Application of Context Aware Laundry Management in Medical Settings

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***Abstract*—To enhance infection prevention measures, administrators at healthcare facilities and hospitals are increasingly emphasizing the importance of nurses and staff being vigilant about the laundry they handle. It is crucial for staff to understand the necessary policies for transporting, cleaning, and storing laundry to prevent contamination. Additionally, they need to grasp the distinctions between hygienic and sanitized laundry and linen. This paper discusses how Information and Communication Technologies can be used to manage the laundry process in medical settings. It presents a context aware laundry management architecture specifically designed for hospitals. Such an information architecture allows sustainable operations in hospitals for better resource management, waste reduction and raising medical staff awareness about the importance of handling hospital laundry.**

***Keywords*—context-aware systems, medical laundry, hospital laundry management**

I. Introduction

Preventing hospital-associated infections is essential. Identifying the source of these infections can be complex due to the numerous potential sources of transmission within a hospital, including healthcare laundry. It is logical to assume that hospital linens are reservoirs for infectious organisms. Healthcare linens typically include patient and staff bedding, towels, clothing (such as scrubs, coats, uniforms, patient pajamas, and gowns), surgical drapes, curtains. The decision on which textiles are reused and laundered versus those that must be discarded varies between healthcare facilities. Administrators at healthcare facilities and hospitals are increasingly emphasizing the importance of nurses and staff being vigilant about the laundry they handle and maintaining strict cleanliness and proper management of hospital laundry. It is crucial for staff to comprehend the necessary policies for transporting, cleaning, and storing laundry to prevent contamination. Additionally, they need to grasp the distinctions between hygienic and sanitized laundry and linen. To illustrate and substantiate the ideas presented in this paper that describe a laundry management system specifically designed for medical contexts, the following scenario is introduced. This scenario also sets the stage for the remainder of the paper.

"*Mr. Jones is staying in the infectious diseases ward of ABC Hospital, where he is struggling with Hepatitis B, a severe condition with a high risk of spreading. The department is seriously concerned about the transmission of viral pathogens through the laundry and has decided that some of Mr. Jones's hospital laundry items need to be destroyed. Meanwhile, Ms. Smith, who has received the good news from her doctor that she will soon give birth to a healthy baby, is awaiting the arrival of her first child in the maternity unit of the same hospital.*"

As described in the scenario, Mr. Jones and Ms. Smith have different hygiene needs due to their distinct contexts. Solutions must take these contexts into account to effectively meet hygiene requirements, reduce costs, and improve laundry logistics by properly setting data within the context. To further illustrate the need for a context-aware solution, consider that hospital management may require stricter washing and drying policies for health textiles due to the challenges posed by the Covid-19 pandemic. These revised policies introduce new laundry process steps, which necessitate updated washing rules and methodologies. For example, Mr. Jones falls under Policy 1 or 2, while Ms. Smith is subject to Policy 2. Therefore, a context-aware, personalized solution is needed. Table I shows an exemplary risk-policy relationship and outlines the necessary actions when implementing such a policy.

This paper discusses how Information and Communication Technologies (ICT) can be utilized in managing the laundry process in health care settings and demonstrates how a context aware software approach is highly suitable for handling such a system. The paper proposes a context-aware Hospital Laundry Management system which uses a layered software architecture.

TABLE I. Policy Based Risk Assignment

Policy1 – Too High	**Destroy without being subjected to washing.**
(e.g. Surgical textiles or heavy infectious that cannot be disinfected with high heat)	
Policy2 – High	**Thermal washing cycle**
(e.g. Heat disinfectable linens or surgical textiles.) • Healthcare textiles can be washed up to 10 times. • Washing methodology: - Pre-wash required with water, soap and detergent. - Main washing: High temperature -- 70°C - 90°C (158°F - 194°F), special bleaches, 10 minutes. - Rinse cycle: Water - Drying: 50 minutes with drying machine, 50°C (122°F)	
Policy 3 – Medium	**Low temperature Washing Cycle**
(e.g. low-level pathogens in general textiles) • Healthcare textiles can be washed up to 50 times or six mounts. • Washing methodology: - Pre-wash required with water, soap and detergent - Main wash: High temperature -- 60°C (140°F), special bleaches and Sodium hypochlorite (NaClO), 10 minutes. - Rinse cycle - Drying: 50 minutes with drying machine, 50°C (122°F)	
Policy 4 – Low	**Dry-cleaning**
(e.g. Low-level pathogens in curtains and carpets) • Hospital textiles can be washed up to 6 times a year.	

