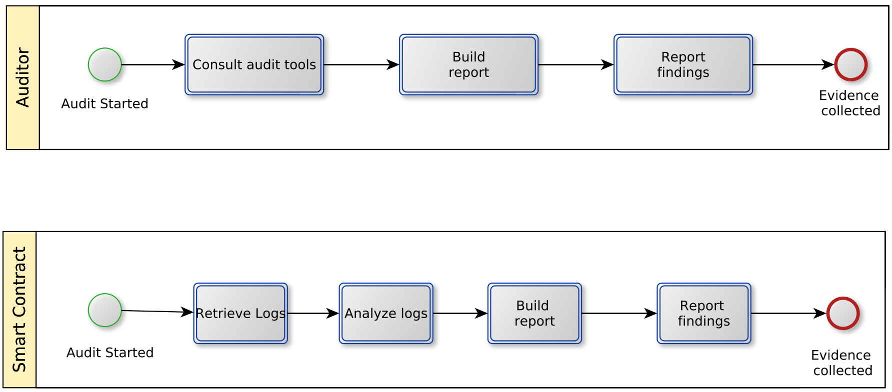

Figure 1.
Auditor and smart contract (representing a blockchain consortium) concerns regarding the collection of evidence for a semi-automatic audit

For views to be merged, first their similarities need to be identified (Mendling *et al.*, 2007). Typically, techniques from *process model matching* are used to compare models, highlighting their similarities and differences. Process model matching encompasses the ability to automatically identify relations between activities of process models. Thus, view integration might imply a pre-processing phase that supports process model matching (Antunes *et al.*, 2015). When we refer to view integration in this paper, by default we mean BPVI. However, this term can also refer to other integration techniques (e.g. database schema integration), so view integration is a superset of BPVI. The existence of different views stems from stakeholders conducting a BP in different ways. BPVI addresses three main challenges: (1) languages widely used for BP modeling are not adequate to promote the reuse of models (Tran *et al.*, 2010); (2) while processes executed by one stakeholder are easy to document, processes involving stakeholders with different incentives and views are much more cumbersome (Colaço and Sousa, 2017) and (3) business modeling reflects the modeling team's perspective and a different team might come up with a different representation (Colaço and Sousa, 2017). Therefore, human participation in BPs needs to be addressed (Holmes *et al.*, 2008).

BPVI processes create *integrated views*. The concept of integrated view has its roots in database schema integration. Database schema integration is the set of activities that integrates the different schemas on a single, unified schema (Batini *et al.*, 1986). In schema integration, a global conceptual description of a database is created. This concept influenced business analysts to perform the same on BPs.

One of the practical applications of view integration is *blockchain*. Blockchain is an emerging technology that provides decentralized, immutable, append-only data storage (Correia, 2019; Peck, 2017). On top of such secure storage, a computing framework can be maintained by a network of untrusted participants (or nodes) via smart contracts (Belchior *et al.*, 2020). Nodes hold a replica of this data structure locally (called the ledger), agreeing on the next global state via a consensus mechanism. Changes to the global state are done via transactions, which are calls issued against an account or a program running on the blockchain (often called a smart contract or chaincode). Thus, blockchain is used where stakeholders/organizations do not entirely trust each other, being suitable for cross-organizational interactions. Blockchain has been widely studied in the past years, in particular interoperability (Belchior *et al.*, 2020), security (Li *et al.*, 2020), scalability (Yu *et al.*, 2020) and applications (Zhu *et al.*, 2019).

More recently, blockchain has attracted a high interest from the BP research community (Koens, 2020; Viriyasitavat *et al.*, 2020; Weber *et al.*, 2016). Concretely, blockchain has been used to enhance traceability and transparency of BP execution (Silva *et al.*, 2019), where each participant on the blockchain network corresponds to a stakeholder of that BP. The information a participant can observe on the blockchain is a view. However, contrarily to common knowledge, *blockchain does not necessarily provide a single source of truth*. Considering that different blockchain stakeholders might have different views, a unique, integrated view should be extracted to facilitate information integration (e.g. to be used for audits). In fact, blockchains can facilitate audits (Dyball and Seethamraju, 2021), given that there are tools supporting such processes.

The need for allying the areas of view integration and blockchain is exacerbated by the existence of private blockchains and the need for blockchain interoperability (Belchior *et al.*, 2020). Permissioned blockchains such as Hyperledger Fabric provide enhanced privacy features comparatively to permissionless blockchains. To implement this feature, blockchains do not provide consistency, i.e. there is not a single global state but rather partial consistency. Parties share state with parties from a group they belong to. In other words, parties may see only a view, but these views put together should result in a consistent global state. The study of views is important to understand which information is visible by each group of parties at each time, specifically when one attempts to expose information from a private blockchain to the exterior. In particular, if a blockchain is private, interoperation capabilities are difficult because by default its state is hidden. Blockchain views can be a dependable mechanism to provably share state from private blockchains, enabling blockchain interoperability.

Another need is for migrating privacy-preserving blockchain-based applications (namely, its infrastructure). Since different parties in such blockchain-based applications may only see part of the global state (different views), the information to be migrated should be the global view (or a view resulting from merging the available partial views). However, applications from the view integration research area are largely unexplored. We hypothetise this is due a unique combination of several factors: the recent emerging for information confidentiality within private blockchains and the need for interoperation across private blockchains.

Blockchain views could then help tracking cross-chain state, integrating views from each blockchain in a consolidated one. A practical example is shown by the blockchain gateway paradigm for interoperability, where blockchain gateways conduct cross-jurisdiction asset transfers (namely, promissory notes), supported by different (possibly private) distributed ledgers. Auditing such solution would rely on the concept of blockchain view, where the general cross-chain state is a consolidated view over the different stakeholders' views composing the BP (Belchior *et al.*, 2021a, b). However, the intersection of these fields is largely unexplored.

In this paper, we lay the foundations to apply view integration to blockchains so that use cases such as blockchain audits, blockchain migrations and data portability are facilitated.

This paper reviews the state of the art regarding BP view integration and explores its trends. We, therefore, address the following *research questions* (RQ):

RQ1. What is the origin of BP view integration, and what is its evolution?

RQ2. What are the current BP view integration techniques in the literature, and what taxonomy can be used to characterize them?

RQ3. How can view integration be applied to blockchain?

To answer RQ1, we first elaborate on the past of BP view integration: database schema integration, providing an informal survey of papers dated from the 1970s to around the 2000s. After that, we refer to RQ2 by providing a systematic and comprehensive survey that reviews and classifies existing techniques for view integration. Finally, we argue that view integration can be applied to blockchain technology, answering RQ3.

This document is organized as follows: Section 2 introduces view integration and presents this survey's methodology. After that, it elaborates on the classification criteria and the identified view integration techniques. Section 3 discusses the results. Section 4 presents future trends for BP view integration, followed by the related work, in Section 5. Finally, Section 6 concludes the paper.

2. BPVI systematic literature review

In this section, we introduce the view integration research area. First, we provide the historical framing by recalling database view integration. After that, we execute a systematic literature review on view integration regarding BP view integration.

