Distributed Information Organization and Management Framework for Regulation Compliance

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Abstract

Regulation compliance is one of the critical services to citizens and businesses for E-government, as identified by the U. S. Office of Management and Budget. Regulation compliance is a complex process and offers many challenges in the design and implementation of a regulatory information management system that is able to support the regulation compliance process. It is important to first gain an understanding of the information flow in the regulation and compliance process, and to develop appropriate IT tools for building such a system. Focusing on environmental regulations related to hazardous waste management, we investigate the issues towards building an information infrastructure for a compliance assistance framework. This paper will describe a prototype distributive regulation framework for: (1) the management of regulations and related information to support compliance assistance; (2) an Internet-based information management system; and (3) supporting the interoperability among the parties (regulatory agencies, businesses and third party waste handling facilitators), who are involved in the environmental regulation compliance process

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1. Introduction

1.1. Background

The E-Government initiative in US aims at transforming the Federal Government into a citizen-centered, results-oriented, and market-based efficient government [3]. The Office of Management and Budget (OMB) has been developing the Federal Enterprise Architecture (FEA), a business-based framework, for Government-wide improvement. Within the framework of the FEA, the Business Reference Model (BRM) is the key component that describes the Federal Government's Lines of Business and its services to the citizen. The BRM identifies three major business areas of the Federal Government operations: services to citizens, support delivery of services, and internal operations. In the services to citizen business area, regulation compliance is identified as one of the two types of critical services the federal government provides. Many functions of the federal government involve the development and enforcement of regulations and laws, and the enforcement of the compliance process. Currently, most of the regulation compliance process is still a manual process, which is inefficient and error-prone. In the upcoming E-Government implementation, automating the regulation compliance process is a necessity.

Regulation compliance process is a distributed process where multiple participants are involved. Building an integrated and distributed information management system for regulation compliance checking is a challenging and complex task. By an integrated information management system, we mean that the system integrates various information sources to handle the compliance checking process. By a distributed information management system, we mean that the system can handle distributed information access by different participants during the compliance process. In order to deal with fundamental research topics, it is necessary to focus on building such a system for a specific regulation compliance area that has an urgent demand. We select hazardous waste regulation compliance as an area for focus. This research focuses on topics that are related to building a distributed information management framework for hazardous waste regulation compliance.

1.2. Hazardous waste regulation compliance process

Companies produce hazardous waste as a byproduct of their normal production activities. These generators of hazardous waste need to meet requirements imposed by federal, state and, in some states, local environmental regulations. Both federal and state Environmental Protection Agencies (EPAs)

have strict regulations imposed on the treatment and disposal of such hazardous waste [7]. Many companies contract for removal and management of their waste to hazardous waste treatment, storage, and disposal facility (TSDF) companies. These TSDF companies must meet permitting and handling requirements in addition to the requirements imposed on hazardous waste generators. Both generators and TSDF companies are responsible for reporting and record-keeping on their own generated and treated hazardous waste to Federal and state EPAs. Collaboration among generators, TSDFs, and the regulators (EPAs) is essential.

The management of hazardous waste is a complex task, and is shared and coordinated among the generators, TSDFs and the EPAs. The reports and records are needed for every hazardous waste and the activities related to it. Both generators and TSDFs must maintain operating records of the activities and report these activities based on the regulatory requirements, while EPAs must keep all the records for regulation compliance checking and enforcement [4]. The major motivation of this research is to investigate whether it is possible to develop an integrated and distributed information management infrastructure to support hazardous waste compliance; if so, to what degree can the process be automated.

