Managing Multi-Jurisdictional Requirements in the Cloud: Towards a Computational Legal Landscape

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ABSTRACT

Although cloud services allow organizations to transfer the planning and setup to the service provider and thus reduce costs through reuse, these services raise new questions regarding the privacy and security of personal information stored in and transferred across systems in the cloud. Prior to cloud services, personal information was commonly stored within the owning or licensing company's locality where the company maintained its facilities. Cloud services, however, move data to remote, potentially unknown, locations maintained by third parties. The responsibility for data protection and integrity no longer remains exclusively with its owner or licensee, but with these third parties. Thus, both parties must identify and manage the many regulatory requirements that govern their services and products in this multi-jurisdictional environment. To simplify this problem, we are developing methods to extract and codify regulatory requirements from government laws. We apply previously validated metrics to measure gaps and overlaps between the codified regulations. Our findings include a semi-formalization of the legal landscape using operational constructs for high- and low-watermark practices, which correspond to high- and low standards of care, respectively. Business analysts and system developers can use these watermarks to reason about compliance trade-offs based on perceived businesses costs and risks. We discovered and validated these constructs using seven U.S. state data breach notification laws that govern transactions of financial and health information of residents of these seven states.

Categories and Subject Descriptors

D.2.1. [Requirements/Specifications] Languages; D.2.8 [Metrics] Complexity Measures; K.5.2 [Government Issues] Regulation

General Terms

Standardization, Languages, Legal Aspects

1. INTRODUCTION

Cloud computing provides a number of benefits to organizations looking to grow their information technology (IT) infrastructure. Previously, these organizations invested in their own IT systems, which involved purchasing, installing, and maintaining the hardware and software over the lifetime of the systems. These investments are expensive, time-intensive, and risky, and require significant experience that organizations may not have readily available. Today, these same organizations can provision their services using a cloud service provider (CSP) on an as-needed basis, often reducing both the time and costs to achieve the desired end result. Though the power of the cloud may be harnessed for nearly any purpose or application, one of the more controversial purposes is the storage and manipulation of customer records and other data that contains personal information [2].

Within the United States, storage and protection of personal information is a complex multi-jurisdictional problem due to a mix of state and federal laws that govern data privacy. This includes jurisdictions associated with different geographical boundaries (states vs. nation) as well as activities governed by different federal agencies (healthcare vs. finance). Though many such laws have been proposed, current state regulations specify what information types are considered personal information, in addition to what measures must be taken to protect the information. Requirements imposed by regulations vary widely across states. For example, Wisconsin's Notice of Unauthorized Access to Personal Information (§134.98) defines personal information to include biometric data, such as a fingerprint or DNA profile, whereas Arkansas's Personal Information Protection Act (§4.110) does not specifically include biometric data. The Arkansas law only governs organizations that possess data on residents of Arkansas; whereas, Wisconsin's law also governs organizations that operate within its boundaries, whether or not they possess information on Wisconsin residents. Organizations who maintain data on individuals from multiple states must be aware of these regulations and design their systems and business practices, accordingly. This matter is further complicated when organizations conduct many of their operations in the cloud, which not only involve a third-party (the CSP), but further abstract and potentially conceal the physical location of the data itself. Many states offer clarification in their regulations on the responsibilities allocated to the owners of the data versus those who own or operate the systems on which it is retained, using conditional phrases such as "licenses personal information" vs. "stores personal information". These statements are often further compounded with other conditions, such as the presence of a contract with the data owner. In practice, some CSPs allow users to specify the region for storing data [1]. This could be of particular relevance for European users of the cloud, who are wary of the U.S. law enforcement access granted to EU citizen's data by the USA PATRIOT Act [2].

The challenge for cloud-utilizing organizations and CSPs, is to distill regulations into actionable requirements that are traceable across their business practices and that serve to easily distinguish who is responsible for which actions. We believe that existing approaches to governance, which consist of independently

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published, paper-based laws and policies, can no longer scale with the rate of technology innovation. If an honest expectation of compliance is to be preserved in this rapidly changing environment, regulations must be made accessible to policy makers, business analysts and software developers, alike. To this end, we report our efforts to formalize a portion of the legal landscape using a requirements specification language (RSL) [6] and apply previously validated metrics [4] to compare regulatory requirements using a gap analysis. Using the RSL and gap analysis results, we propose operational constructs for high- and low-watermarks to identify and resolve potential conflicts across multi-jurisdictional requirements and provide system developers with guidance on how to operationalize regulations. By making potential conflicts salient, system developers can consider the trade-offs based on business costs and risks through guided discussions with their legal advisers.

The remainder of the paper is organized as follows: in Section 2, we discuss related work; in Section 3, we introduce the RSL by example; in Section 4, we review our metrics for comparing requirements; in Section 5, we present our empirical case study design; in Section 6, we discuss our research findings, including prominent examples of watermark-motivated trade-offs; in Section 7, we discuss threats to validity; and in Section 8, we conclude with discussion and future work.

2. RELATED WORK

Requirements engineering occurs in the early stages of modern software engineering, wherein terminology is to be grounded "in the reality of the environment for which a machine is to be built" [22]. As such, significant effort is invested into managing and analyzing natural language requirements and discovering new ways to formalize this informal domain. We now discuss related work in requirements engineering, artificial intelligence, and law.

Requirements specification languages (RSLs) and requirements modeling languages (RMLs) have a rich history in requirements and software engineering [24]. RSLs and RMLs include informal, natural language descriptions to provide readers with context and elaboration, and formal descriptions, such as mathematical logic, to test assumptions across requirements using logical implications [15]. Goal-oriented RMLs, such as i* [34] and KAOS [11], and object-oriented notations, such as ADORA [19], include graphical notations to view relationships between entities, such as actors, actions and objects. Because of computational intractability and undecidability of using highly expressive logics [17], RMLs often formalize only a select class of requirements phenomena, e.g., using various temporal logics, including interval [29], real-time [11] or linear [16] temporal logic, or description logic [5]. Consequently, RSLs and RMLs may struggle with the balance between expressability and readability [15].

Unlike i*, KAOS, and ADORA, the RSL presented herein is designed for the policy domain by integrating formal expressions of document structure with semi-formal expressions of rights, permissions and obligations, which are required to express regulatory requirements [7]. The RSL emphasizes readability by requiring limited formalization of: actor roles, constraints on those roles, and Boolean logic to express pre-conditions; definitions and their scope; and cross-references as typed relations between requirements. Finally, the RSL codifies the document structure (sections, paragraphs, and references) to ensure certain legal effects from cross-references are traceable and operational, which has been identified as a shortfall in current practice [23, 28, 32].

Studies to formalize laws have long been a topic of interest. Early work in the 1980's to encode laws in first-order logic began with a focus on decision support tools [3, 30], whereas a recent resurgence in formalization of privacy and security regulations have sought to test new theories as expressions of law [13, 27, 25]. In software requirements engineering, the emphasis is on requirements specification and analysis to develop tools for managing legal requirements. This work has emphasized methodology for encoding laws as rights, permissions, obligations [7], ownership and delegation [17] and techniques for formalizing the legal effects of cross-references, definitions, and exceptions in a comprehensive legal requirements management strategy [8]. Recent analysis of external cross-references emanating from the Health Information Portability and Accountability Act (HIPAA) shows the potential for conflicts between laws governing different industries [26].