2.1 An historical perspective

Database view integration is the research area that prompted the emergence of BP view integration. In the context of databases, the goal of view integration is to produce a holistic description of databases by combining the different database users' views. User views are collected and integrated, yielding the conceptual database schema. Past trends include view integration techniques applied to database schema integration, having its inception in the late 1970s and popularized in the 1980s. This historical perspective is illustrated in Figure 2.

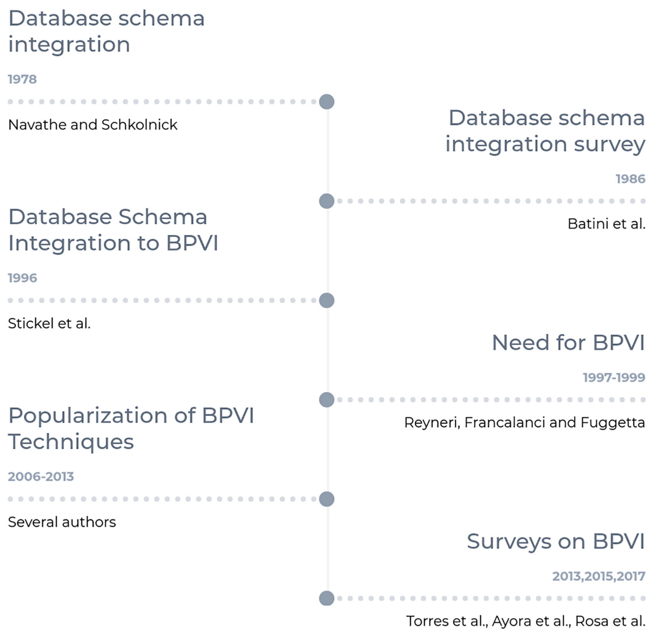

Figure 2.
Historical perspective on BPVI

In database schema design, the general idea is to capture different stakeholders' views on the data that are identified and analyzed into several *input schema*. After that, the input schemes are consolidated, based on their similarities, producing integrated schemas. Navathe and Schkolnick popularized the idea of database schema integration in 1978 (Navathe and Schkolnick, 1978). The same authors present a conceptual framework for logical database design, including the view modeling and view integration steps, contributing to view integration in database design (Navathe and Gadgil, 1982; Navathe and Schkolnick, 1978).

Later, in 1984, Dayal and Hwang expanded database schema integration to multiple, heterogeneous distributed databases (Dayal and Hwang, 1984). The authors describe a view definition schema applied to a functional data model resolving inconsistencies across heterogeneous databases, creating a consolidated view. View integration then became part of the larger database design activity, required to respond to the data requirements users have. These studies influenced future work on view integration for object-oriented databases (Gotthard *et al.*, 1992).

In 1986, Batini *et al.* provided a systematic literature review on methodologies for database schema integration (Batini *et al.*, 1986), comparing methodologies for database schema integration. In 1996, schema integration was considered a necessity to eliminate redundancies and maintain consistency across database systems (Stickel *et al.*, 1996). The authors from the same study established the bridge between database schema integration and "a business process-oriented strategy for data integration" (Preuner and Schrefl, 1998) to study the integration of views of object life-cycles represented by behavior diagrams.

Spanoudakis *et al.* (1996) discuss the ViewPoint96 workshop, reporting findings on the nature of viewpoints (views), detection of variability, integration by resolution and representation, from a software engineering perspective. This study is a clear example of the heterogeneity of this area: views are reasoned from different levels of abstraction and formality, always reflecting the strong tie to people and organizations.

Bergamaschi *et al.* (1998) developed the MOMIS (Mediator envirOnment for Multiple Information Sources) approach that integrated heterogeneous information sources, with both structured and semi-structured data. This approach relied on the definition of an object-oriented data model called ODL to describe schemas to construct a shared ontology that provides the basis for integration. In particular, data collected from databases are directly translated into the common data model using transformation rule-sets or a simple syntactic translation. The integrated view is built by merging elements in clusters, which are grouped by the affinity coefficient, a measure of the semantic relationship between classes. Later, in 2000, Bergamaschi *et al.* further explored MOMIS, presenting its system architecture and performing a comprehensive evaluation (Bergamaschi *et al.*, 2001).

The final years of the 20th century then paved the way for the study of view integration techniques in BPs (Dijkman *et al.*, 2006) highlighted “that schema integration is not able to cope with heterogeneous control flow representation of BPM schemas” (Stumptner *et al.*, 2004), defined consistency criteria for behavior integration (Vöhringer and Mayr, 2006) and presented a parallel between schema integration and view integration, pointing out the same challenges, namely structure heterogeneity and user communication.

2.2 Current trends in BPVI

Many of these contributions fostered the transition of schema integration to view integration by applying concepts from databases to BPs. We now introduce the methodology for our survey on BPVI. We applied the procedure proposed by Webster and Watson (2002), also taking into account ideas from Briner and Denyer (2012). Thus, we divide our review methodology into the steps as follows:

(1) Identification of the RQs and the goals of the systematic literature review (RQ1, RQ2 and RQ3);

(2) Preparation of a proposal and review protocols for the review;

(3) Search the literature for relevant studies addressing the RQs (study identification);

(4) Select the studies, critically appraise the study, take notes and summarize the collected information (study selection) and

(5) Disseminate the review findings.

Step 1 corresponds to the definition of the RQs (Section 1). The present section implements the second step of the methodology.

2.2.1 Paper inclusion criteria. The eligibility of the studies for this survey is based on predefined inclusion and exclusion criteria. Papers included in this survey satisfy, at least, one inclusion criterion: (1) the paper includes an exposition and discussion on BPVI techniques (in particular, database schema integration or BP view integration); (2) the paper selected to be included in this review describes a technique that supports BPVI and (3) the paper provides relevant discussions to establish a bridge between BPVI and emerging research areas, namely blockchain.

2.2.2 Study identification. To address the exposed RQs, we perform a systematic literature whose scope encompasses work up to June 2021. This time-frame covers since the inception of related areas to BPVI up to the present, following the recommendations from standard systematic literature review guidelines (Kitchenham and Charters, 2007; Webster and Watson, 2002). First, we performed a keyword-based search on electronic databases. The following query strings to identify the relevant publications regarding BPVI: “business process view integration,” “business” AND “process” AND “view” AND “integration,” “business process view” AND “integration” and “business process” AND “view integration.”

Due to the high number of search results, the analysis of search results was skipped for most searches. The search with the keywords "business process" AND "view integration" seems to be the most specific. However, we also added the terms "business process matching" and "business process merging" to the string. Thus, the final string stands as "business process" AND "view integration" OR "business process matching" OR "business process merging." The first group of papers was obtained from the Google Scholar database, throughout April 2020–June 2021, according to Table 1. We also performed the queries on Science Direct – however, as Google Scholar indexes more documents than the ones stored at Science Direct, so we used the first library (Kitchenham and Charters, 2007).

We believe this combination of keywords covers the current available knowledge in this field because it includes both keywords on the specific topics we study (e.g. "business process matching") and more generic keywords that let us find other papers that may use slightly different keywords (e.g. "business process"). We finished the search after 30 irrelevant publications. After that, a selection of the identified literature was conducted based on the abstract and titles. We searched for referenced works on those papers (called "snowballing") and in different gray literature sources – the process was repeated until theoretical saturation was reached (i.e. snowballing did not yield relevant results).