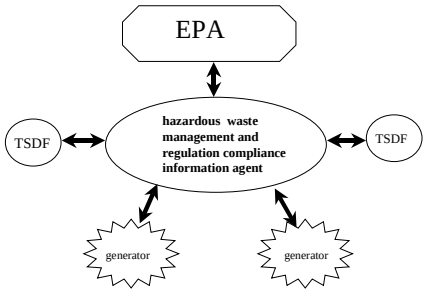


Figure 1. An information management brokerage for hazardous waste regulation compliance

In this research, we propose an information brokerage model for the compliance process. A high level description of an information brokerage for hazardous waste compliance checking is shown in Figure 1. The information brokerage, shown at the center of the schematic, coordinates the compliance task among the generators, TSDFs, and the EPAs. It can deal with information management for multiple generators, TSDFs, and EPAs. The brokerage model is analogous to the business model often adopted for the Electronic Commerce [6]. This information brokerage model is aimed at replacing the current labor intensive and written record based hazardous waste information management model.

1.3. Research focus

The research addressed in this paper focus on two key topics: the information and knowledge organization and a regulatory compliance framework. The scope of the research focuses on the Code of Federal Regulations (CFR) Title 40. A distributive regulation framework is discussed in Section 2. Section 3 describes a prototype of an Internet based distributive information management system for regulation compliance checking. Finally, Section 4 presents a summary and discusses of future work.

2. Distributive regulation framework

2.1. Introduction

Hazardous waste regulation compliance checking is a distributed process conducted among the regulators, waste generators, and TSDFs. Individuals from these parties with different professional backgrounds and domain expertise, while individually responsible for certain specific tasks, must collaborate with one another. Currently, compliance checking is performed manually, with the exchange of information recorded in written forms.

To better understand the compliance process, we interviewed individuals from semiconductor companies, TSDF and legal professionals and conducted an analysis of the information flow among the participants. Let's use one of the compliance checking tasks, namely, the identification for hazardous waste for waste generator to illustrate. Because of the complexities involved in applying the regulation codes for compliance checking, generators usually contract TSDFs to handle waste identification and other related waste management tasks. TSDFs specialize in waste management and provide procedures for dealing with the waste identification and compliance assistance for the generators. To comply with regulatory requirements related to hazardous wastes, the generator follows the regulation codes from the EPAs and the interpretation of the codes from the TSDFs. There is an active interaction and exchange of information and knowledge among the three parties, which is shown in Figure 2.

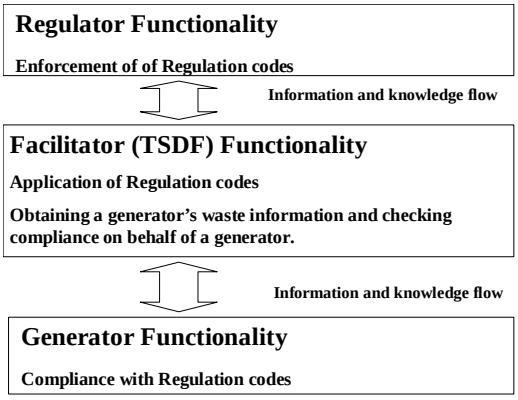


Figure 2. Information flow during hazardous waste regulation compliance process

2.2. A context-based model for distributed regulatory information

We focus on building a distributed information management paradigm to enable information flow and interaction among the different parties during the hazardous waste compliance process. There are several approaches to deal with complex information flow and interactions. One approach is to employ domain based information representation [12] to express the information exchange interfaces and the information representation within a domain. However domain based representation does not support the interaction among diverse information sources in a distributed environment. Another approach to describe the interaction among the different information sources is to employ context, hierarchy of contexts, and information and knowledge interchanges among contexts [10,11]. It is argued that in a complex information environment, participants organize and use knowledge for their own purpose within their individual subcontexts. The information and knowledge created from individual subcontexts does not support direct sharing in a more general context [11]. Therefore, we need to make explicit the individual context when sharing information among multiple participants. In this work, a context-based concept is employed to organize the information and knowledge for the hazardous waste compliance process. Contexts are organized locally from the perspective of an individual party and globally to coordinate the information and knowledge sources among all parties.

