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Semantic-Rich Recommendation System for Medical Emergency Response System

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ABSTRACT

The emergency response process consists of methodical and coordinated series of actions and protocols executed by individuals and organizations to proficiently address crises. When planning for medical emergencies, it is vital to work with responsive medical organizations to ensure good communication and coordination. Unlike e-government processes, emergency response processes are focused on knowledge and may frequently change as the emergency situation develops. It is important to change the emergency response plan for dynamic situations and the proposed method helps to create a flexible plan for emergency responses. The proposed approach uses a system for organizing knowledge to figure out the needs and the resources essential for an emergency. It helps to identify the organizations to be involved based on their rules for mutual aid and jurisdiction. Experimental analysis shows that the proposed method outperforms Smart-c and DCERP in suggesting a greater number of hospitals during medical emergency and achieves 0.8, 0.9 and 0.9 precision, recall, and f-measure approximately.

KEYWORDS

Business Process Composition, Emergency Response Processes, Emergency Management Ontology, Knowledge-Centric Business Processes, Process Evolution

INTRODUCTION

An emergency refers to a circumstance that presents an imminent peril to human well-being, survival, and assets, necessitating prompt measures to avert its exacerbation. The interventions are structured as a procedural framework, commonly referred to as an emergency response procedure. This procedure is typically outlined in an emergency plan (Liu et al., 2015). The emergency response plan serves the

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purpose of delineating the necessary courses of action to be undertaken to effectively manage crisis situations. Additionally, it furnishes vital details pertaining to the many organizations and resources that are engaged in the emergency response process (Ni et al., 2020). The premise underlying this concept is that the process of emergency response bears resemblance to that of a business, thereby rendering it amenable to being represented as a workflow model. A workflow can be characterized as a visual depiction of a specific process, including clearly defined operations, commonly known as tasks.

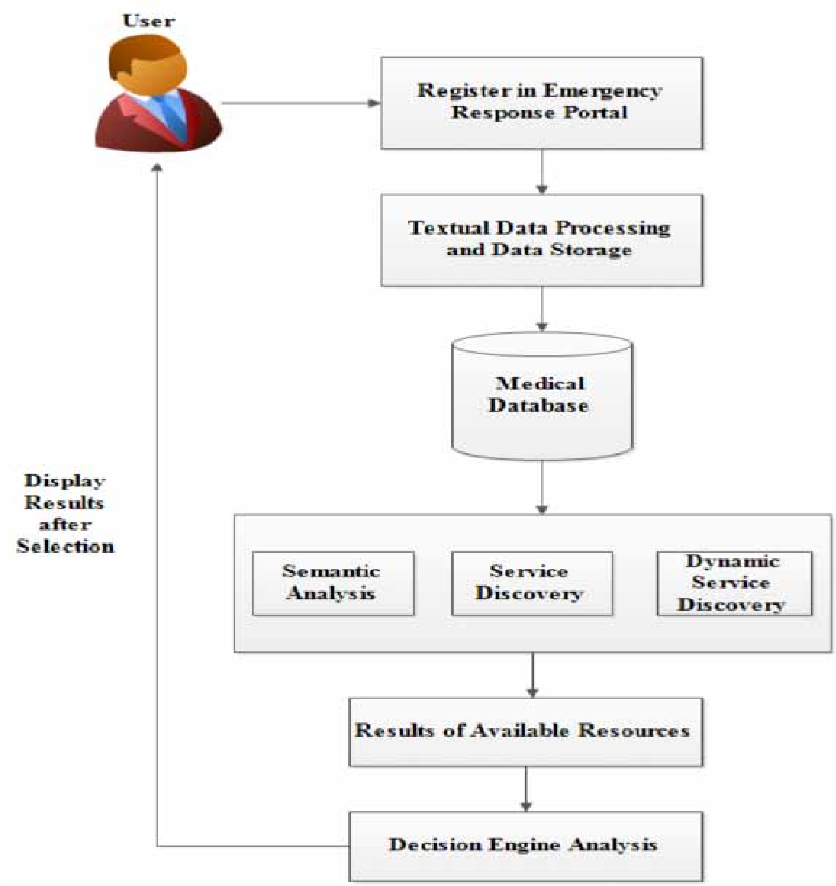
An emergency response refers to the coordinated efforts and actions taken in a crisis situation. It involves various activities that are carefully planned and executed to address the emergency effectively. The key to successful emergency planning is ensuring clear communication and collaboration among different operational systems. Agencies from both the public and commercial sectors, as well as government agencies, are involved in this cooperative effort. Government agencies typically rely on public sector processes, such as e-government, to facilitate their emergency response activities. On the other hand, nongovernment agencies often use private sector processes, such as e-commerce, to support their efforts. The emergency response workflow is designed to accommodate both predictable and nondeterministic elements, allowing for flexibility in adapting to different environments (Elahraf et al., 2022).