Research to compare natural language has long focused on document-level comparisons. K-means cluster [20] and latent semantic indexing [12] have been applied to compare documents by examining term frequencies after cleaning the text by removing term suffixes, called stemming [31], punctuation, etc. Similar techniques have been applied to requirements analysis to create traceability links between regulatory requirements and product requirements [10]. In a recent gap analysis between regulatory and product requirements, we discovered that significant domain knowledge is required to recognize semantic differences between requirements, i.e., subsumption, polysemy or synonymy [4]. While tools such as WordNet [14] are used in NLP to supplement domain knowledge for many problems, our research indicates that comparing requirements remains largely a manual process.

3. THE REQUIREMENTS SPECIFICATION LANGUAGE

In preparation to compare regulatory requirements across jurisdictions, we translate the original regulations into a canonical form using a requirements specification language (RSL). The RSL makes several assumptions about the domain of requirements. These assumptions were first observed in our study of regulations and thus they were incorporated into the RSL syntax and semantics described here. In the discussion that follows, we use the following excerpt from Arkansas Title 4, §110.105 to present the RSL:

4-110-105. Disclosure of security breaches.

(a)(1) Any person or business that acquires, owns, or licenses computerized data that includes personal information shall disclose any breach of the security of the system… to any resident of Arkansas…

(2) The disclosure shall be made in the most expedient time and manner possible and without unreasonable delay, consistent with the legitimate needs of law enforcement as provided in subsection (c) of this section

Figure 1. Excerpt from the Arkansas (AR) Title 4, §110.105 of the Personal Information Protection Act

3.1. Document Model

Human translators apply the RSL directly to original text, converting statements and phrases from the text into expressions in the RSL. Figure 2 shows the excerpt from Figure 1 expressed in the RSL: reserved keywords, special operators, and line numbers (found along the left side) appear in bold. The `DOCUMENT` keyword (see line 1) is used to assign a unique index to the specification. The `SCHEMA` keyword (see line 2) is followed by an expression consisting of *components* in curly brackets. Each component corresponds to a different reference level within the document model, beginning with the outermost component, in this case the title and chapter. References within the specification will be parsed using this schema. Line comments are indicated by the "`//`" operator. We use the ellipsis "…" to indicate omissions from the specification to simplify presentation in this paper.

```
1    DOCUMENT US-AR-4-110
2    SCHEMA{title:4}-{chapter:110}-{section:\d+}{par:
     \([a-z]\)}{par:\(\d+\)} //...
3    TITLE 4-110 Personal Information Protection Act
4
5    SECTION 4-110-105 Disclosure of security breaches
6    PAR (a)
7    PAR (1)
8    person!
9      |business!
10     & acquires, owns, or licenses computerized data
         that includes personal information
11     : shall disclose a breach of the security of the
         system to any resident
12   PAR (2)
13   disclosure!
14     : shall be made in the most expedient time and
         manner possible and without unreasonable delay
15     ANNOTATE timing requirements
16     REFINES (1)
17     EXCEPT (c)(1) #1
```

Figure 2. Excerpt from Arkansas 4-110-105 expressed in the RSL

The document model consists of sections and nested paragraphs, expressed in the RSL by the `SECTION` and `PAR` keywords, respectively. These keywords are followed by a reference and an optional title. For example, line 5 shows the section reference 4-110-105 followed by the section title from §105 in the excerpt in Figure 1; sub-paragraphs (a) and (1) follow on lines 6-7. The parser validates the references against the previously declared document schema and constructs an internal document model that is used with cross-references to lookup definitions and requirements.

3.2. Roles, Constraints and Requirements

Requirements consist of roles and constraints on a role, organized into first-order logical expression using operators "|" for logical-or (see line 9), and "&" for logical-and (see line 10). Associativity in logical expressions is inferred from the number of tabs before the logical operator: one less tab than the previous line is right associative; otherwise the logic is left associative. Roles are noun phrases that describe the actors or objects to whom the requirements apply and are followed by "!" (see lines 8-9); constraints on a role are phrases that begin with a verb (see line 10). For a role *R* and constraint *C*, we always assume the sentence "*R* who *C*" is valid and grammatically correct for the purpose of generating natural language from this formalization. Roles and constraints are part of the *pre-conditions* in a requirement. Next follows the requirement *clause*, preceded by a ":" and modal verb, such as "shall" to indicate an obligation (see lines 11 and 14). We identify these modal verbs using established phrase heuristics [7]. Finally, the analyst can write commands in the RSL to instruct the parser to perform special operations on rules. In Figure 2, the command keyword `ANNOTATE` (see line 15) indicates that the following text contains comma-separated annotations that should be linked to the requirement. Annotations can be used to group requirements by shared themes.

3.3. Relations and Cross-References

Requirements are related to each other through relations and cross-references. The RSL includes several commands by default for expressing relations and can accommodate more as needed. The default commands are:

- `REFINES`, with the inverse `REFINED-BY`, indicates that this requirement is a sub-process or quality attribute that describes how another requirement is fulfilled.
- `EXCEPT`, with the inverse `EXCEPT-TO`, indicates that this requirement has an exception (another requirement). If the pre-conditions of the exception are satisfied, then this requirement does not apply (it becomes an exclusion, e.g., *is not required*).
- `FOLLOWS`, with the inverse `PRECEDES`, indicates that this requirement is a *post-condition* to another requirement, e.g., this requirementis permitted, required, or prohibited after the other requirement is fulfilled.

In Figure 2, the command keyword `REFINES` (see line 16) indicates that this requirement refines the requirements in paragraph (1). This example is a quality attribute, because the refinement on line 13 elaborates the act on line 11 (to disclose), elaborating when the act must occur (expediently, without delay). Generally, quality attributes describe the act or an object in the act of another requirement. The command keyword `EXCEPT` (see line 17) indicates this requirement has one exception in paragraph (c)(1): the first requirement.

Relative references in these commands are expanded by the parser: in Figure 2, starting from the source paragraph (2), the parser ascends the document model checking the document schema for a *descending match* rooted at the current paragraph. Thus, the first check is for a matching sibling paragraph: in this case, the index (a)(1) is a match. References may be either: an index to a singular paragraph; a paragraph range separated by the"--" operator; the ".." operator, which matches the parent paragraph; or the "." operator, which matches the current paragraph. References followed by a "*" operator refer to the paragraph and all sub-paragraphs (i.e., transitive closure). Rule selection is done in three ways: a) by default, references select all rules within the referenced paragraph(s); b) singular paragraph references followed by the ordinality operator "#"and a number *n* will identify the n^{th} rule in that paragraph (see line 17); and c) references followed by a comma-separated list of annotations will find rules that share those annotations (e.g., all "permissions" or all "timing requirements").