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II. Literature Review

Hospital laundry cleaning policy, rules, and guidelines for the reduction of risks related to laundry against potential or actual contamination with an infectious agent can be found in [1], [2], [3]. There are numerous studies that propose context aware architectures and solutions for different domains [4], [5], [6]. There are also many studies in literature that address various aspects of laundry system implementations. For instance, the work reported in [7] introduced a context-aware system designed to manage end-to-end laundry business processes. Lu et al. [8] proposed a service-oriented software architecture that utilizes washable RFID tags, focusing on tracking items between the factory and laundry shop but not examining the factory's internal processes. Tajima et al. [9] developed a context-aware hanging system with hangers that automatically detect the status of clothes and communicate updates through multiple channels. Van et al. [10] proposed an RFID-based Laundry Management System incorporating RFID tags and wireless RFID hangers. Noor et al. [11] created a "smart basket" system aimed at optimizing resource use during laundry activities. Pawłowicz et al. [12] analyzed communication issues on the spatial identification of a large number of textile tags.

III. Hospital Laundry Process

This section describes the operations of a laundry from a medical setting perspective to help determine the basic requirements of an ICT-based solution. Laundry operations in a hospital are quite different from other domains such as hotel and hospitality. As such, they exists in different contexts, necessitating a context-dependent solution. Even within a medical setting like a hospital, different hospital units operate in different contexts, requiring varying cleaning requirements and generating different context data for the same task (i.e. infectious diseases and maternity wards may use different pH, and temperature values). The example of Mr. Jones and Ms. Smith in the earlier scenario illustrates that the context determines the actions to take. A context-aware system utilizes the information present in the context to deliver services to users or to other entities in the system [6].

A. Hospital Laundry Context Information

Deciding what needs to be included in hospital laundry context is an important task in the solution. The authors will utilize the two-tier taxonomy proposed by Abowd et al. [15] for classifying context in our study. Context types will be categorized into primary and secondary. Primary context types—considered more significant—include location (where), identity (who), time (when), and activity (what). Secondary context types are attributes associated with the primary types, meaning each secondary type is linked to a primary type. Table II offers an example list of attributes included in the context information. Examples of context data include wash temperature, water pH value, washing frequency, and item type.

B. Hospital Laundry Management Process

Conceptually, the Hospital Laundry Management Process contains five major activities as shown in Fig. 1.

Laundry Collection, Pick-up and Sorting (LC): During the collection process, laundry is picked up from hospital units. Items without tags are tagged and initialized with relevant information. Electronic washable RFID tags stitched into clothing or textiles can store instructions and symbols for washing, drying, ironing, and other care needs such as laundry type, laundry color, clinic ID, and the total number of washings. They are read by RFID readers which use differing frequency and antenna types, reading distances, and connectivity. Reading the RFID tag can also be done using a smartphone. Some RFID tags may contain NFC chips which limit the reading distance but offer better storage and security. The inherent security issues found in RFID based system such as RFID sniffing, skimming, cloning; or protecting the backend systems and communication can be addressed by using the well-accepted security solutions in ICT such as encryption and access control. NFC supported mobile phones can read RFID tags that have NFC chips on them as well as other tags that operate at a frequency of 13.56 MHz [13]. Fig. 3 shows examples of washable RFID tags.

Data Collection (DC): During the Data Collection activity all necessary information is acquired so that the Risk Analysis activity can assign a risk level. Data Collection activity may involve using physical hardware for data acquisition in addition to manual provisioning data. In this architectural proposal, it is suggested to use washable RFID tags to store information about the items used in a hospital. This approach allows for more effective management of the laundry process by properly classifying and separating items. An operator can update the data on the tag by a smartphone and monitor the process route. Data can also be manually provided by the medical staff. They may visually examine the item and enter information into a data repository (i.e., database) regarding the item's condition. The visual inspection conducted by the medical staff will be used in the risk assignment process. Additionally, medical staff may make instant judgements and assign a risk level to a laundry item immediately, and dispose of the laundry in appropriate color-coded collection bins.

User Interface (UI): This process facilitates interaction between the human users and the rest of the system. Medical staff enter data described in the Data Collection activity using a user interface device, such as a mobile phone or a terminal.