We remark that some of the work done in view integration is performed within the industry. To address that, and to reduce the publication bias, we included gray literature in our research as advised by Mahood *et al.* (2014). Publication bias stems from the fact that studies with statistically significant results (e.g. hypotheses corroborated by the authors) are more likely to be published and thus discovered in search processes. We thus define gray literature as academic theses, unpublished research, blog posts and technical reports. To evaluate gray literature, additionally to the documents indexed by Google Scholar, we evaluated the first 100 hits from Google Search with the same keywords that we used on Google Scholar. Gray literature and other sources accounted for ten studies.

Initially, we retrieved 918 studies (893 from Google Scholar and 25 from other sources). We removed the duplicates and obtained 912 studies. After that, we analyzed the title, abstract and keywords, yielding 249 relevant studies. After the initial screening, full-text articles were assessed for eligibility; this yielded 17 studies directly related to BPVI and 15 support studies (contributing to the area of BPVI), yielding a total of 32 articles that answer RQ2. A total of 39 articles were included to answer RQ1 and RQ3. Figure 3 represents an adapted *preferred reporting items for systematic reviews and meta-analyses* (PRISMA) diagram (Moher *et al.*, 2009) considering all steps of our literature research methodology.

2.2.3 Study processing. We read the selected 71 articles (directed related to BPVI and supported studies). We mapped the information contained in each paper to one of the three RQs defined. We inspected the code and datasets of each paper when available. The analysis of the literature is present in Sections 2.3 and 2.4.

2.2.4 Threats to validity. The main threats to the validity of the present survey are: *language bias*, *selection bias* and *the focus on view integration.*

Search term	Database results
"business process view integration"	5
"business" OR "process" OR "view" OR "integration"	6,270,000
"business process view" AND "integration"	899
"business process" AND "view integration"	772
"business process" AND "view integration" OR "business process matching" OR "business process merging"	893

Table 1. Literature review search results on Google Scholar

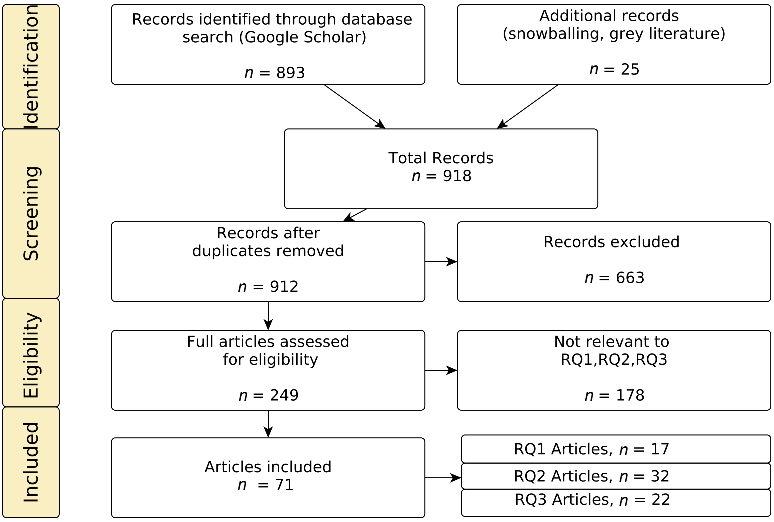

Figure 3.
PRISMA diagram specifying our literature research methodology

Language bias refers to the fact that only studies in English have been included. Selection bias occurs because the search for papers focused on academic venues, including journal, conference and workshop papers. Although we alleviate this threat by consulting gray literature, some relevant works may be left out. Lastly, we state that the area of BP view integration is more encompassing than what we focus on in this survey. For instance, we deliberately leave out most work on consolidated models, a term related to integrated view. We illustrate how our study differentiates from others (and how the reader can obtain a complete perspective accordingly) in Section 5.

2.3 Classification criteria for view integration techniques

In this section, we outline the categories and classification criteria for view integration techniques. We follow an adapted version of a taxonomy for BP variability modeling (La Rosa *et al.*, 2017) explained in this section since process variability is often studied as a superset of BP (view) integration.

We classify each view integration solution in one of two categories. The first category, *automation*, regards the business analyst's effort of setting up the view integration technique and has three values: manual, semi-automated and automated. Manual automation happens when the analyst wants to merge two or more views, mostly manually (with a tool). Semi-automated methods rely on matching criteria, which allow decreasing some effort from the analysts. The analyst matches parts of the views to be integrated, and the corresponding tool performs the integration. Automated methods do not rely on user input, merging all components of the views.

The second category, *matching*, refers to how elements of a BP are linked to a predicate over properties of the application domain. In other words, it refers to how objects are linked with their correspondent objects on the other view. Matching is divided into *annotations* and *behavior*.

Annotations allow to systematically capture process knowledge, providing the necessary semantics for analysts to model processes. Using this concept, process performers can systematically capture process knowledge, and process engineers can incorporate it into process models for process model maintenance. Annotations are useful since they attribute semantics to certain objects of a business model, matching them with similar objects.

Annotations are attached to model artifacts referring to implicitly defined elements of the discourse domain, typically using ontology-supported linguistic techniques, and can be matched with a similar one on a different view, creating a link. Behavior matching evaluates the effects or functionality of a BP, usually leveraging domain ontology. In other words, two elements are linked if they produce the same results.

Finally, we categorize solutions by their *merging* technique. We label methods with *formal* if the merging technique follows a well-defined algorithm or *adhoc* if the merging technique is not explicit or varies. This practical and summarized classification allows for assessing the practicality of each solution – regarding its effort (automation), matching technique (annotation/behavior) and merging technique (formal/*adhoc*).

To further classify models, we explicit the following properties, based on a recent survey (La Rosa *et al.*, 2017). In this survey, Rosa *et al.* propose a similar but different concept for view integration: consolidated model. A consolidated model is referring to the BP, whereby its elements originate from different processes. The consolidated model is semantically equivalent to the original processes and can be changed dynamically, conserving the relationships of its elements (Morrison *et al.*, 2009; Rosa *et al.*, 2010). With this in mind, the consolidated model includes the concept of the integrated view.

For each technique, we analyze the aspects as follows:

(1) *Language* criteria refer to the primary BPML used.

(2) *Extension* encompasses a consolidated view that contains the behavior shared by all views. The consolidated view can be extended to produce a specific view.

(3) *Restriction* allows obtaining a variant of a consolidated view by enforcing restrictions on the original model (for example, skipping activities on the original model).

(4) *Abstraction* criterion is fulfilled if a user can customize a view. For example, some approaches rely on "annotations" or another explicit linkage to provide semantics.

(5) *Structural* (correctness) assesses to if the tool can provide guarantees about the correctness of consolidated views (e.g. no isolated nodes).

(6) *Behavioral* (correctness) assesses to if the tool can guarantee the correct behavior of the consolidated models (e.g. avoiding deadlocks).

(7) *Formalization* defines if a method has concrete algorithms and/or definitions.

(8) *Implementation* criteria define if a method is implemented.