3.4. Definitions and Exemptions

Definitions describe the actors and objects in the environment of the system. They can be used to organize roles and constraints into a single term-of-art, which allows document authors to substitute the term for repeated logic across requirements. For requirements with complex pre-conditions, we found this simplification to make reading the specification much easier. Because regulations govern multiple industries and systems, it is also important to coordinate and reuse definitions across separate regulations. Consider the following RSL specification in Figure 3, acquired from Nevada Chapter 603A, Security of Personal Information, §215(5), which describes definitions related to security measures for businesses who collect payment cards.

```
1   PAR 5.
2   INCLUDE 603A.215.5* 603A.215*
3   PAR (a)
4   data storage device
5     = device
6     & stores information or data from any electronicor
        optical medium
7     < computers
8       | cellular telephones
9   // ...
10  PAR (c)
11  facsimile
12    = electronic transmission between two dedicated
        fax machines using Group 3 or Group 4 digital
        formats...
13    ~ onward transmission to a third device after
        protocol conversion, including, but not limited
        to, any data storage device
14  PAR (d)
15  INCLUDE EXTERNAL NV-205.602 603A.215* "payment card"
```

Figure 3. Excerpt from Nevada §603A.215(5)(c)

In Figure 3, paragraph (a) on lines 3-9 contains a definition for *data storage device*, indicated by the "=" operator. Definitions are expressed similar to pre-conditions and can use the logical operators for logical-and and logical-or, in addition to the operator "<", which means "includes" and precedes examples or sub-classes (see line 7), and the operator "~", which means "excludes" (see line 13). The parser assumes definitions apply to the paragraph in which they occur, unless instructed using the `INCLUDE` keyword, followed by two references: the source location of the definitions, and the target section or paragraph to which the definitions will apply. The instruction in Figure 3, line 2 tells the parser to apply all the definitions from paragraph (5) and all sub-paragraphs (indicated by the "*") to §215. In contrast, the `INCLUDE EXTERNAL` instruction on line 15 instructs the parser to lookup the definition "payment card" by finding a regulatory document indexed by NV-205.602, and to apply this definition to §215. This second usage enables reuse of definitions from and across multiple regulations.

The RSL parser cross-links definitions to requirements by matching terms-of-art in definitions with phrases in requirements pre-conditions and clauses. Recall from Figure 3 the definitions for terms *data storage device* (line 4) and *facsimile* (line 11) and the imported term payment card (line 15) from another law, NV §205.602. The instructions `INCLUDE` (lines 2 and 15) orchestrate these definitions by applying them to all sub-paragraphs in §603A.215, which in turn instructs the parser to link each term to each matching phrase in the pre-conditions and clauses for all requirements contained therein. This includes other definitions, such as the phrase on line 13 that excludes "data storage device" from the onward transmission of a facsimile. Figure 4 illustrates the implication these definitions have on requirements in paragraphs §603A.215(1) and (2): the underlined phrases correspond to those phrases that match the terms-of-art from Figure 3 as determined by the parser.

Both *when to apply* a prescription and *the extent of* the prescription can be computationally adjusted by relaxing or tightening definitions using the includes "<" and excludes "~" operators, respectively. For example, if we redefine *payment card* to exclude *gift card*, then the scope of when to apply the requirement to comply with the PCI DSS standard (on line 6) would be further restricted to omit the case of gift cards. Alternatively, if *data storage device* were redefined to include *USB drives*, then the extent of the prohibition on moving such devices (on line 16) would be extended to include this interpretation. The ability to shape *when to apply* and *the extent of* prescriptions using the RSL can enable regulators and businesses to evolve the conditionality of regulations as new technologies emerge over time.

```
1   SECTION 603A.215
2   PAR 1.
3   data collector!
4     & doing business in this State
5     & accepts a payment card in connection with a sale
        of goods or services
6     : shall comply with the current version of the
        Payment Card Industry (PCI) Data Security
        Standard...
7   PAR 2.
8   data collector!
9     & doing business in this State
10    EXCEPT 1.
11  PAR (a)
12    & does not use encryption to ensure the security
        of electronic transmission
13    : shall not transfer any personal information
        through an electronic, non-voice transmission
        other than a facsimile to a person outside of
        the secure system of the data collector
14  PAR (b)
15    & does not use encryption to ensure the security
        of the information
16    : shall not move any data storage device
        containing personal information beyond the
        logical or physical controls of the data
        collector or its data storage contractor
```

Figure 4. Excerpt from Nevada §603A.215(1) and (2)

Whereas definitions shape terms used in pre-conditions and clauses of requirements, exemptions fine-tune what is excluded from pre-conditions and clauses. Figure 5 shows a description of the role "telecommunications provider" (in the RSL) with a role constraint on line 4. The `EXEMPT` keyword instructs the parser to exclude this role and constraint from all rules in §215 and all sub-paragraphs therein. While such an exemption could be stated in a definition using the excludes operator "~", exemptions provide a mechanism to tighten meanings across a document cross-section, unbounded by a single term-of-art or definition.

```
1   PAR 4.
2   PAR (a)
3   telecommunications provider!
4     & acting solely in the role of conveying the
        communications of other persons, regardless of
        the mode of conveyance used, including, without
        limitation (1) optical, wire line and wireless
        facilities; (2) analog transmission; and (3)
        digital subscriber line transmission, voice over
        Internet protocol and other digital transmission
        technology
5     EXEMPT 603A.215 *
```

Figure 5. Excerpt from Nevada §603A.215(4)(a)

Figure 6 illustrates a high-level architecture for how constraints, expressed as definitions and exemptions, are traced by the parser to requirements. The arrows route constraints through parser instructions as follows: the `INCLUDE EXTERNAL` instruction imports (in purple) the *payment card* definition from another regulation, NV 205.602, into NV 603A.215(5)(d). The `INCLUDE` instruction maps (in blue) the definitions from 603A.215(5), including any imported definitions, onto 603A.215; this mapping includes the inner link from *data storage device* to *facsimile*, and the outer links to requirements in 603A.215(1) and (2). Finally, the exemption from 603A.215(4)(a) is mapped (in red) onto the requirements 603A.215 to specifically exclude interpretations that may be implied by the definitions.

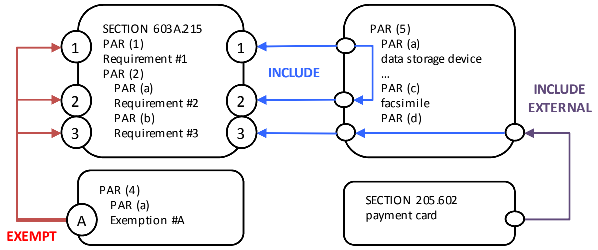


Figure 6. Summarizing the Effects of Conditionality

3.5. Tool Support and Generated Artifacts

The RSL is complemented by an automated parsing tool, which checks the translated documents for syntax errors, such as malformed or unassociated logical expressions, and semantic errors, such as incorrect references, empty relations that refer to no rules, unreferenced definitions, and cycles among relations of the same type, e.g., `REFINES`, `EXCEPT`, `FOLLOWS`. The parser also handles pre- and post-clause continuations [7], wherein one or more roles and constraints apply to rules in sub- or parent paragraphs, respectively. Lastly, the parser annotates the requirements using phrase heuristics that indicate the modality of the clause [7], for example, "may" indicates a "permissions" annotation, or "shall" indicates an "obligations" annotation. Annotations are used to sort and reference requirements.

The parser constructs a model from the RSL, which is exported to other formats, such as the eXtensible Markup Language[1] (XML), HyperText Markup Language[2] (HTML) and the Graph Markup Language[3] (GraphML). Each format offers a different perspective: the HTML allows users to browse the specification by clicking hyperlinks, viewing definitions and referenced rules *in context* of a single rule; the GraphML allows users to visualize relationships across multiple requirements; and the XML enables data interoperability and exchange with other tools. Figure 7 shows a graph generated from the RSL example in Figure 1: text labels include a unique requirement identifier (e.g., AR-7), followed by the roles in parentheses and the requirement clause (abbreviated in this figure). Nodes are colored by whether they are permissions (green), obligations (yellow), prohibitions (red) and exclusions (blue) based on annotations. Directed edges represent relations and point to referenced rules as follows: solid edges are `REFINES`, dashed edges are `EXCEPT`, and dotted edges are `FOLLOWS` relations.