The dynamic workflow structure of an emergency response emerges based on various factors. Situational considerations include user choices, available resources, and response organization guidelines and regulations. The operational system follows jurisdictional rules that determine the responsibilities of local agencies in extending resources during emergencies. Public and private organizations can work together under the same or separate jurisdictions as a result of mutual aid agreement regulations. Before proceeding with the emergency situation, organizations should determine whether the emergency news is real or not. Zhang et al (2023) introduced a rapid fake news detection model for cyber-physical social services that employs deep learning techniques.

A growing need has emerged for ontologies to be interoperable with each other to obtain precise information. The presence of ontological heterogeneity further complicates the process of achieving interoperability. Mani and Annadurai (2022) introduced a novel revised framework for propagating similarity in ontology mapping. Tiwari and Garg (2022) discussed the methodology used to assess the quality of ontologies. This research will promote the use of existing ontologies and enhance the compatibility of semantic systems. Ontology and semantic web rules language (SWRL) are used to represent data, allowing for easier sharing and interoperability between various information systems. Because of this facility, timely answers to crises can be crafted on the go. The appropriate actions, resources, and organizations for responding are determined through the use of ontology-based reasoning. Numerous online services that expose the features of operational systems used by response agencies and resource provider organizations enable the execution of each task within the emergency response plan. Specifically, for resource management functions, the crisis management system can communicate with response organizations through the response process created using their respective web service application programming interfaces (APIs) (Lemos et al., 2015).

Smart devices allow internet-connected devices to communicate. User interfaces on these devices allow administrative tasks via a web browser linked to the device's server. Attackers most often breach smart devices using cross-site scripting (XSS) in web applications. Chaudhary et al. (2023) presented a system to protect smart devices from XSS attacks. Organizations that respond to disasters make their operational systems accessible online and make their APIs public so that other businesses can use them. Response operations are constructed by fusing the various response organizations' systems and web service APIs. Because of the changing nature of the situation and the introduction of new requirements, the response process may need to be revised and restructured to accommodate these changes. The task at hand necessitates an assessment of the most recent circumstances, as well as the identification of the relevant agencies and organizations capable of supplying the necessary resources. Furthermore, it involves the integration of the web services of these agencies and organizations into the instantiated response process.

Figure 1. Flow diagram of emergency response system



Response organizations have difficulty composing and managing response processes because they do not have a unified system that can easily integrate with their operational systems. In addition, structured business processes that employ event-condition-action rule-based reasoning for process adaptation are limited to the scope of the present techniques for adaptive process construction (Yu et al., 2015; Song & Jacobsen, 2018). Many different scenarios are accounted for in the rules, such as when a service fails and must be replaced by another. Certain types of emergencies, however, call for emergency response process management in which the specific steps to take may not be known in advance. Businesses considering the adoption of workflow technology should be ready to commit a substantial amount of time and effort because the business landscape is highly dynamic, and processes are rarely set in stone, requiring constant adjustments. To enhance flexibility in executing business processes, goal-oriented dynamic workflows are a promising solution. Various goal-oriented frameworks are available in published studies to serve this purpose (Bucchiarone et al., 2017).

Nonetheless, note that defining and modeling goals can be a challenging task for business analysts. The complete diagram of the workflow for a medical emergency response system is shown in Figure 1. User authentication for registering in the emergency response portal can be learned from literature, such as papers by Gupta et al. (2023) and Vinoth et al. (2022).