(9) *Validation* criteria apply if a method was applied to a real-world scenario through discussions with domain experts.

2.4 View integration overview

This section elaborates on the different view integration techniques, separated by the matching technique criteria: annotation or behavior.

2.4.1 Matching by annotation. This section describes solutions whose matching method is "annotation."

In Mendling and Simon (2006), it is presented a view integration technique applied to EPCs. The study introduces a merge operator that takes two EPCs and their semantic relationships as input and produces an integrated EPC. For that, semantic relationships have to be identified by a BP designer. Each pair of nodes describing the same real-world events is merged into a single node, and the former input and output arcs are joined and split with AND connectors, respectively. The arcs of each pair of nodes part of a sequence are refactored. Finally, a set of restructuring rules is proposed to eliminate unnecessary structure (i.e.

reducing the resulting EPC size). After the annotation, the tool merges the models by following a specific set of rules.

Morrison *et al.* (2009) provide a theoretical framework for assessing the integration of BPs, exemplifying its application to a family of processes merged via an *adhoc* method. The authors use clustering techniques to classify BPs. For example, k-mean clustering can be used to create clusters of BPs sharing common traits. After that, the integration goals are defined (they can be provided by analysts or inferred based on each BP). The integration occurs where nodes and edges are added or removed from the model representing a pair of semantic processing nets (SPNets). The outcome of the integrations is assessed using similarity metrics.

Tran *et al.* (2007, 2010) propose a name-based matching approach for view integration, based on the *view-based modeling framework*. The proposed matching approach, name-based, is a semi-automatic method that pairs the modeling entities by their name, which pose the same functionality and semantics. In this scheme, the BP analyst defines the BP using a custom framework, a view-based modeling framework. The main idea of name-based matching for view integration is to find all integration points (elements from different views that share the same name) between two views and merge those two views at the integration point.

In Colaço and Sousa (2017), the authors propose an incremental approach to infer consolidated BP diagrams from different views, which were applied to BPMN 2.0. Their approach is based on previous work (Caetano *et al.*, 2012; Marques Pereira *et al.*, 2011; Pereira *et al.*, 2011) in which an organizational taxonomy is proposed by specifying six BP dimensions. A BP model repository has the "time factor" embedded, allowing time dependencies on the possibly various versions of a business model. The integration process begins with the modeling of a specific view of a process. The classification of each view is performed by the stakeholder while inputting information to the repository.

In Huang *et al.* (2014), BPMN process models are decomposed into fragments. The authors annotate each activity with its immediate effects and calculate the effect accumulation. Later, the E-RPST merging algorithm is applied, mapping nodes with their highest similarity score pair, yielding a consolidated model.

Derguech *et al.* (2017) propose an algorithm for merging process models into a configurable process model anchored on annotations for capability-annotated process graphs, abstracting from BPMN, EPC and other commonly used notations in this research area. The paper proposes an algorithm that inputs a set of capability-annotated process models and outputs a capability-annotated configurable model.

In Kunchala *et al.* (2017), the authors propose a method for merging collaborative inter-organizational BPs, providing a theoretical contribution to the types of merging techniques (synchronous vs asynchronous and interactive vs non-interactive). In subsequent work (Kunchala *et al.*, 2019), the authors generate artifact lifecycles from the activity centric from the inter-organizational BPs. The proposed approach combines the nodes of collaborating processes to generate a consolidated process.

La Rosa *et al.* (2013) and Rosa *et al.* (2010) present an algorithm that produces a unified, configurable BP model from two different ones. This algorithm works with several representations of business models, such as EPC and BPMN, and leverages a merging operator. The first step of the merging algorithm is to process BP models into configurable process graphs.

Cardoso and Sousa (2020) propose an approach that follows previous work (Colaço and Sousa, 2017; Sousa *et al.*, 2019) and generates stakeholder-specific models using functional decomposition by recursively breaking down a process as sub-activities. Such models are generated from a consolidated model and user input in the six Zachaman dimensions: what, when, how, why, who and where. The "What" refers to the enterprise's information, focusing on data. "When" expresses how an artifact evolves with the timeline, focusing on time. "How" tackles the execution of the enterprise's mission, focusing on the function. "Why" translates motivation into objectives. "Who" indicates people behind business operations. Finally, "Where" refers to the enterprises' artifacts' distribution, focusing on the network.

2.4.2 Matching by behavior. This section describes solutions whose matching method is "behavior."

Grossmann *et al.* (2005) propose integration operators to create, manage and finalize composition between autonomous object-oriented systems. A structured sequence of integration steps that analyzes the relationships between processes to be integrated is presented. After that, a set of integration options is proposed that can specify a high-level integration operator that conducts the integration.

Gottschalk *et al.* (2008) present a three-phase approach that merges two BP models, which were represented by EPCs into a consolidated model. First, the EPCs to be merged are reduced to function graphs, which are entities that depict the active behavior of the EPCs. Second, the two function-graphs are reduced to a single, consolidated one. Finally, the consolidated function graph is transformed into an EPC.

Gerth defines the concept of single-entry-single-exit (SESE) regions for BP models as the basilar concept to identify and visualize differences between models that are merged (Gerth, 2007). Differences are computed by checking the conflict matrix over SESE regions. Merging takes place by applying executable operations (insert, delete and move) over position parameters.

Küster *et al.* (2008) present a simple prototype focused on BP development. In this paper, differences between process models to be merged are detected using correspondences between model elements and the technique of SESE fragments. For each detected difference, a resolution transformation is generated, merging the models.

Li *et al.* (2009) propose an algorithm to output a consolidated model by conducting a heuristic search across the process graph (represented in ADEPT), using a measuring distance to find reference models with minimal average weighted distance to the variants.

Bulanov *et al.* (2011), propose to automate the view integration process by converting the processes to temporal process logic (TPL) formulas, merging them at the language level, and then generate the consolidated process. This technique allows compatibility with variability techniques, allowing to mix declarative and imperative process specifications in a single consolidated process.

In Assy *et al.* (2013), authors merge process fragments around BPMN activities to construct a consolidated fragment for each activity instead of merging whole process models. The authors abstract some BPMN concepts to build a notation graph.

Assaf (2016) proposes as scheme for integrating of heterogeneous artifact-centric processes. In the modeling phase, the artifacts belonging to a process to be merged are translated into business artifact modeling notation (BAMN). After that, business artifact specifications are generated from the constructed model. Specifications are written in the artifact definition language (ADL queries). ADL queries are executed to generate business artifact systems (such as information models). At the integration phase, conceptual local models are matched, using flow connectors. After that, an integrated global model is derived from the matching produced.

3. Discussion

This section discusses and classifies view integration techniques as defined in Section 2.3.

3.1 Overview of view integration approaches

Issues on the integration of BPs (Francalanci and Fuggetta, 1997) and reusability of BP models started to be tackled as early as 1997 and 1999 (Reyneri, 1999), respectively. Early research suggested that a BP would not need to be redesigned from scratch every time a model is modified by employing reusable building blocks.

Table 2 depicts the comparison between the various view integration techniques. We present the main techniques for database view integration, in Section 2.1, as a contextualization of BPVI techniques. From the present table, one can see that most of the available solutions are semi-automatic solutions relying on annotations to produce an integrated view.