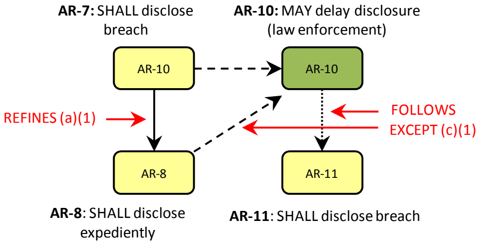

AR-7: SHALL disclose breach
AR-10: MAY delay disclosure (law enforcement)
AR-10
AR-10
REFINES (a)(1)
FOLLOWS
EXCEPT (c)(1)
AR-8
AR-11
AR-8: SHALL disclose expediently
AR-11: SHALL disclose breach

Figure 7. Excerpt from Arkansas §110.105 expressed in GraphML

We foresee importing our models into other requirements tools that support open exchange formats, such as Requirements Interchange Format[4] (RIF) and User Requirements Notation (URN).

4. METRICS FOR PERFORMING THE GAP ANALYSIS

Regulations from multiple jurisdictions contain potential conflicts due to differences in the administrative hierarchy (federal, state and local jurisdictions) and requirements coverage (*who* is required to do *what*, *when*). To measure coverage gaps in natural language requirements, Breaux et al. developed a set of statement and phrase-level metrics that an analyst can apply to rationalize and document similarities and differences [4]. Unlike software quality metrics that yield numerical measurements [21], our metrics yield nominal measurements in the form of logical assertions. These metrics were validated in an empirical case study, wherein investigators performed a gap analysis between CISCO product requirements and the U.S. Access Standards (Section 508) that govern access to information by individuals with disabilities. For comparing two requirements A and B, the metrics used in this paper are:

Metric S-E (Equivalent): Requirements A and B are equivalent, with some portions of the requirements describing the same or a similar action.

Metric P-G1 (Generalized Concept): The "phrase in B" describes a more general concept than the "phrase in A."

Metric P-G2 (Missing Constraint): The "phrase in A" is missing from Requirement B.

Metric P-R1 (Refined Concept): The "phrase in B" describes a more refined concept than the "phrase in A."

Metric P-R2 (New Constraint): The "phrase in B" is missing from Requirement A.

Metric P-M (Modality Change): The "phrase in A" has a different modality than the "phrase in B."

The process for applying these metrics to statements encoded in the RSL proceeds by: (1) identifying near-equivalent statement pairs A, B and recording a logical assertion S-E(A, B); and (2), comparing phrases between statements A, B and recording logical assertions P-G1(A, B, p_A, p_B) or P-G2(A, B, p_A) for some phrase p_A in statement A and some phrase p_B in statement B. The metrics P-G1 and P-R1 are symmetric, as are the metrics P-G2 and P-R2, based on which document the analyst begins with. The metric P-M yields an assertion P-M(A, B, p_A, p_B), wherein the phrases correspond to modal phrases, such as *may*, *must*, and *shall not*, and determine whether the requirement is a right, obligation, or prohibition [7]. For example, consider the definitions for person and business from the regulations MA and MD, respectively, shown in Figure 8 and expressed in the RSL.

MA Definition of Person:

```
person
  = a natural person
    | corporation
    | association
    | partnership
    | legal entity
```

MD Definition of Business:

```
business
  = sole proprietorship
    | corporation
    | association
    | partnership
    | business entity
    & whether or not
      organized to operate
      at a profit
```

Figure 8. Related stakeholder definitions in MA and MD

[1] http://www.w3.org/XML/

[2] http://www.w3.org/html/

[3] http://graphml.graphdrawing.org/

[4] http://www.omg.org/spec/ReqIF/

The analyst would compare these definitions by assigning statement-level and phrase-level metrics to yield the measures in Table 1. For definitions, the S-E measure presumes the analyst believes the terms at hands are at least partially synonymous, with the remaining measures used to itemize differences.

Table 1. Measures comparing definitions from MA §93H(1)(a) and MD §14-3501(b)(1)

Stmt. A	Stmt. B	Metric	Measure
MA-D-1	MD-D-7	S-E	
MA-D-1	MD-D-7	P-G2	a natural person
MA-D-1	MD-D-7	P-G1	legal entity *generalizes* business entity and whether or not organized to operate at a profit
MA-D-1	MD-D-7	P-R2	sole proprietorship

To compare requirements, the metrics are applied by separately comparing the requirement clauses and the pre-conditions between two requirements. Consider the requirements MA-20 and MD-10, from MA §93H(3)(a) and MD §14-3504(c)(1), respectively, which describe an obligation to send a security breach notification. This example includes the obligated actor in parenthesis.

MA-20: (Person or Business) shall provide notice, as soon as practicable and without unreasonable delay, to the owner or licensor

MD-10: (Business) shall notify the owner or licensee of the personal information of a breach of the security…

Table 2 presents select measures acquired by applying the metrics to requirements MA-20 and MD-10. Notably, the P-G2 and P-R2 metrics capture an important difference: under MA §93H(3)(a), the business must notify licensor (upstream data providers), whereas under MD §14-3504(c)(1), the business must notify licensee (downstream data providers). This difference means that organizations that must comply with both regulations must notify data providers both up and downstream. Recall from Figure 6 in Section 3.4 that definitions transfer constraints to multiple requirements. In the case of MA-20 and MD-10, the definitions for person and business, shown in Figure 8, also apply to these two requirements, respectively. In addition, the measures acquired from comparing these definitions (see Table 1) apply to our gap analysis when comparing the difference in coverage for MA-20 and MD-10 (elaborating *who* must comply).

Table 2. Measures comparing requirements from MA §93H(3)(a) and MD §14-3504(c)(1).

Stmt. A	Stmt. B	Metric	Measure
MA-20	MD-10	S-E	
MA-20	MD-10	P-G2	licensor
MA-20	MD-10	P-R2	as soon as practicable and without unreasonable delay
MA-20	MD-10	P-R2	licensee

5. RESEARCH METHODOLOGY

We now describe our case study research method [33] used to compare multi-jurisdictional requirements from repeated observations of natural language expressions in regulatory documents. The method includes our selection criteria, the translation process, units of analysis, and analysis procedure.

This paper only presents preliminary results towards our goal to observe variation in regulations across multiple jurisdictions with the aim of understanding how regulations introduce complexity into system requirements. To observe this variation, we selected a single theme (data breach notification) to limit the effects of dissimilarity while we build new theory to reconcile differences and potential conflicts. In the United States, this theme represents the recent enactment of 46 state and territorial laws from 2002-2009, each governing personal information about state residents. For distributed and pervasive systems, variations in these laws require businesses to reconcile different practices for customers of different states. The laws we selected in this study are as follows:

- **AR**: *Personal Information Protection Act*, Arkansas Chapter 4.110, enacted 2005.
- **CT**: *Breach of Security Regarding Computerized Data Containing Personal Information*, Connecticut General Statute §36a-701b, enacted 2006.
- **MA**: *Security Breaches*, Massachusetts Chapter 93H, enacted 2007.
- **MD**: *Personal Information Protection Act*, Maryland Subtitle 14-35, enacted 2008.
- **NV**: *Security of Personal Information*, Nevada Chapter 603A, enacted 2006.
- **UT**: *Protection of Personal Information Act*, Chapter 44, enacted 2006.
- **WI**: *Notice of Unauthorized Access to Personal Information*, Wisconsin Chapter 134.98, enacted 2006.