In the following sections, we discuss the issues in establishing the local context for individual participants, and for forming a global context for compliance process. Finally, a mediation [14] approach is proposed to facilitate the regulation compliance checking process, utilizing the context based organization of information sources.

2.2.1. Knowledge in compliance process. Different participants have different knowledge and, very often, different understanding about the regulations, the compliance procedure, and the supplementary regulatory documents. The differences can be illustrated using the regulation codes for identifying a hazardous waste. A general process of waste identification for a generator can be summarized as shown in Figure 3. When identifying a waste, a generator encounters environmental law in the form of statutes and regulation codes [7]. The first step is to determine which regulation codes to use. Then, the generator must examine the codes to find the applicable provisions. The generator needs to interpret the provisions related to the waste. Often, the generator may not fully understand the regulation codes, and usually relies on the service by TSDF for the waste identification task.

For the regulator, the procedure for identifying a waste is more direct and explicit. The process is shown in Figure 4. The regulator, being the drafter of the codes, has detailed knowledge about the structure of the codes, the terms used in the provisions, and the content and applicability of the codes. However, a regulator usually does not have the information on how a generator may use the codes.

A TSDF is the participant that has the knowledge of the regulation codes and of when and how to use them for identifying the wastes. By working with the generators, a TSDF also has the knowledge about what the generators need to know for identifying wastes. From a functionality viewpoint, a TSDF is the mediator that tries to provide the information and knowledge to a generator so that a generator can perform the waste identification process as much as what a regulator would require a generator to comply. The interaction between a generator and a TSDF is shown in Figure 5.

In summary, the information and knowledge of a participant in the regulation compliance process has three aspects: (1) the characteristics of the information and knowledge source, including the structure or relations of the sources, (2) the content of the information and knowledge, and (3) the background knowledge for interpreting this particular information and knowledge content. They form a local context for

representing the information and knowledge for an individual participant.

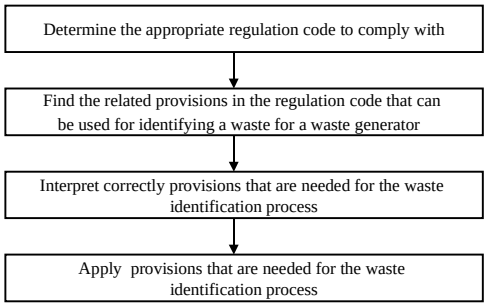


Figure 3. The procedure for identifying a waste for a waste generator from a generator viewpoint

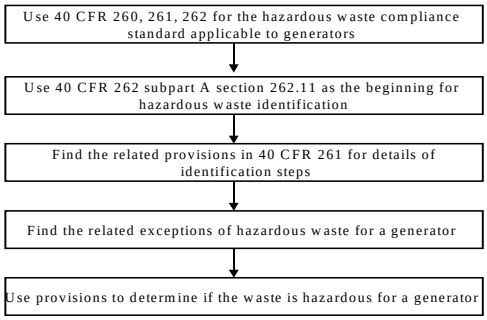


Figure 4. The steps for determine a waste for a generator from a regulator viewpoint

2.2.2. Interoperation among the participants. To coordinate the information and knowledge from individual participants requires the determination of the relations among the local contexts of the participants and their interoperations. The relations include not only the individual contexts but also the interaction among the participants. The distributed information system for regulation compliance checking is thus a combination of multiple local contexts for the participants together with the meta data for interoperability among the local contexts.

Since each local context usually does not contain sufficient information and knowledge for the compliance purpose, we need to include the contexts about the coordination and cooperation among the three local contexts. Figure 6 shows an interaction among the local contexts for the three participants during a compliance checking process. To coordinate the information and knowledge in regulation compliance, the interaction and the interoperation among local context of participants are important.