Formal merging rules are used as a matching mechanism, along with annotations. Behavior-based matching solutions, such as Gottschalk *et al.* (2008) and Morrison *et al.* (2009) utilize clustering mechanisms, thus allowing for a more automated and "semantic-based" approach, which was influenced by early work on database view integration (Bergamaschi *et al.*, 1998, 2001). Both techniques require some sort of "ontological overlap" between views. This overlap introduces inconsistencies, the basis for integration, by annotation (typically best directed to static inconsistencies, at artifact description level) or by behavior (best directed to dynamic inconsistencies) (Spanoudakis *et al.*, 1996). While a greedy generation of integrated views can reduce manual labor, typically it is not as accurate as annotation-based methods. Typical languages that are used to integrate views are EPC and BPMN. The majority of the solutions allow constructing an integrated view by extension (vs a minority

Reference	Year	Citations	Automation	Matching	Merging	Language	Extension	Restriction	Abstraction	Structural	Behavioral	Formalization	Implementation	Validation
(Mendling & Simon, 2006)	2006	121	SA	Annotation	FMR	EPC	+	–	–	+	+	+	–	–
(Tran *et al.*, 2007)	2007	56	SA	Annotation	FMR	BPEL	+	–	–	+	+	+	+	–
(Gerth, 2007)	2007	6	SA	Behavior	FMR	IBM WebSphere Business Modeler	+	+	+	+	–	+	+	–
(Gottschalk *et al.*, 2008)	2008	107	A	Behavior	FMR	EPC	+	–	–	+	+	+	+	–
(Küster *et al.*, 2008)	2008	24	SA	Behavior	Ad-hoc	BPMN	+	+	+	–	–	–	–	–
(C. Li *et al.*, 2009)	2009	115	A	Behavior	FMR	ADEPT	+	+	+	+	–	+	+	–
(Morrison *et al.*, 2009)	2009	28	SA	Annotation	Ad-hoc	EPC (1)	+	–	+	+	–	+	–	–
(L. Rosa *et al.*, 2010)	2010	137	SA	Annotation	FMR	EPC	+	–	+	+	+	+	+	–
(Tran *et al.*, 2010)	2011	11	SA	Annotation	FMR	VbMF (2)	+	–	+	+	+	+	+	+
(Bulanov *et al.*, 2011)	2011	14	A	Behavior	FMR	TPL	+	–	–	–	+	+	–	–
(La Rosa *et al.*, 2013)	2013	241	SA	Annotation	FMR	EPC	+	–	+	+	+	+	+	+
(Assy *et al.*, 2013)	2013	12	SA	Behavior	FMR	BPMN	+	–	–	+	+	+	+	+
(Huang *et al.*, 2014)	2014	5	SA	Annotation	FMR	BPMN	+	–	+	+	+	+	+	–
(Assaf, 2016)	2016	5	A	Behavior	FMR	BAMN	+	–	–	+	–	–	–	–
(Colaço & Sousa, 2017)	2017	3	SA	Annotation	Ad-hoc	BPMN	+	–	+	–	–	–	–	+
(Kunchala *et al.*, 2017)	2017	2	SA	Annotation	FMR	BPMN	+	+	+	+	–	–	–	–
(Derguech *et al.*, 2017)	2017	6	SA	Annotation	FMR	Capability-Annotated Process Graph	+	–	+	+	+	+	+	+
(Cardoso & Sousa, 2020)	2020	2	SA	Annotation	Ad-hoc	BPMN	+	+	+	–	–	–	+	+

Note(s): A- Automated; SA- Semi Automated; FMR- Formal Merging Rules
1 - Supports arbitrary languages
2 - An abstraction supporting several models such as BPMN, EPC, and UML Activity
We used a "+" on a green background to indicate a criterion that is fulfilled, and a "–" to indicate the criteria is not fulfilled. Updated on June 11, 2021

Table 2.
Evaluation of BP view integration methods, which were ordered by year of primary publication

allowing to build by restriction). This is because often the starting point for studying BP variability is standalone views that are merged and combined into an integrated view and not a consolidated view that derives specialized views. Structural and behavioral guarantees can be given by the formal generation of integrated views, semantically equivalent to the original ones (distinguishable based on a given predicate) (Barat *et al.*, 2006; La Rosa *et al.*, 2017). While most solutions have formalization available, only approximately half are validated with a real-world use case scenario. Implementations, even if just proof of concepts, have been provided. This fact implies that there is a considerable gap between theory and practice. Several enterprises try to bridge this gap by developing enterprise solutions (such as Apromore [1] or Atlas [2]).

Next, we elaborate on work that directly or indirectly supports the discussed BPVI techniques (see Table 3).

3.2 Supporting studies

Some studies indirectly support BP view integration, such as managing view workflows (Colaço and Sousa, 2017; Nguyen *et al.*, 2017) (Schumm *et al.*, 2010), present a meta-model for process BP views and illustrate the elementary process viewing patterns. The authors provide an implementation that supports the alteration pattern for modification of attributes and their values, which were applied to the BPEL specification. Another example is Weidlich *et al.* (2011), who define a set algebra for behavioral profiles to identify redundancies across BP models (Küster *et al.*, 2007), present the notion of compliance of a BP model with an object lifecycle. The generality of the solutions is typically reduced: most solutions are tied to a specific implementation, although some authors provide a technology-agnostic model (Mendling and Simon, 2006; Rosa *et al.*, 2010).

The study of consistency across BP models was also relevant to the advance of the area (Weidlich and Mendling, 2012). Weidlich and Mendling studied control flow aspects and consistency notions. The authors concluded that the perception of consistency is tied to the behavioral equivalence (if two processes have the same behavior, they are consistent). Other authors studied horizontal BP model integration by formalizing semantics using abstract state machines (Schewe *et al.*, 2015).

Later, several authors (Milani *et al.*, 2015) studied how different decomposition heuristics affect process model understandability and maintainability, concluding that “no comparable consent regarding the question of how to decompose a process model.” Along with process visualization techniques for multi-perspective process comparisons (Pini and Brown, 2015), the way has been paved for the settlement of the view integration area.

There are some efforts to classify the quality of the integration of BPs (Morrison *et al.*, 2009), which provide one of the first theoretical frameworks for assessing the integration quality of BPs. Morrison *et al.* establish a distance measure between two SPNets to ensure the consolidated model does not deviate considerably from the originating models. Others propose an algorithm to output a consolidated model by learning from a collection of (block-structured) process variants, using heuristics (Li *et al.*, 2009), and evaluate such models. Process model repositories (Colaço and Sousa, 2017; Rosa *et al.*, 2009) allow business analysts to manage a large number of models for analyzing, visualizing, transforming and creating customizable process models. In particular, Atlas allows to consolidate and derive views from a consolidated model.

In the next section, we elaborate on how BPVI can be extended to the blockchain research area.

4. Application of view integration to blockchain

In this section, we discuss how to leverage view integration research in the blockchain area.