TABLE II. An Example Hospital Laundry Context Data

Primary Context		Secondary Context		Description
Name	**Sample Values**	**Attributes**	**Sample Values**	
Location	Hospital, Hotel	Unit	Intensive care unit	The location of the item, such as a bed linen in the hospital's intensive care unit.
Identity	Bedding, Carpet, Curtain	Material, Condition	Cotton, Synthetic Risky	The item to be washed has attributes such as material and condition, which can be stored in the tag. An item can also be manually classified as a risky item.
Activity	Washing, Drying	# of wash, Water temp., PH value	60°C (140°F), 7	The number of times an item is washed and the water temperature used during washing. The data for this context can be obtained from RFID tags or sensors
Time		Wash and Dry time, Duration	50 min., 12/24/24, @13:00	The amount of time spent on the washing and the time of the wash.

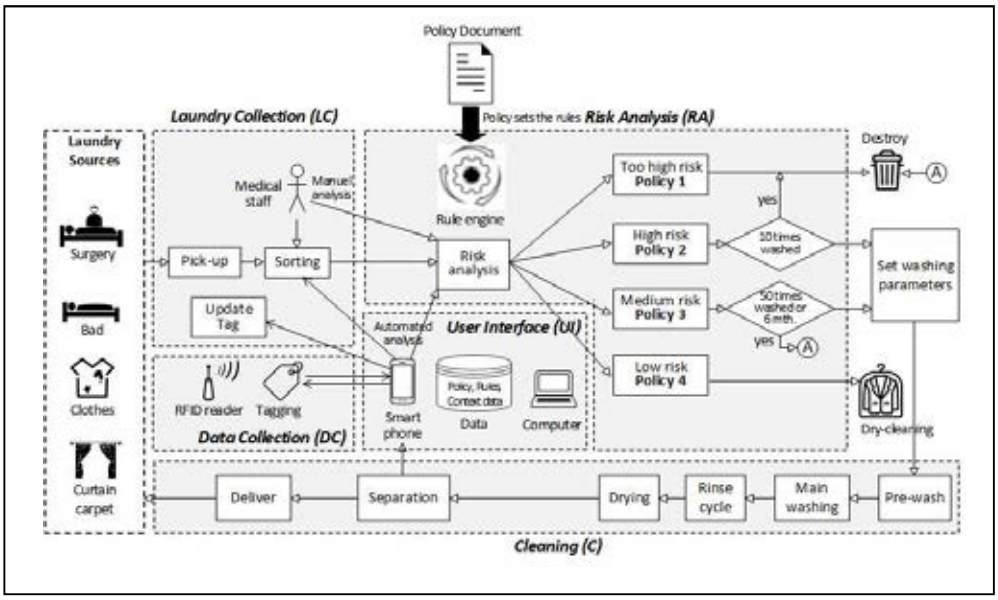


Fig. 1. Health Laundry Management Activities

Risk Analysis (RA): The Risk Analysis process assigns a risk level to each item using the information obtained from the RFID tag and medical staff based on the instructions in the policy document. The laundry's risk level determines how the item is cleaned or whether the item must be destroyed. Risk Analysis activity can incorporate additional techniques, such as artificial intelligence or image processing, to assess the risk level of fabrics or monitor the number of uses. After the risk assessment is completed, the rule engine executes the rules according to the established policies to set the parameters that control the washing process as shown in the example in Fig. 2.

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When an item is identified as high risk,
the instructions outlined in Policy 2 under the
general Policy Document should be followed.
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Fig. 2. A rule example

Cleaning: The Cleaning activity consists of two sub-activities. The details of the cleaning sub-activity are outside the scope of this paper. However, the accurate delivery of items is within the responsibility of the solution, as items must be sorted using the tag information and forwarded to their designated location after cleaning. This study primarily focuses on describing the activities leading up to the cleaning, namely Collection, Sorting, Data Acquisition, and Risk Analysis, as well as the Separation and Delivery activities that follow the cleaning process. The actual washing and drying of the items will not be discussed.

IV. Technical Architecture

The layered architectural model divides the system into distinct, functionally independent layers, each offering services through a clearly defined public interface. These layers interact with one another in a specific sequence, utilizing these interfaces. This approach ensures that the system is reliable, serviceable, and maintainable. Fig. 4 illustrates our layered model, with an explanation of each layer's purpose provided below.