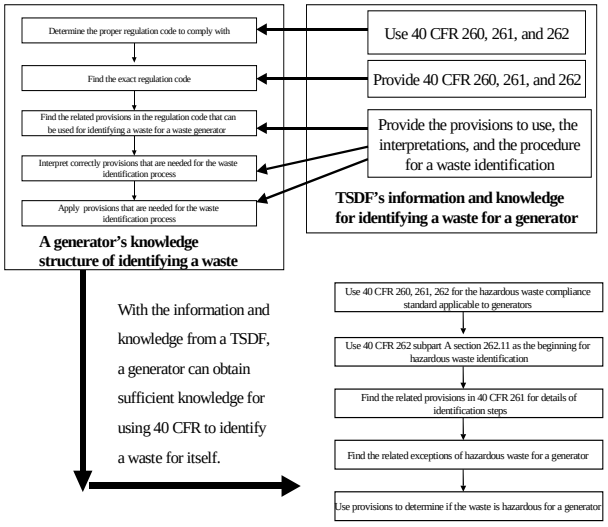


Figure 5. Interaction between a TSDF and a waste generator

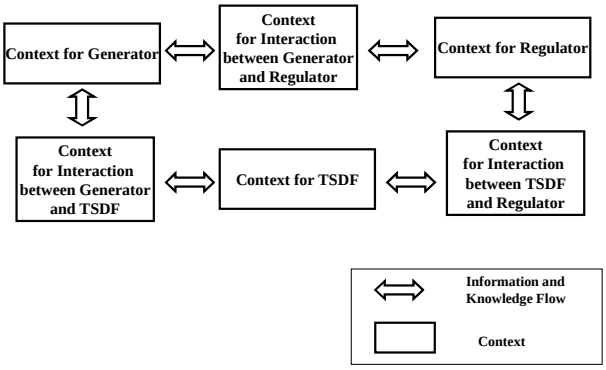


Figure 6. Information and knowledge interaction during compliance process

2.2.3. Hierarchical organization of compliance knowledge. The overall organization of a regulation compliance checking process can be structured as a hierarchy of knowledge bases. The knowledge sources (KS) and knowledge contents (KC) in the local contexts are the physical entities that need to be interoperable with one another in order to fulfill the functions for the regulation compliance checking. The hierarchy can be formally organized as a context graph structure shown in Figure 7. The lowest level of the hierarchy contains the local information and knowledge organization of individual participant. The middle layer consists of the meta information to enable interoperability among the local contexts. The top level of the hierarchy contains the knowledge about the information flow during regulation compliance process.

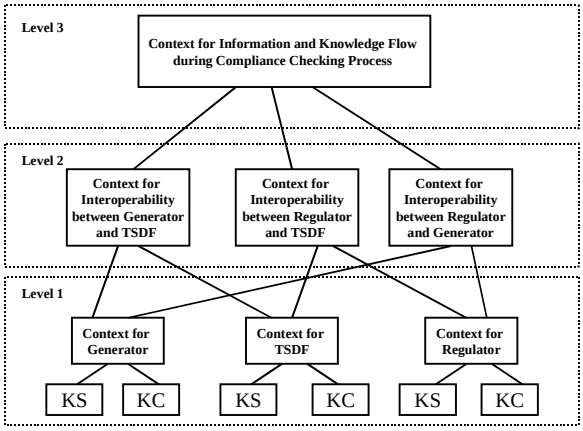


Figure 7. Hierarchy of contexts for information and knowledge flow

For example, within the interoperation between a generator and its TSDF, the generator can obtain sufficient knowledge for using 40 CFR to identify a waste for itself. It is the contexts for individual participants (Level 1 context) together with the information and knowledge between the local contexts (Level 2 context) that enable a generator to perform waste identification.

The context-based hierarchy provides a procedure for requesting and obtaining the necessary information and knowledge for a regulation compliance process. The procedure for context based information and knowledge interaction is based on two criteria: (1) using the information and knowledge from the nearest local context and (2) using the information and knowledge that is the most trustful one. This means that we need to make an assumption that the nearer the context is, the more trustful it is. This assumption has been used either explicitly or implicitly in various approaches for other distributed information and knowledge organization approach [8,9,14].