#	Reference	Year	Authors	Title	Publication forum
1	Navathe and Schkolnick (1978)	1978	Navathe, S and Schkolnick, M	View representation in logical database design	ACM SIGMOD international conference on management of data
2	Dayal and Hwang (1984)	1984	Dayal, U and Hwang, H	View definition and generalization for database integration in a multidatabase system	IEEE transactions on software engineering
3	Gotthard *et al.* (1992)	1992	Gotthard, W and Lockemann, P and Neufeld, A	System-guided view integration for object-oriented databases	IEEE transactions on knowledge and data engineering
4	Batini *et al.* (1986)	1986	Batini, C. and Lenzerini, M. and Navathe, S	A comparative analysis of methodologies for database schema integration	ACM computing surveys
5	Stickel *et al.* (1996)	1996	Stickel, E and Hunstock, J and Ortmann, A	A business process-oriented approach to data integration	*Distributed information systems in business*
6	Preuner and Schre (1998)	1998	Preuner, G and Schrefl, M	Observation consistent integration of views of object life-cycles	*BNCOD advances in databases*
7	Dijkman *et al.* (2006)	2006	Dijkman, R and Ferreira Pires, L and Joosten, S	Integration of heterogeneous BPM schemas: The case of XPDL and BPEL	The 18th conference on advanced information systems engineering
8	Stumptner *et al.* (2004)	2004	Stumptner, M and Schrefl, M and Grossmann, G	On the road to behavior-based integration	Proceedings of the first Asia–Pacific conference on conceptual modelling
9	Vöhringer and Mayr (2006)	2006	Vohringer, J and Mayr, HC	Integration of schemas on the pre-design level using the KCPM-approach	*Advances in information systems development*
10	Mendling and Simon (2006)	2006	Mendling, Jan and Simon, Carlo	Business process design by view integration	*Business process management workshops*
11	Morrison *et al.* (2009)	2009	Morrison, E and Menzies, A and Koliadis, G and Ghose, A	Business process integration: method and analysis	Proceedings of the Sixth Asia–Pacific conference on conceptual modelling
12	Tran *et al.* (2010)	2011	Tran, H and Zdun, U and Dustdar, S	Name-based view integration for enhancing the reusability in process-driven SOAs	*Business process management workshops*
13	Tran *et al.* (2007)	2007	Tran, H and Zdun, U and Dustdar, S	View-based and model-driven approach for reducing the development complexity in process-driven SOA	International working conference on business process and services computing
14	Sousa *et al.* (2007)	2007	Sousa, P and Pereira, C and Vendeirinho, R and Caetano, A and Tribolet, J	Applying the Zachman framework dimensions to support business process modeling	Digital enterprise technology

Table 3.
Studies answering RQ1, RQ2 and RQ3

(*continued*)

#	Reference	Year	Authors	Title	Publication forum
15	Colaço and Sousa (2017)	2017	Colaco, J and Sousa, P	View integration of business process models	European, Mediterranean and Middle Eastern conference on information systems
16	Caetano *et al.* (2012)	2012	Caetano, A and Pereira, C and Sousa, P	Generation of business process model views	Conference of ENTERprise information systems–aligning technology, organizations and people
17	Huang *et al.* (2014)	2014	Huang, Y and He, K and Feng, Z	Business process consolidation based on E-RPSTs	IEEE world Congress on Services
18	Derguech *et al.* (2017)	2017	Derguech, W and Bhiri, S and Curry, E	Designing business capability-aware configurable process models	Information systems
19	Kunchala *et al.* (2017)	2017	Kunchala, J and Yu, J and Yongchareon, S and Han, Y	Towards merging collaborating processes for artifact lifecycle synthesis	*Proceedings of the Australasian computer Science Week Multiconference*
20	Kunchala *et al.* (2019)	2019	Kunchala, J and Yu, J and Yongchareon, S and Liu, C	An approach to merge collaborating processes of an inter-organizational business process for artifact lifecycle synthesis	Computing
21	Rosa *et al.* (2010)	2010	Rosa, L and Dumas, M and Uba, R and Dijkman, R	Merging business process models	*On the Move to Meaningful Internet Systems*
22	Cardoso and Sousa (2020)	2020	Cardoso, D and Sousa, P	Generation of stakeholder-specific BPMN models	*Advances in enterprise engineering XIII*
23	Grossmann *et al.* (2005)	2005	Grossmann, G and Ren, Y and Schrefl, M and Stumptner, M	Behavior-based integration of composite business processes	International conference on business process management
24	Gottschalk *et al.* (2008)	2008	Gottschalk, F and Van Der Aalst, W and Jansen-Vullers, M	Merging event-driven process chains	On the move to Meaningful Internet systems
25	Li *et al.* (2009)	2009	Li, C and Reichert, M and Wombacher, A	Discovering reference models by mining process variants using a heuristic approach	Business process management
26	La Rosa *et al.* (2013)	2013	La Rosa, M and Dumas, M and Uba, R and Dijkman, R	Business process model merging: An approach to business process consolidation	ACM transactions on software engineering and methodology
27	Assy *et al.* (2013)	2013	Assy, N and Chan, N and Gaaloul, W	Assisting business process design with configurable process fragments	*IEEE International Conference on Services Computing*

(*continued*)

Table 3.

#	Reference	Year	Authors	Title	Publication forum
28	Küster *et al.* (2008)	2008	Kuster, J and Gerth, C and Forster, A and Engels, G	Process merging in business-driven development	Proceedings of the Forum at the CAiSE'08
29	Nguyen *et al.* (2017)	2017	Nguyen, T and Hong, T and Le Thanh, N	An ontological approach for organizing a knowledge base to share and reuse business workflow templates	International conference on information Science and technology
30	Schumm *et al.* (2010)	2010	Schumm, D and Leymann, F and Streule, A	Process viewing patterns	IEEE International enterprise distributed object computing conference
31	Weidlich *et al.* (2011)	2011	Weidlich, M and Mendling, J and Weske, M	A foundational approach for managing process variability	International conference on advanced information systems engineering
32	Küster *et al.* (2007)	2007	Kuster, J and Ryndina, K and Gall, H	Generation of business process models for object life cycle compliance	International conference on business process management
33	Sowa and Zachman (2010)	2010	Sowa, J and Zachman, J	Extending and formalizing the framework for information systems architecture	*IBM systems journal*
34	Pereira *et al.* (2011)	2011	Pereira, C and Caetano, A and Sousa, P	Ontology-driven business process design	Conference on e-Business, e-Services and e-Society
35	Weidlich and Mendling (2012)	2012	Weidlich, M and Mendling, J	Perceived consistency between process models	Information systems
36	Schewe *et al.* (2015)	2015	Schewe *et al.*	Horizontal business process model integration	*Transactions on Large-Scale Data- and Knowledge-Centered Systems XVIII*
37	Milani *et al.* (2015)	2015	Milani, F and Dumas, M and Matulevivcius, R and Ahmed, N and Kasela, S	Criteria and heuristics for business process model decomposition: Review and comparative evaluation	*Business and Information Systems Engineering*
38	Pini and Brown (2015)	2015	Pini, A and Brown, R	Process visualization techniques for multi-perspective process comparisons	Asia–Pacific conference on business process management
39	Rosa *et al.* (2009)	2009	Rosa *et al.*	APROMORE: An advanced process model repository	*Expert Systems With Applications*
40	Belchior *et al.* (2020b)	2020	Belchior, R and Vasconcelos, A and Guerreiro, S and Correia, M	A survey on blockchain interoperability: Past	arXiv
41	Nakamoto (2008)	2008	Nakamoto, S	Bitcoin: A peer-to-peer electronic cash system	Available online