MOTIVATING FACTORS OF A MEDICAL RECOMMENDATION SYSTEM

The unpredictability of business operations necessitates that workflow systems possess the capability to adapt dynamically to the evolving environment. To achieve this goal, the research community is actively working on enhancing the system's flexibility during runtime, allowing for on-the-fly modifications. Artificial intelligence and deep learning models have accelerated research on knowledge graph (KG) methods and applications in medical services, social media, and other fields. To accomplish named entity recognition with imbalanced labels, Wang et al. (2022) proposed a deep learning model that integrates conditional random field and bidirectional long short-term memory (LSTM). The effectiveness of an information system is typically measured by its ability to align with the organization's requirements; therefore, the focus of research has been on initiatives that use goals to define operational milestones and constraints (Carroll et al., 2004). Sabatucci and Cossentino (2019) introduced an automated approach for extracting implicit goals from a Business Process Model and Notation (BPMN) to support the execution of dynamic workflows. The concept involves identifying goals by observing how the workflow's state changes and combining these states based on logical connections derived from the workflow gateways.

The proposed methodology presents a cohesive framework for the interactive construction of a functional response protocol. Users of this approach draw upon the ideas of jurisdiction and mutual help agreements. They use ontology-based reasoning to ascertain the suitable default actions and resource requirements for a given crisis scenario. Additionally, this approach is used to identify the appropriate response organizations and the APIs of their operational systems. Subsequently, users of this approach create a dynamic response procedure by leveraging the web service APIs of different response organizations (van der Aalst, 2010). This procedure is designed to effectively respond to the evolving environmental conditions and the resources that are currently accessible, ensuring real-time adaptability.

Despite relying on semantic-based reasoning to aid in preparation and decision-making during crises, such systems cannot execute semantic-based emergency response operations in real time (Dijkman et al., 2009). In other words, they do not have the capability to adapt and modify the response processes in real time based on the evolving situation. Service-oriented architecture is a technology that helps different response organizations work together in emergencies (Rosemann & van der Aalst, 2007). There are platforms and systems that allow these organizations to exchange information, plan responses, discover resources, increase the number of iterations, and automate processes.

EMERGENCY RESPONSE SYSTEM CHALLENGES AND OBJECTIVES OF THE PROPOSED SYSTEM

An emergency response system is a recommendation system that is helpful for the stakeholders during medical emergencies. This system is useful for a majority of people, ranging from children to senior citizens. The major concern of using such a system is that the availability and delivery of static preferential content to the user may sometimes be useless and cannot be used under emergency life-saving situations. Some of the other problems include the semantic understanding of textual content that is very challenging, discovery of suitable services in accordance with the emergency situations, selection of the most accurate services, and the reachability concerns of such resources. Several systems might be able to provide a business system that could comfortably aggregate all the components of the emergency response system (Reijers et al., 2009). These problems have led to the following challenging research questions:

- How do organizations understand the textual content entered by the user in web application semantically?
- How do organizations discover the availability of services based on the user's input information?

- What kind of suitable algorithms shall be applicable for accurate decision-making to select the most appropriate services based on the emergency conditions and also in a limited time since the system is meant to cater to the needs of critical emergency situations?
- How do organizations address the problems of dissatisfaction of the users in case they are not satisfied with the display of available services?

With reference to these research questions, we summarize the major objectives of our research for this paper as follows:

- To develop a semantically rich system for resource identification from the given user information
- To provide an efficient decision-making system for resource allocation to the users
- To develop an efficient system for dynamic discovery of resources available to the users

In the rest of this paper, we present a brief survey of the related works, describe the framework in detail, and address the framework's performance analysis. We also include a conclusion and a few suggestions for future research.

RELATED WORKS

The field of business process automation has largely concentrated on managing and composing structured business processes. It encompasses dynamic service composition, process adaptation to shifting conditions, and process structure management. Knowledge-driven processes are unpredictable and emergent, but there is a dearth of integrated techniques that cater to their unique dynamic composition needs. In this work, we outline the fundamental needs and related methodologies for assembling processes in real time. Service-oriented architecture is a technology that enables different applications and systems of response organizations to work together and coordinate their efforts in emergency response processes. Several platforms and systems have been developed to facilitate interoperable information exchange and response planning in emergency management.

To properly analyze the event, determine the required emergency response resources, and develop response strategies, sharing relevant information across various government agencies, nongovernmental organizations, and commercial groups is crucial. Yet, different organizations may use different incident management systems, each including data that is both useful and presented in a different way. Sharing applications across government boundaries will speed up emergency response and eliminate the need for human labor. However, the interoperability problem must be resolved before data from different systems and institutions may be shared. The Unified Incident Command and Decision Support (UICDS) (Morentz et al., 2009; Shafiq et al., 2012) middleware framework is an endeavor that facilitates the exchange of information across all commercial and government incident management systems to establish incident-specific, role-based situational awareness and information sharing.