2.2.4. An example. To illustrate the application of the context based information organization and interoperation, we provide an example for resolving vagueness in the regulation codes.

The definition of a hazardous waste is usually not clear for a generator, or more specifically, the information and knowledge sources for the definition of a hazardous waste are often incomplete. On the other hand, a TSDF usually knows the definition of a hazardous waste. Therefore, a TSDF can always provide a generator better information about the compliance requirements. However, a generator handles the information quite differently from a facilitator, although they deal with the same problem. To be more specific, there is a case where the same term can have different meaning in different local context. For example, the term “solid waste” may mean “the waste that is solid” to a generator, but the same term “solid waste” may include the waste that is not necessary in a solid form to a TSDF or a regulator. To facilitate the discussion, we denote the symbol *C("participant")* to mean a context of information and knowledge of a *participant* in the compliance process, the symbol *C("participant"): Definition("key word") := "the definition content"* to represent that, in the context for a *participant*, the definition of the "*key word"* is "*the definition content"*. For the case of the definition of "solid waste", we have:

C("generator"): Definition(“solid waste”) := “the waste that is solid”

C("TSDF"): Definition(“solid waste”) := “the waste that is defined in regulation codes, using either federal code 40 CFR 261 or a state specific code, or both”

C("Federal EPA"): Definition(“solid waste”) := “the waste that is defined in 40 CFR 261”

Obviously, the information and knowledge mismatch cannot be resolved in any of the local context alone, since none of the local contexts has the complete information about the other. Only by organizing the meta information for a resolution can we resolve the mismatch. For the above example, we provide the following mechanism, as shown in
. We observe that the term “solid waste” is defined in a local context and its exact meaning varies from one local context, say *C("Generator")*, to another local context, say *C("Federal EPA")*. The solution for this problem is to define a global view for the term “solid

waste" that has the exact meaning in the regulation compliance process. The way to unify the meaning of the term "solid waste" depends on the decision of choosing the most reliable concept for "solid waste". In this case, we use the definition of "solid waste" from the local context of the facilitator as the global concept of "solid waste" as the meta information for all the other local contexts. More specifically, we use a symbol *C("regulation compliance"): Definition( )* to define the concept "solid waste" in the context for regulation compliance checking:
C("regulation compliance"): Definition("solid waste")

:= "the waste that is defined in regulation codes, using either federal code 40 CFR 261 or a state specific code, or both."

After combining the definition into the global context, we arrive at a concept of "solid waste" that can be used in the regulation compliance domain as shown in the Figure 8.

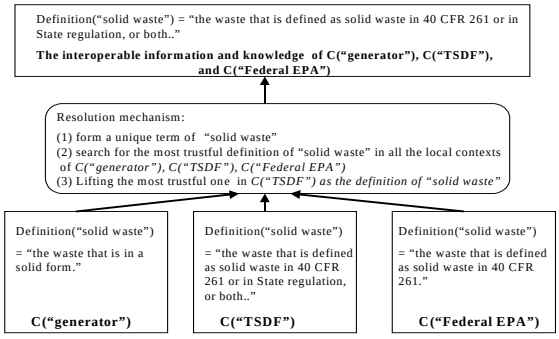


Figure 8. Using context lifting to resolve definition content conflicting from different contexts

The organization of contexts and their interoperations for compliance checking offers a way for supporting modularity in system implementation. Next, we map the context based information and knowledge organization to a mediation based paradigm [14] to build a distributed information management system for hazardous waste regulation compliance process.

2.3. A distributed computing paradigm

Mediation is a technology that is intended to provide a scalable information and knowledge integration in a multiple information source environment [14,15]. The purpose of the mediation is to scale local domain based or context based knowledge so that the information and knowledge from many heterogeneous local sources can contribute to a certain application [8]. In this section, the topic of using mediation based information and knowledge integration for supporting context-based information and knowledge interaction for regulation compliance checking is discussed. We focus on mapping the context based organization to a mediation based information and knowledge organization paradigm.