We down-selected from 46 laws to 7 laws using two criteria: first, we invited suggestions from a legal expert with seven years of privacy and security law expertise to highlight industrial challenges, resulting in AR, MA, MD, NV, and lastly, we included the State of Wisconsin, because it uniquely covers biometric information, including fingerprints, voice prints, retinal images and unique physical characteristics. We include CT and UT to illustrate important contrasts with MD and NV, respectively.

Our translation process was conducted by two investigators (the authors) separately translating each statement within each law using the RSL. The process includes a general classification of each statement, as a definition, requirement, or exemption, and writing an expression in the language to characterize the statement. Definitions were identified by common phrases, such as "*x* means *y*", where a term *x* has the logical definition *y*. Requirements were identified using the phrase heuristics identified by Breaux et al. [7], which were extended during this study. Comments were used in the translation to capture questions, issues and other discrepancies. We maintained a *caveats list* of translation strategies that reflect unusual cases and how the parser should treat such cases, and a *proposed changes list* of requirements with examples for new language constructs. As a new construct was introduced, we reviewed each law to update the translation to reflect the new construct to ensure consistency across the entire dataset.

The units of analysis correspond to the translated requirements, definitions, exemptions, and relations between requirements, in addition to the measures produced by the gap analysis. The RSL acts as a natural filter, capturing only what it can express, which is a threat to validity discussed in Section 7. After the translation, we analyze the units of analysis to identify propositions that link the units to our findings through pattern-based inferences [9]. These patterns consist of constant features (the types of relations and metrics) and the manner by which these constant features structure variable features in the observable phenomena (the different requirements in the relations and the phrase-level measures). We explain the different patterns in our research findings in Section 6.

In the analysis procedure, we first compare similar definitions, which either have the same term (two definitions for "breach of security") or share similar constraints (two definitions, one for "person" and the other for "business" both include "corporation" as a kind or sub-type). We applied the phrase-level metrics to the definitions to identify the dissimilar sub-types and constraints on those types. Second, we compared the requirements by applying the metrics from Section 3 to the requirements clauses and pre-conditions. We analyzed the measures as follows: for two requirements clauses measured using the S-E metric, we applied the phrase-level metrics to distinguish the differences in terms of *who* is permitted, required or prohibited to do *what*. Next, we consider the dissimilarity between these two requirements in terms of the relations (e.g., does one requirement have an exception not observed in the other, different refinements, or pre- or post-conditions). We call these two types of comparisons intra- and inter-dissimilarity, respectively. We now discuss our research findings, including the patterns observed through our analysis.

6. RESEARCH FINDINGS

The translation of the seven laws by two investigators (the authors) required an average of 2.72 minutes per statement with the first document requiring an average of 2.75 hours or 4.23 minutes per statement, which includes the time to discover the RSL; the longest document consisting of 49 statements required an average of 1.5 hours. Each investigator spent an average total of 12.5 hours to encode the seven laws. Figures 9 and 10 present summary statistics for the units of analysis encoded in the RSL. Recall these laws cover the same theme (data breach notification). We observed the number of definitions did not vary greatly and the number of exemptions was a matter of writing style; neither the numbers of definitions nor exemptions are proportional to requirements.

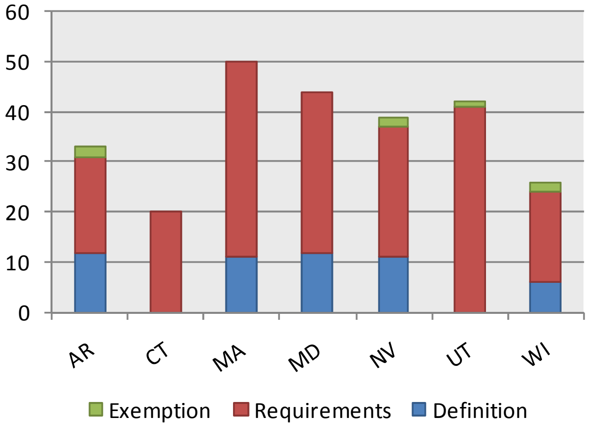


Figure 9. Summary Units of Analysis– Statements

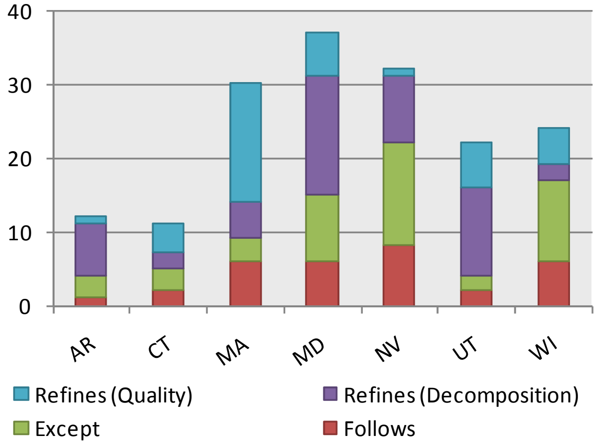


Figure 10. Summary Units of Analysis – References

The references reported in Figure 10 originate from multiple sources, including: *anaphora*, which is indicated by determiners (such) and pronouns (this); *case-splitting*, which is indicated by English conjunctions (and, or) separating verb clauses that are headed by a modal phrase (must, may, shall); and direct references to sections and paragraph that may be anaphoric (*this* section, *this* paragraph) or indexed by paragraph number, such as "paragraph (a)." Because operationalized paragraph references in the RSL are more precise, we determined that the RSL reduces ambiguity by eliminating false-positives for these seven laws from the set of referenced requirements in another paragraph or section introduced by cross-references.

Our analysis of statements, relations and measures acquired from the gap analysis yielded several observations. These observations include patterns of dissimilarity, heuristics for reconciling differences and for discovering a legal landscape, and variations in document writing styles that affected our method.

6.1. Patterns of Dissimilarity

When an organization is subject to multiple regulations governing similar business practices, it is likely that the requirements will overlap to some extent by sharing the same subject, action and/or object. Near identical requirements, identified by the S-E metric, without any observed phrase measures to account for any differences, pose no particular issue: complying with one requirement is compatible with complying with the other. However, when the overlap is partial, then the differences between each requirement must be reconciled in order to achieve compliance with both regulations. We now outline various differences between requirements and demonstrate by example how an analyst can reconcile these differences. These differences are defined as follows:

Intra-dissimilarity: differences *within* two requirements from two different documents, as determined by comparing the requirement statements using phrase-level metrics

Inter-dissimilarity: differences *among* two requirements, as determined by comparing dissimilar REFINES, EXCEPT, and PRECEDES relations to other requirements

An organization must address and reconcile these types of differences before integrating multi-jurisdictional requirements into their systems, policies, and procedures. Normally, this integration is a difficult procedure due to the lack of traceability. However, the RSL and gap analysis offer an improved method for traceability by enabling an analyst to identify, display, and address these differences, incrementally, as evidenced by the following examples of intra-dissimilarity. Consider Figure 11, which shows requirements UT-7 from Utah §44-201(1)(b) and NV-9 from Nevada §603A.220(1) expressed in the RSL.