Table 3. (*continued*)

#	Reference	Year	Authors	Title	Publication forum
42	Androulaki *et al.* (2018)	2018	Androulaki *et al.*	Hyperledger fabric: A distributed operating system for permissioned blockchains	EuroSys
43	European Parliament and European Council (2019)	2019	European Parliament and European Council	Blockchain and the general data protection regulation can distributed ledgers be squared with European data protection law?	Available online
44	KPMG (2018)	2018	KPMG	Auditing blockchain solutions	Available online
45	Marques Pereira *et al.* (2011)	2011	Marques Pereira, C and Caetano, A and Sousa, P	Using a controlled vocabulary to support business process design	Workshop on enterprise and organizational modeling and Simulation
46	Navathe and Gadgil (1982)	1982	Navathe, S and Gadgil, S	A methodology for view integration in logical database design	International conference on very Llarge databases
47	Pereira *et al.* (2011)	2011	Pereira, C and Caetano, A and Sousa, P	Ontology-driven business process design	Conference on e-Business, e-Services and e-Society
48	Sousa *et al.* (2019)	2019	Sousa, P and Cardoso, D and Colaco, J	Managing multi-view business processes models in the atlas tool	Forum/Posters/CIAO! DC@EEWC 2019
49	Rosa *et al.* (2010)	2010	Rosa, L and Dumas, M and Uba, R and Dijkman, R	Merging business process models	On the move to Meaningful Internet systems
50	Hyperledger Foundation (2020)	2020	Hyperledger foundation	Hyperledger fabric private data	Available online
51	Belchior *et al.* (2020a)	2020	Belchior, R and Vasconcelos, A and Correia, M	Towards secure decentralized and automatic audits with blockchain	European conference on information systems

Table 3.

Blockchain can be a supporting infrastructure of BPs not only accounting for its decentralized execution, but also for a multitude of other use cases (Belchior *et al.*, 2020). With this into mind, one can analyze a blockchain with the six Zachman's dimensions (Sousa *et al.*, 2007; Sowa and Zachman, 2010) as Figure 4 shows. The Zachman Framework is a framework for describing an enterprise architecture, using six dimensions.

By using smart contracts as the core functionality provider of blockchains, Zachman's framework provides us hints to understand how view integration can be applied to blockchain. Each dimension is as follows:

(1) What: corresponds to the data managed by an enterprise. The data correspond to the blockchain state that changes according.

(2) Where: in which blockchain and in which node (and with which configuration) does the transaction take place.

(3) Who: the entities that have active behavior. Correspond to stakeholders submitting a transaction to a smart contract.

(4) How: translates organizational goals into its business. Smart contracts enforce functionality and thus do that translation.

(5) When: expresses how each artifact evolves with the timeline. The timeline corresponds to the lifecycle of a smart contract.

(6) Why: corresponds to the desired goals of a BP. A blockchain provides immutability, transparency and traceability.

Although a particular smart contract follows a specific lifecycle (When), on a specific blockchain (Where), following specific rules (How), the state accessed can differ (What), depending on the stakeholder accessing it (Who). A blockchain – namely, its data (states) and functionality (smart contracts) – can represent enterprises' concerns. Enterprise concerns vary according to its stakeholders – thus, local views and a global view exist. For example, blockchains are widely used in supplychain (Rane and Thakker, 2020) and financial sectors (Khalil *et al.*, 2021), where multiple conflicting stakeholders exist. In these use cases, different views on the global state of blockchains can exist due to the blockchain's nature or data privacy necessity. A supplychain represents the transfer of value among stakeholders, typically from the raw material to the finalized product. Its management is a complex process due to the lack of trust of its participants. Blockchain can be used to lower the required trust on maintaining a shared audit trail of operations. However, parties might only want to share its state with certain participants (for example, a supplier might want to share the cost of an item to a distributed or supplier but not a retailer or wholesaler. Thus, this necessity, which is often addressed by private blockchains, requires the study and management of partial views for the correct operation of on-chain processes. However, not only in private blockchains it is useful to study views.

For instance, in Bitcoin (Nakamoto, 2008), the first public blockchain, the consensus is probabilistic, meaning that temporary views can exist. Concurrently, on private blockchains tailored for enterprises, different views are not only common but desirable. For example, at Hyperledger Fabric, a popular enterprise-grade blockchain, the private data feature allows participants to hide part of the state they hold effectively, only sharing proof of the existence of such data (Androulaki *et al.*, 2018; Hyperledger Foundation, 2020). Enterprise needs lead to the (permanent) existence of different views in the same blockchain.

A practical case for studying view integration on the blockchain is merging different blockchain views into an integrated one (Belchior *et al.*, 2020). This process has several real-world applications: blockchain migration, analytics for audits and complying with legal regulations.

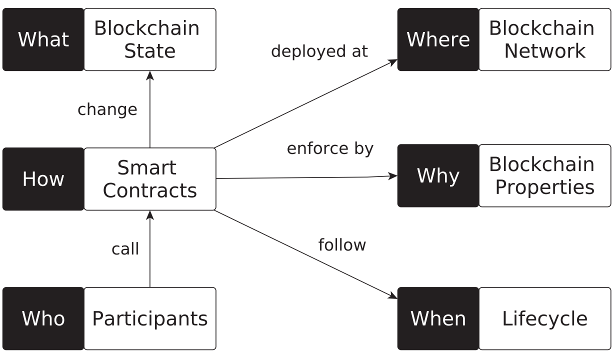

Figure 4.
Representation of a blockchain state

Blockchain migration: given the high variability of existing blockchains, migrations are sometimes necessary (for security issues, performance, new features available on other blockchains or simply better strategic positioning). For example, a consortium deploying an Ethereum-based solution might want to migrate its decentralized application to Hyperledger Besu, an Ethereum-based blockchain that may not charge transaction fees. In fact, Bandara *et al.* identified several projects that needed to migrate (Bandara *et al.*, 2019). Thus, setting up the new infrastructure requires an integrated view of the first blockchain. However, currently migrating among heterogeneous blockchains is a challenge, as different views may exist – implying that the area of view integration might provide a solid basis. Blockchain migration is being studied at the Hyperledger Cactus project, a project dedicated to blockchain interoperability [3] (Montgomery *et al.*, 2020);

Analytics for audits: for auditing processes, the concept of view is immensely important – many times encoded into log analysis (Belchior *et al.*, 2020a; Sutton and Samavi, 2017). The need for auditing a specific participant in a specific moment of time requires the construction and analysis of a static view (snapshot) or dynamic view (collection of snapshots during a certain timeframe). Furthermore, legal frameworks are starting to regulate blockchains (European Parliament and European Council, 2019), putting the focus on audits [4] (KPMG, 2018).