To realistically form an integration model for context-based information structure, we need the mappings for transforming the distributed contexts into tangible information and knowledge entities. Basically, we need the mappings (1) from the local contexts of participants to information and knowledge representation for the participants, and (2) from the interoperability contexts to the mediation based meta information structures.

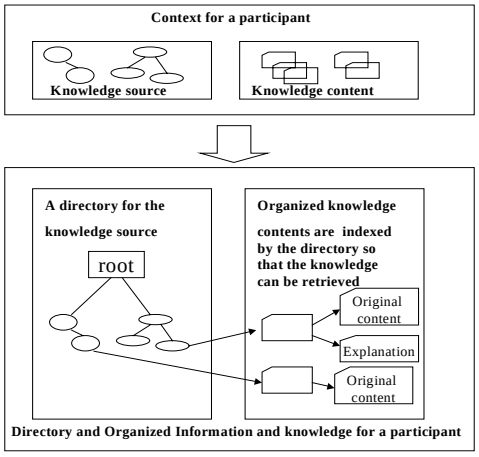


Figure 9. Directory and organized information and knowledge for a participant in regulation compliance process

A procedure, as shown in Figure 9, is employed to map the elements of a local context to an organized information and knowledge service. An organized information source can be a local information directory together with the enriched (that is, raw information that are interpreted) and well organized (that is, the one that has a schema) information content. The mapping from a local context of information to a structured local information source for a participant can be conducted by organizing the information sources to (1) reveal the available sources, (2) to make the implicit assumptions explicit and provide explanation about original information whenever necessary, and (3) to establish a directory. Figure 10 shows the mapping between the context and the meta

information, and information matching mechanism. The meta information consists of a directory for finding the information about the different participants and their meta-information in the local subcontext. To support the interoperability among the local context of information and knowledge, the following steps are taken: (1) identifying the necessary information and knowledge for communication among the local contexts, (2) building a directory for interpretation among the local contexts, and (3) building the matching rules, whenever necessary for resolving information mismatches.

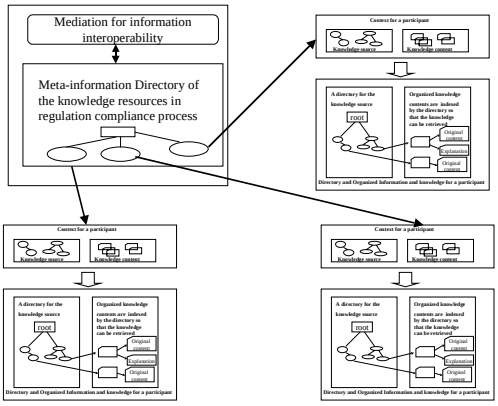


Figure 10. Meta-information directory and information interoperation for participants in regulation compliance process

In mediation based information infrastructure, we view a local context as a piece of distributed knowledge, while we view an interoperability context as a globally available interoperable knowledge supported by a trustful mediator. In this sense, a mediator of regulation compliance serves as the global information and knowledge coordinator for a distributed framework for regulation compliance process.

2.4. Related research

The context based organization approach described is related to various methods used in the distributed information and knowledge paradigm. Among them are the research in formalizing context [9,10], mediation and its related ontology [14,15], knowledge and meta knowledge in distributed systems [1,5].

The formal theory of context argues that the information and knowledge created from the subcontext is not ready for direct sharing in a more general context [9,10]. Therefore, we need to make explicit the individual context when sharing information among multiple participants. In the hazardous waste compliance process, the information and knowledge for each participant has its own local context and in order to make the local contexts work together, we must explicitly formalize the local contexts together with the interoperability contexts [13]. We have presented an explicit formulation of the distributed framework to deal with local contexts in the compliance checking process.