UT-7
```
person!
  & +investigation… reveals the misuse of personal
    information
  : shall provide notification to each affected Utah
    resident
```

NV-9
```
data collector!
  : shall disclose the breach to the resident…
```

Figure 11. Utah and Nevada disclosure details (RSL)

UT-7 and NV-9 both obligate the entity to notify the individual of a data breach, but their pre-conditions differ significantly: UT-7 requires that the entity conduct an investigation into the breach, whereas NV-9 requires no investigation. If it is unlikely that this investigation would interfere with the notification proposed by Nevada, an entity could achieve compliance with both regulations by conducting the investigation as a precondition to both obligations.

Alternatively, regulatory requirements may contain thresholds to limit the scope of an obligation. These thresholds can and do vary across jurisdictions, as seen in Figure 12 below. Consider CT-13 from Connecticut §36a-701b(e)(4) and MD-18 from Maryland §14-3504(e):

CT-13
```
person!
  : may provide substitute notice
    & demonstrates that the cost of providing notice...
      would exceed $250,000
      | demonstrates that the affected class of
        individuals to be notified exceeds 500,000
```

MD-18
```
business!
  : may give notification by substitute notice
  & demonstrates that the cost of providing notice would
    exceed $100,000
    | demonstrates that the affected class of
    individuals to be notified exceeds 175,000
```

Figure 12. Connecticut and Maryland substitute notice (RSL)

Both Maryland and Connecticut provide the option of substitute notice when the standard notification methods would be prohibitively complex or expensive. However, the levels at which substitute notice become available differ for each state. Due to these quantitative limits, reconciliation to yield one requirement would require choosing the higher Connecticut threshold, thus losing the insight that Maryland residents could be referred to the less expensive substitute notice at the lower threshold. In such cases, the optimal decision may be to keep the requirements separate and satisfy each individually.

In an effort to reduce overhead or maintain simplicity, some organizations may only wish to adopt the similarities as a baseline, after excluding the differences. While possible, this practice comes with inherent risk. As shown in Figure 13, requirement WI-3 from Wisconsin 134.98(2)(b) and CT-1 from Connecticut §36a-701b(b) conflict over when notice should be issued. Wisconsin only requires notice when an organization "knows" of a breach of personal information, whereas Connecticut requires notice when the data is "reasonably believed" to have been accessed by an unauthorized person. Presumably, the former "knows" requires a stronger standard for direct evidence, and "reasonably believes" may be based on indirect evidence or a worst-case scenario. An organization might choose "knows" to apply this requirement less frequently. These differences, though subtle, can be significant; organizations must maintain traceability from the choices they face to their decisions to implement those choices in practice.

WI-3
```
entity!
    & knows that personal information … has been
      acquired…
    : shall make reasonable efforts to notify…
```

CT-1
```
person!
    ...
    & ~following the discovery of a breach of personal
      data in which the personal data was, or is
      reasonably believed to have been, accessed…
    : shall disclose any breach… to any resident of
      Arkansas
```

Figure 13. Wisconsin and Connecticut disclosure details (RSL)

In addition to intra-dissimilarity observed in phrase-level measures, inter-dissimilarity appears in the presence or absence of relations to other requirements. The following example demonstrates how relations used to link requirements – `REFINES`, `EXCEPT`, `PRECEDES` – result in inter-dissimilarity. In Figure 14, requirement UT-2 from Utah §44-201(b) and NV-4 from Nevada §603A.210(1) are compared using the S-E measure (shown in the Figure by a double solid line).

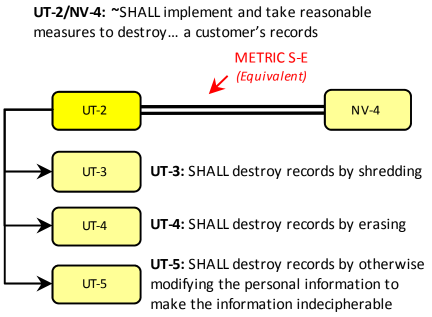

UT-2/NV-4: ~SHALL implement and take reasonable measures to destroy… a customer's records
METRIC S-E
(Equivalent)
UT-2
NV-4
UT-3
UT-3: SHALL destroy records by shredding
UT-4
UT-4: SHALL destroy records by erasing
UT-5
UT-5: SHALL destroy records by otherwise modifying the personal information to make the information indecipherable

Figure 14. Excerpt from Utah and Nevada Comparison

Both UT-2 and NV-4 require that companies take reasonable measures to destroy customer records that are no longer in use; however, Utah further constrains the solution space through a `REFINES` relation (the solid arrow to UT-3, UT-4, and UT-5 in Figure 14) to ensure that reasonable measures make personal information unreadable or undecipherable. If applying UT-2 to Nevada state resident's personal information is unlikely to add significant burden, the organization can adopt UT-2 as a standard for destroying data under both regulations. In most cases, the presence of a `REFINES` on one requirement but not the other can be handled by duplicating the additional refinement(s) across the equivalency, establishing these additions as a standard to be followed for both jurisdictions. Figure 15 presents a more complex example in which three parallel equivalencies are identified: AR-7 and NV-9, which require disclosing data breaches to state residents; AR-8 and NV-10, which require the disclosure to occur expeditiously; and AR-10 and NV-12, which are exceptions to permit a delay by law enforcement.

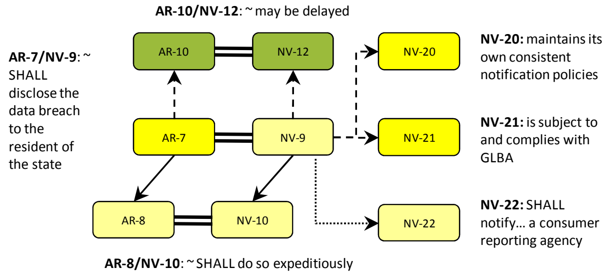

AR-10/NV-12: ~ may be delayed
AR-7/NV-9: ~ SHALL disclose the data breach to the resident of the state
AR-10
NV-12
NV-20
NV-20: maintains its own consistent notification policies
AR-7
NV-9
NV-21
NV-21: is subject to and complies with GLBA
AR-8
NV-10
NV-22
NV-22: SHALL notify… a consumer reporting agency
AR-8/NV-10: ~ SHALL do so expeditiously

Figure 15. Excerpt from Arkansas and Nevada Comparison

Apart from these three equivalencies, Nevada has additional requirements linked by `EXCEPT` relations (the dashed arrows to NV-20, NV-21) and `PRECEDES` relations (the dotted arrow to NV-22). The exceptions provide alternative notification options (comparable internal policies or procedures or compliance with the GLBA). The post-condition NV-22 requires additional notification to consumer reporting agencies to occur after notifying state residents. Because exceptions can halt the discharge of an obligation, the presence of exceptions in one regulation and not another at these equivalencies can cause conflicts. The post-condition, however, is an additional obligation that extends the requirements of the organization, and can be treated in a similar fashion as a `REFINES` relation by duplicating it across the equivalency; i.e. notifying a consumer reporting agency for a breach of Arkansas resident data as well as Nevada resident data.