Fig. 3. Example of washable RFID tags [14]

Physical layer: This layer provides the interface with the hardware devices and the system. A washable RFID tag, as discussed earlier, is an example of hardware device. A mobile phone or RFID reader reads the content of the tag and passes the data to the layer above – Data Acquisition Layer. In addition to tags, sensors can also take place in obtaining data and they will also be managed by this layer.

Data Acquisition Layer: The primary responsibility of this layer is to store context data in a repository (e.g., database). The data values obtained through tags, sensors or manually provided by the medical staff are used collectively to select a policy and determine the specific wash program for each type of linen. This layer also handles the storage and management of application data and policy rules. Application data includes business-oriented operational information, such as user profiles and business rules. In addition to directly obtaining data from tags and sensors, this layer can gather and aggregate context data from external sources through a virtual sensor abstraction, which might involve web services, and store this data in its database. For instance, the external context-aware application development platform PCAD [6] offers an interface to provide its context data to requesting parties. In this scenario, PCAD acts as the context data provider for HLM, which processes this data. There is also the option to enhance this integration by transferring the responsibility for context data storage from HLM to PCAD, while HLM would retain responsibility for storing business-related operational data.

Inference Layer: The Inference Layer plays a crucial role within the system, primarily focusing on decision-making. A rule engine performs inferences and reasoning using the information stored in the repository by the Data Acquisition Layer. Policy files that are stored in the repository are also utilized by inference layer. The advantage of using layered architecture becomes evident as changes to policies addressing new cleaning requirements will not cause any changes in the rest of the system. Machine learning algorithms and AI-based techniques are promising alternatives in decision-making.

Presentation Layer: Presentation layer contains usability components and navigational elements that enable medical staff to interact with the system through services offered by this layer. Manual interventions, data entry by medical staff, and tasks such as creating, reviewing, updating policy documents are performed through a graphical user interface.

V. Discussion and Conclusion

We have presented a software system to handle the needs of medical laundry. Such a system is considered context aware because for example the cleaning requirements of a hotel and a hospital differs from each other hence must be handled in a context aware manner. The system uses RFID tags to identify hospital laundry items, signaling that these items are part of a hospital's laundry process and setting parameters for their cleaning. Based on this data, the system can choose specific *cleaning agent* [context attribute] that require particular temperature ranges and may opt for air drying rather than using a dryer. The context-aware laundry system monitors and adjusts the cleaning process using hospital-specific context information, including item IDs (RFID tags), *detergent type, temperature, drying conditions* (such as circulating air at room temperature), *time*, and *cost* [context attributes]. The system's flexibility allows for the addition of other context attributes. For example, if the hospital prefers not to reuse bedding items that have been washed more than three times, this requirement can be easily integrated by adding a "*number of washes*" attribute. The benefits of preventing infections far outweighs the costs. The RFID readers and tags used in our solution are cheaper equipment considering other hospital treatment and diagnosis devices. Tags are extremely cheap and can resist over 200 washing cycles. Software development and maintenance costs depend on factors such as deployment and configuration. With a service-oriented architecture based on web services, operators can continuously and remotely oversee the process, check the status of items linked to various hospital departments, and make adjustments as needed. The proposed layered architecture is modular, extensible, and cohesive, and the use of web services ensures a high degree of component decoupling and agility in today's IT landscape. As a future work we plan to integrate more automation such as using image processing to analyze the images of the soiled linens to determine its condition without staff intervention and estimate and predict the status of an item based on previous data using machine learning techniques.

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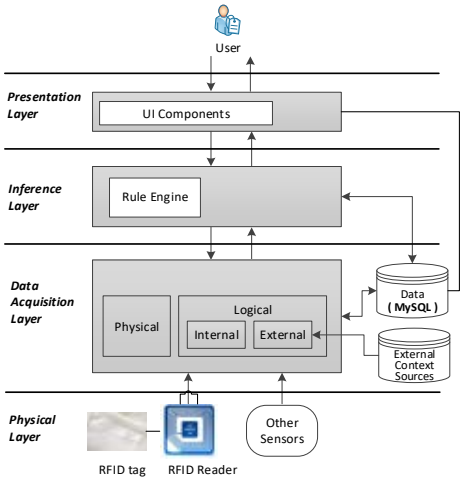


Fig. 4. Context-Aware Architecture for the HLM (adapted from [7])

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