Mediation and the related algebra over ontology provide intermediary services in distributed information systems [8,14,15]. The need for mediation is the result of dealing with only the interrelated information, not the complete information in a distributed system. Mediation and the related algebra over ontology also provide a formal methodology for organizing the interoperability of information. There are many applications that employ mediation as a major tool for distributed information system design [15]. The application of mediation in regulation compliance checking process is a new attempt. In particular, we use it for organizing distributed information and knowledge infrastructure for compliance checking.

Knowledge and meta knowledge is a research topic in the theory of distributed systems [1,5]. In our research, the topic motivates us to investigate what is the explicit information and knowledge globally known in a distributed compliance checking process and what is the hidden knowledge that is used to interpret the explicit information and knowledge. The distinction between the explicit knowledge and the hidden knowledge is of particular importance in forming a context of information and knowledge for a participant during a compliance checking.

3. A prototype system for distributive regulation compliance checking

3.1. Information system architecture

The system architecture for the hazardous waste regulation compliance checking system is depicted as shown in Figure 11. The prototype system is used to demonstrate the feasibility of using the mediation based information integration approach and the information brokerage model for compliance process. The regulation code, 40 CFR, is downloaded from a U.S. government regulation repository site

http://www.access.gpo.gov/. To illustrate the distributed framework, we employ two computer servers, one for implementing the necessary regulation code information processing and organization and the other for compliance assistance designed for waste generators. The first server is employed to store the original regulation codes and to convert the plain text file codes to an XML encoded semi-structured representation format. The second server is used to translate the XML based CFR regulations and the relevant code explanation into the corresponding regulation code objects, which are then stored in Oracle database for further regulation compliance checking and information retrieval. The procedure for organizing the code objects is implemented using the mediation approach discussed earlier. The second server also implements the business logic for a checking service typically employed for hazardous waste generators. More specifically, the first server provides three major functionalities: (1) retrieving the original hazardous waste regulations from the U.S. government regulation repository sites, (2) preprocessing the original file for the CFR regulation codes, and (3) transferring the preprocessed XML formatted regulation code documents to client Server 2 for compliance checking purpose. The underlying transferring mechanism used in this system is a HyperText Transfer Protocol (HTTP) based client-server data transport model. The second server implements a number of facilities to provide the functionalities for hazardous waste compliance checking. The functionalities implemented include: (1) storing the preprocessed XML encoded regulation documents, translating them into database SQL language and importing them to the Oracle database tables designed for modeling regulation codes, (2) building regulation code objects from the Oracle database tables, (3) generating compliance checking procedures from the regulation code objects, (4) retrieving waste lists from waste generators, (5) normalizing particular waste lists to a canonical form suitable for compliance checking, (6) providing compliance checking for the input waste lists, (7) returning the compliance result to the client user, who is either a waste generator or a TSDF.

3.2. Implementation and features

The prototype is implemented using Java and SQL. Java is selected as the programming language for its rich object-oriented feature and cross-server-platform support. SQL is a standard database query language that can be employed for efficiently manipulating regulation code provisions stored in the Oracle database. The prototype implementation is a three-tier architecture that is managed by a WebLogic application server [2]. The first tier is the user interface for the waste generators; the second tier is to implement the business logic and the compliance checking related functionalities; and the third tier is for the regulation code provisions stored in database.