Lastly, Figure 16 shows a subtle dissimilarity that may be overlooked by a casual reader of the regulations: the requirements NV-2, and AR-5 and AR-6, specify the same procedure, which is to implement reasonable security measures, and are thus equivalent when comparing the statements. However, these requirements apply to different entities: Nevada applies to the "data collector", whereas Arkansas applies to any person or business, which also includes the data collector and any other data owners or data licensees. Thus, the equivalent measures for statements (S-E) do not tell the whole story: one must also consider the differences in definitions governing various entities linked to the statements.

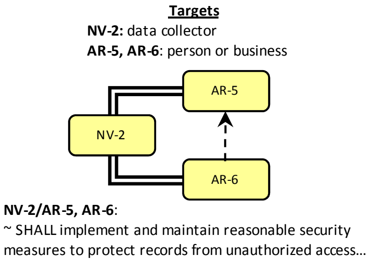

Targets
NV-2: data collector
AR-5, AR-6: person or business
AR-5
NV-2
AR-6
NV-2/AR-5, AR-6:
~ SHALL implement and maintain reasonable security measures to protect records from unauthorized access…

Figure 16. Excerpt from Nevada and Arkansas Comparison

6.2. The Legal Landscape and Positioning

The patterns of dissimilarity illustrate potential conflicts between two regulatory documents as binary comparisons between single requirements. We analyzed the seemingly vast number of comparisons that can be made, and discovered three heuristics for reconciling differences, which appear in Figure 17. Our previous discussion in Section 6.1 presents examples in which these heuristics can be used to resolve potential conflicts or differences between requirements.

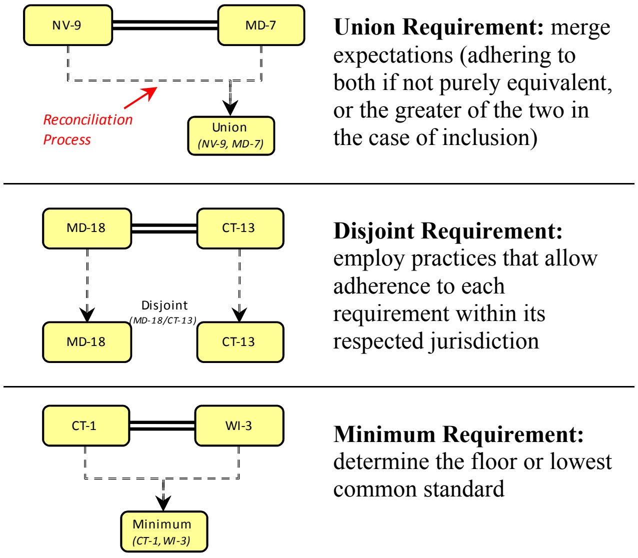

NV-9
MD-7
Reconciliation Process
Union (NV-9, MD-7)
Union Requirement: merge expectations (adhering to both if not purely equivalent, or the greater of the two in the case of inclusion)
MD-18
CT-13
Disjoint (MD-18/CT-13)
MD-18
CT-13
Disjoint Requirement: employ practices that allow adherence to each requirement within its respected jurisdiction
CT-1
WI-3
Minimum (CT-1, WI-3)
Minimum Requirement: determine the floor or lowest common standard

Figure 17. Types of Heuristics for Reconciling Regulatory Differences

We believe these heuristics can be applied to potential conflicts across regulatory requirements to discover a legal landscape. The landscape consists of choices that system designers must consider in the context of their products and services, business practices, internal policies, preferences, and risk profiles. The borders of the landscape are defined by different standards of care for a finite set of requirements across multiple regulations. A *low watermark standard* is a standard of care that satisfies the minimum requirements by making the fewest decisions in the reconciliation of differences between requirements and occurs when two requirements are precisely equivalent (because there is no requirement from which to presume a higher standard in the finite set of requirements). A *high watermark standard* is a standard set in which an organization proposes to achieve compliance by the "union" or the "disjoint" separation of differences between requirements. The low watermark standard results from equivalent requirements or the abandonment of relevant details: usually refinements measured by the P-R1 or P-R2 metrics. Alternatively, the high watermark standard seeks to maintain these details in order to achieve or exceed compliance.

Table 3. Qualities of Watermarks

	High Watermark		**Low Watermark**	
Decisions	***Union***	***Disjoint***	***Equivalent***	***Minimum***
Compliant	Yes	Yes	Yes	No
Source of Cost	Exceeds Standard	Multiple Standards	Base Costs	Cost of Discovery
Risk	Low	Low	Low	High

Achieving a high watermark may incur costs beyond those necessary to satisfy the individual requirements by themselves. If dissimilar requirements are reconciled through the use of unions, additional resources will likely be needed given that the covered entities (in this case, additional jurisdictions) have increased in number. If the two requirements are kept disjoint, we anticipate the need for additional resources (overhead) to maintain separate practices or processes. However, while both of these approaches to dissimilarity resolution result in higher costs, they take on less risk than adhering to the low watermark, minimum standard, which fails to achieve full compliance.

6.3. Variation Among Practices

While our heuristics offer guidance in reconciling differences, some documents contain inconsistent styles that inhibit uniform processing and interpretation based on our method, which we now discuss. For example, MA §93H constrains what *may*, *must*, or *must not* be done within definitions, as opposed to moving these constraints into rules. Alternatively, NV §603A lacks an overarching goal to lend direction and context to the document and under which other requirements can be linked as refinements, exceptions, and post-conditions. We now discuss examples of these inconsistencies that we observed during our study and how they affected our findings.

Within our documents set, we found common practice was to define notice incrementally across multiple requirements, leveraging pre-conditions to add or remove constraints on *when* the notice must be delivered, such as the permission (or prohibition) for notice to be given through an organization's website as opposed to individual mailings. However, MA §93H(1)(a) retains many of these constraints in the definition of notice (see Figure 18). This definition describes three kinds of notice, written, electronic or substitute, and may include conditions indicated by the keyword "if" regarding when the notice is provided. Other regulations have expressed these notices using separate permissions to provide the notice, which are refinements upon the obligation to provide notice. For our method, analysts must ensure they compare requirements to definitions to capture these potential overlaps and conflicts.

"Notice" shall include:—

(i) written notice;

(ii) electronic notice, if notice provided is consistent with the provisions regarding electronic records and signatures set forth in § 7001 (c) of Title 15 of the United States Code; and chapter 110G; or

(iii) substitute notice, if the person or agency required to provide notice demonstrates that the cost of providing written notice will exceed $250,000, or that the affected class of Massachusetts residents to be notified exceeds 500,000 residents, or that the person or agency does not have sufficient contact information to provide notice.

Figure 18. MA §93H(1)(a) Notice Excerpt

Definitions were also used inconsistently among the regulations we examined, which is of particular interest to CSPs. Whereas some jurisdictions chose to define multiple entities in order to distinguish responsibility, others rely on a generic term (e.g. "entity") and use conditions to scope the responsibility to a particular organization. For example, both NV §603A and AR §4-110 distinguish between organizations that use personal information for their own intent and those that simply retain the information (see Figure 19).