Complying with legal requirements: there is some controversy on the topic of the suitability of blockchains to address the general data protection regulations (Voigt and Bussche, 2018). Restructuring views to comply with the personal data privacy requirements in a permissioned setting (maintaining proofs or links to the original views) could be a solution to this problem (Manevich *et al.*, 2021; Montgomery *et al.*, 2020).

To conclude, as Figure 5 suggests, blockchain is often applied to mediate conflicting stakeholder concerns, while providing one generic, global view or, depending on the blockchain type, multiple views (Belchior *et al.*, 2020). Typically, as no entity fully controls the blockchain, the process of creating a consolidated view is manual and cumbersome. Future research is needed to systematically analyze those views, as well as automatically retrieve the consolidated view.

4.1 Practical implications

Allying two distinct and heterogeneous research areas is needed because blockchain is in its maturing phase, where users and enterprises expect a better integration between their enterprise systems and blockchains. In particular, blockchain views can help not only realize certain blockchain-based use cases (e.g. migration), but also provide a reliable basis for

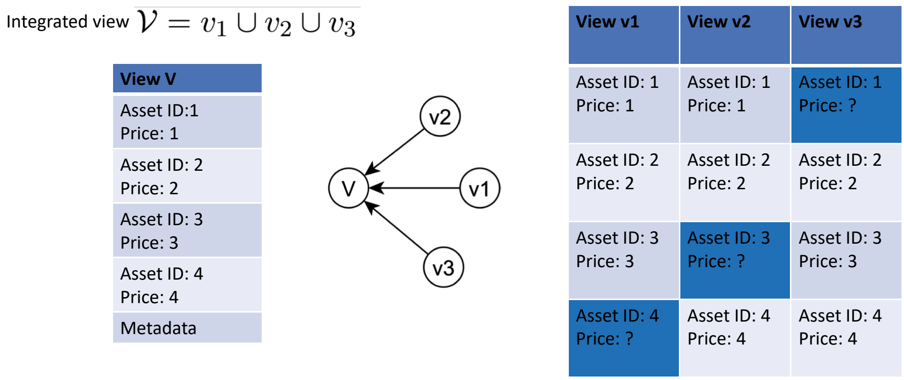

Figure 5.
Blockchain view integration

audits. Private blockchains and blockchain interoperability exacerbate this need, as each stakeholder can have different views built on one or more blockchains. We hope to pave the way for the development of blockchain view generators by software components that can create, manage and merge blockchain views to facilitate BPs.

4.2 Future research directions

BP modeling has undergone a substantial evolution over the last 20 years, being aligned with good practices on sharing, reusing, optimizing and specializing BP models, leading to better performance within organizations where several views on BPs exist. However, there are gaps in this research area as follows:

(1) Empirical comparisons between view integration models and tools, given the challenge of comparing the quality of view integration tools across heterogeneous domains (Antunes *et al.*, 2015; La Rosa *et al.*, 2017);

(2) Lack of models and tools to support the full lifecycle of integrated views (Cardoso and Sousa, 2019, 2020);

(3) Management, interaction, coordination and evolution of viewpoints (Cardoso and Sousa, 2020; Dijkman *et al.*, 2011; Valenca *et al.*, 2013) and

(4) The application of this research area to several new domains, namely where there exist stakeholders with different incentives.

The application of the area of BPVI to blockchain can open up a new field of research that concerns with the privacy of stakeholders operating in a permissioned network. Future work on applying view integration to blockchain includes as follows:

(1) Creating ontologies for representing blockchain-agnostic views;

(2) Developing tools to create, process, integrate, and evaluate blockchain views and

(3) Research applications of blockchain views, such as migration, audits and analytics.

The evolution of the view integration field with regards to applications in blockchain will require an orchestration of different research areas, such as BPM, distributed systems and even human computer interaction.

5. Related work

Valenca *et al.* (2013) analyze the literature around BP variability approaches and build a theoretical foundation around them, indicating the main challenges of the same research area. Similarly, Mechrez and Reinhartz-Berger (2014) investigate BP variability challenges but are more detailed in comparing and describing the solutions.

Torres *et al.* (2013) and Döhring *et al.* (2014) focus on some BP variability approaches and comparing them by leveraging cognitive psychology concepts and empirical evaluation methods, respectively. Torres *et al.* compare behavioral approaches with structural approaches, providing a primer regarding the understability of such approaches. Dohring *et al.* conclude that “we could not show that complexity or the participant’s professional level significantly impacts the task success rate or user contentment.”

Antunes *et al.* (2015) present the process model matching contest 2015, where a common evaluation basis was created to evaluate model matching. Such evaluation takes place by comparing a manual matching by experts and then comparing each technique’s performance in terms of several metrics, such as precision. Additionally, this work presents a literature review on the 12 evaluated model matching techniques up to 2015. Seemingly, process matching got better over the years – meaning that for the techniques that also provide merging of such processes, there are advances on integrating views as well.

On Ayora *et al.* (2015) authors propose the VIVACE framework, an empirical framework that allows assessing the expressiveness of a process modeling language about process variability approaches. The framework focuses on enabling process variability along the entire process lifecycle, contrasting with our study, which focuses on view integration.

La Rosa *et al.* (2017) cover the most relevant literature on BP variability modeling. In this survey, the authors study process variability modeling. Several categories are introduced: node configuration, element annotation, activity specialization and fragment customization approaches based on the criteria as follows: process perspective, process type, customization type, supporting techniques and extra functional. We partially rely on these classification criteria for classifying view integration techniques, as it is validated and well validated by the scientific community. However, we conduct further updates from 2017 until September 2020 and present techniques directly applicable to view integration, a more focused scope than business modeling variability processing.

In short, our survey builds on top of previous work: our classification is based on the theory and practice findings of the area of BPVI and its precedent related disciplines. Our framework thus combines theory and practice by representing the overall process conducting to view integration. We elaborate on the history of BP view integration, providing contextual insights that can guide future developments in the area. Hence, our work serves to pave the way for future trends, where we highlight the application of view integration to blockchain research.

6. Conclusion

In this survey, we have put into evidence the heterogeneity of solutions addressing (BP) view integration. For that, we conducted a systematic literature review, focusing not only on BP view integration but also its predecessor, database view integration.

We introduce the historical area of database view integration that supports BP integration by analyzing its most influential literature. After that, we elaborate on three RQs from the analysis of 71 papers out of the original 918 documents: what is the origin of BP view integration, what are its current solutions and what are its future trends. We found out that this area is maturing quickly, given the existence of robust tools, and that most view integration solutions use annotations and formal matching rules to create integrated views as shown by Table 2. Moreover, some solutions offer behavioral and structural guarantees, providing a formalization of the view integration algorithms. However, empirical comparisons between view integration models and tools are still missing and applications to other research areas can be done.

Our survey paves the way for opening the discussion of applying view integration to decentralized ledger technologies, contributing to the advance of legal frameworks, operations and management. In particular, the concept of blockchain view and its management have practical applications for both the academia and the industry.

Notes

1. https://apromore.org/
2. http://www.linkconsulting.com/atlas
3. https://github.com/hyperledger/cactus
4. https://www.coindesk.com/quadriga-kroll-analytics

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