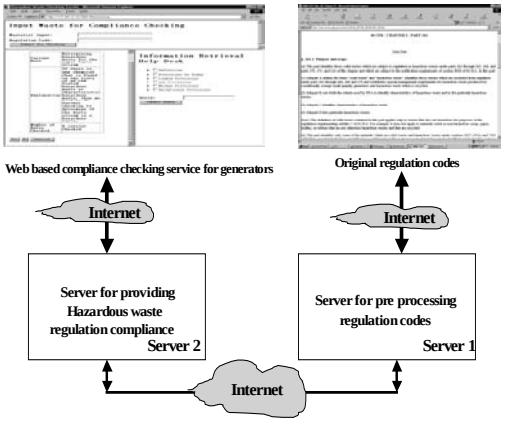


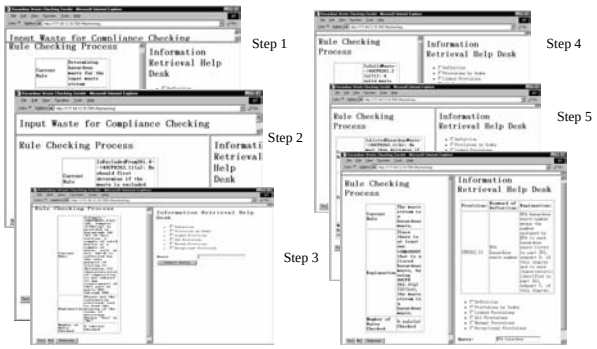
Figure 11. System architecture for the prototype system

Figure 12. Web browser based user interface for hazard waste compliance checking information management system

There are three basic modules for the compliance checking environment. Each of them is implemented as a dedicated Java servlet. The first module, which is illustrated on the upper frame of the web interface

shown in Figure 12, is used for obtaining the waste stream data from the user. The second module, which is shown on the lower right part of the frame, is used for information retrieval for regulation codes and related information. The third module, which is shown on the lower left part of the frame, is used for the interactive compliance checking process.

During a hazardous waste compliance checking process, the user first inputs the waste list through the waste stream data input interface. The user then follows the compliance checking procedure by a decision-tree based rule traversal strategy to find the related regulation provisions. If further explanation is needed for a certain regulation provision during the checking procedure, an information retrieval help desk is provided at the right window to facilitate the retrieval of the expert explanation for the code provision, or the relevant original provision text for the derived rule. As the compliance checking process proceeds, the compliance checking module will present the user the checking sequence for determining if the waste lists submitted by the user is a hazardous waste based on the interactive input. The complete checking process is depicted in Figure 13.



Step 1: beginning check process for the waste.
Step 2: checking if the waste is excluded from being a waste.
Step 3: checking if the waste is a simple waste.
Step 4: checking if the waste is a solid waste.
Step 5: checking if the waste is a listed hazardous waste.
Step 6: concluding that it is a hazardous waste since at least one component of the waste is a hazardous waste.

Figure 13. Sequence of checking rules for determining a hazardous waste for a generator

4. Summary and conclusions

We have investigated three key issues towards the development of a distributed information and knowledge management system for the hazardous waste regulation compliance process. Based on the investigation, we provide a methodology for organizing distributed information and knowledge for such processes. A context-based approach is proposed to organize the information from the participants in the hazardous waste regulation compliance process.

We begin with a detailed analysis of the process for conducting hazardous waste regulation compliance and the related distributed information and knowledge during the process. Then, we define the concept of context of information organization and apply the concept to the local contexts for waste generators, facilitators, and regulators. Furthermore, we define the meta information organization for making the local context interoperable. We introduce the meta information for organizing the hierarchy for searching information and knowledge through local contexts using a combination of criteria of the most trustful and the nearest information and knowledge sources and contents. Finally, we map the context based information organization for regulation compliance process to a distributed computing paradigm using a mediation based method. The mediation methodology is extended to study the information and knowledge representation and information interoperability in the practical compliance checking process.

We also provide a description of the prototype developed in this research for an Internet based information management system for hazardous waste regulation compliance checking. The focus of the prototype system is to demonstrate the feasibility of using the methodology developed in this research for the implementation of the information management system.

The current research focuses on information flow, its integration and interoperability for regulation compliance processes. For the future work, we will investigate issues on knowledge management and knowledge integration during compliance processes, and on integrating knowledge management into a workflow framework for compliance processes. We will also enhance the prototype system by utilizing a better component and web-service based software architecture for managing large-scale distributive information and knowledge for regulation compliance processes.

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