NV-18

```
data collector!
  = government agency
    | corporation...
    & ... handles or otherwise deals with nonpublic
      personal information

business!
  = proprietorship
    | corporation...

data collector!
   : must...
```

AR-14

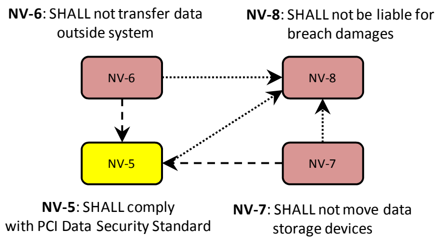
```
person!
  | business!
  & acquires, owns, or licenses personal information...
  : must ...

person!
  | business!
  & controls or has custody of customer's records...
```

Figure 19. Definitions in Nevada and Arkansas

Nevada's reliance on two separate definitions for data collector and business is mimicked in Arkansas, who uses a single phrase ("person or business") and must consistently elaborate further each time it is used in conjunction with a requirement. Nevada's approach of separate definitions in order to specify "who must do what" results in a single distinction and avoids repeating conditional clauses in each requirement.

Safe harbors are important regulatory mechanisms that encourage organizations to accept a predictable outcome or cost in the face of uncertainty. Safe harbors can be conveyed in many ways in the original text and analysts must be aware of these different formats. Using the RSL, safe harbors can be encoded as exemptions and deference to standards, exclusions (is not required to), and "lynchpin" conditions, which, when satisfied or not satisfied cause portions of the regulation to not apply to an organization, their practices or products. All of these safe harbor strategies can be found in NV §603A. To illustrate, consider Figure 20: NV §603A.215 shows deference to another standard, the Payment Card Industry (PCI) Data Security Standard (DSS).



NV-6: SHALL not transfer data outside system
NV-8: SHALL not be liable for breach damages
NV-6
NV-8
NV-5
NV-7
NV-5: SHALL comply with PCI Data Security Standard
NV-7: SHALL not move data storage devices

Figure 20. Nevada §603A Safe Harbors (GraphML)

In general, NV §603A.215 contains several requirements that apply to data collectors that accept the payment cards for their services. In Figure 16, these requirements include restrictions on the use of data storage devices (NV-7) as well as a prohibition against transmitting data over non-secure media (NV-6). Recall from Figure 5 that an exemption excludes telecommunications providers from these requirements in Figure 20, because the providers are viewed as providing the transport infrastructure independently from payment card applications, which are viewed as responsible for data security. In this case, the safe harbor is encoded using the `EXEMPT` keyword (see Figure 5).

Deference to standards is another technique used for providing safe harbors, and occurs when requirements are removed via exemptions or satisfied through compliance with another standard. In Figure 20, the prohibitions NV-6 and NV-7 (in red) do not apply via the `EXCEPT` relation, shown by the dotted line arrows, if the data collector exercises this exception by choosing to comply with PCI-DSS.

Lastly, perhaps the most obscure type of safe harbor is what we call a "lynchpin" condition. These conditions occur in definitions and requirements and, if satisfied, cause the requirement to which they apply to not apply. In addition, all refinements, exceptions, and some post-conditions linked to such requirements effectively become exclusions as a consequence of their dependence on these drop-outs. In Figure 21, a number of requirements can be traced back to NV-9. These requirements elaborate NV-9 in a number of ways, including how the notice must be provided, the types of acceptable notice, and what actions follow the notification.

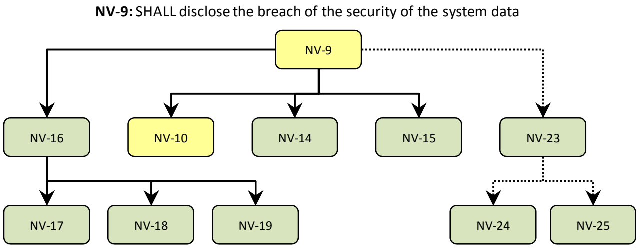

NV-9: SHALL disclose the breach of the security of the system data
NV-9
NV-16
NV-10
NV-14
NV-15
NV-23
NV-17
NV-18
NV-19
NV-24
NV-25

Figure 21. "Lynchpin" Condition in Nevada §603A

However, NV-9 has a precondition that restricts the requirement to a breach of *unencrypted* system data. Provided that an organization has encrypted their data within Nevada's definition of encryption, the entire series of requirements no longer applies to these organizations.

7. THREATS TO VALIDITY

In grounded analysis, multiple analysts derive theoretical constructs from a dataset to describe or explain the data and the constructs are assumed to only generalize to that dataset [18]. Recall from Section 4 that we selected regulations that share a theme (data breach notification), thus our theory may not be externally valid in other regulated domains, such as medical devices or aviation, which may require new language constructs or methods for reconciliation. However, we challenged our assumptions by validating our reconciliation methods (union, disjoint, and minimum) by applying them against potentially problematic requirement equivalencies known to the authors in laws from the remaining 46 U.S. states and territories. We found the methods to be sufficiently robust to reconcile differences between these regulatory documents.

Construct validity is the correctness of operational measures used to collect data, build theory, and report findings [33]. To improve construct validity, during the comparison and reconciliation phase of our process we annotated requirement pairs that constituted unusual cases with comments describing the nature of each case, as well as proposed resolutions for similar cases. As resolutions were accepted we reviewed each law to update the comparison metrics used to maintain consistency across the dataset. We also implemented a research database to collect the statistics reported in this paper.

Internal validity is the extent to which measured variables cause observable effects within the data [33]. Our results, particularly those discussed in Section 6, show that writing styles can positively or negatively impact our methodology, requiring analysts to look beyond the present context to identify dissimilarities between requirements.

Reliability describes the consistency of the theory to describe or explain environmental phenomena over repeated observations [33]. To improve reliability, both investigators (the authors) separately translated the datasets into the RSL and compared their results afterwards to identify alternate modes of expression and language caveats. For the metrics, the investigators compared a subset of their statement equivalencies (S-E measures in the gap analysis) by document pair (e.g. NV-AR, WI-MD, etc.) and determined an initial agreement or "overlap" of over 85%.

8. DISCUSSION AND SUMMARY

In this paper, we present the results of comparing seven regulatory documents using a requirements specification language (RSL) for codifying legal requirements and qualitative metrics to identifying gaps between requirements. We found the time required to translate the regulations into the RSL well worth the ability to debug and analyze the RSL-generated requirements using the metrics. While regulations were not originally written for this type of technical analysis, we believe our analysis can be used to improve the construction of these documents to reach a broader, more participatory audience throughout industry and academia by allowing participation to focus on alternative regulatory structures and the logical implications of those structures.

In Section 6, we show how measures of the RSL-encoded requirements can be used to identify patterns of dissimilarity. In addition, we presented heuristics for analysts to use to reconcile potential conflicts between requirements from different jurisdictions. We believe system designers can use the heuristics to select requirements that position their products in better position to comply with multiple jurisdictions. These selections may be based on costs to design in alternatives based on conflicting requirements, or to choose a common standard that elevates products to a higher standard.

Presently, we are exploring new ways to visualize the regulatory requirements as they apply to different jurisdictions. This includes techniques for organizations to use to classify their data sharing practices. In addition, we are studying ways to inform decision-making to help a particular organization decide which watermarks they might choose as well as how these decisions can be recorded to take a step towards the automatic verification of compliance. This information includes ways to represent and reason about the costs associated with one choice over another. Lastly, we are encoding a notably larger subset of regulations related to data breach notification and data destruction to ascertain the feasibility and potential benefits of achieving near-complete coverage of a domain.

9. Acknowledgment

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