For emergency groups to work together effectively, the team behind SoKNOS (Doweling et al., 2009) envisioned a system in which disparate data sources could be smoothly connected. The goal of SoKNOS is to let emergency response groups share information more efficiently by letting them easily locate and combine data from various sources. Twitter, Facebook, and YouTube have become popular during disasters for communicating information, opinions, experiences, and requests for immediate assistance. The potential for early detection of disasters and assessment of their severity is greatly enhanced by the availability of such platforms. The quick onset of disasters makes it extremely difficult for people to get reliable information and respond appropriately. To overcome this challenge, the goal is to provide individuals with tailored advice that can help them avoid becoming victims and potentially save their lives. SMARTC (Adam et al., 2012) depicts the architecture of a social media platform designed to better inform individuals before, during, and after a disaster by making timely, relevant, and specific recommendations. These platforms or systems aim to support the semantic-based emergency response planning recommendation system. They interact with response organizations' operational systems to share information across varied systems, provide reasoning assistance for response planning, identify response organizations, and automatically compose processes.

A knowledge-intensive process is one in which user decisions, contextual data, and knowledge creation play a significant role. These processes involve complex tasks in the real world aimed at achieving a common objective. However, the real world is not entirely predictable, and such processes need to be resilient in the face of unexpected circumstances and flexible when dealing with unforeseen exceptions. In practical, real-world situations, predefining every possible recovery action for handling potential exceptions is not feasible. To address this challenge, Marrella et al. (2017) introduced SmartPM, a model and a prototype process management system. This system incorporates a range of techniques to facilitate the automated adaptation of knowledge-intensive processes in real time. These techniques can adjust process instances automatically when unexpected exceptions arise, without the need to explicitly define exception-handling policies or involve domain experts during runtime. The primary goal is to reduce the error-prone, costly manual adjustments that users would otherwise need to make, thus making the process more user-friendly.

Afzal et al. (2021) introduced an innovative strategy for collaborative business process development. This method considers attribute similarity, structural similarity, and semantic information to identify connections between the service operations offered and the business process operations needed. When given a set of interrelated business processes and the service operations available within a user organization, this framework enables organizations to calculate a link between the user organization's service operations and the business process operations of other organizations. This proposed approach to service mapping is specifically designed for atomic services and mandates that all web service operations within the user organization and the business process operations are expressed at the atomic level.

Table 1 compares the merits and demerits of the works cited in this section.

Assy et al. (2015) enhanced the design of configurable process models with a focus on reusability. Configurable process models are a way to model variations in reference models that can be adapted to specific requirements. Designing these models is a complex, error-prone task (Assy et al., 2015). The framework suggested by Assy et al. (2015) proposes using configurable process fragments to assist in this design process. Instead of recommending entire configurable models, Assy et al. (2015) recommend smaller focused subprocesses that are closely aligned with the designer's needs. This approach offered fine-grained assistance to the designer by suggesting configurable subprocesses that are relevant to their specific interests. Moreover, it reduced computation time because only smaller portions of the entire process models need to be merged and simplified the management of configurable process models by enabling designers to specify the configurable parts within their models.

Organizations often employ service-based business processes to realize their objectives through the synchronized execution of a collection of activities realized as services and service compositions. To deal with the exogenous context changes and execution issues that arise when business processes are carried out in dynamic, open, and nondeterministic contexts, organizations typically need to modify these processes. Bucchiarone et al. (2011) proposed an adaptation method that automatically modifies a company's procedures when a change in the operating environment threatens to derail progress toward an objective. To automatically derive required adaptation tasks on demand, Bucchiarone et al. (2011) built a framework that uses planning approaches. The change is made by figuring out what must be done to recover so that work can be resumed on a business process and the original objectives can be met.

La Rosa et al. (2013) focused on the problem of creating consolidated business process models from collections of process models that contain shared fragments. The article examines the process of constructing merged models that involve combining numerous models, as well as digests, which involve

Table 1. Comparison of existing works

Author and year	Technique used	Merits	Demerits
Morentz et al. (2009)	UICDS	Supports information exchange and provides reasoning support	Dynamic response organization discovery is not possible.
Doweling et al. (2009)	SoKNOS	Dynamic response organization discovery is possible.	Automated process composition cannot be done.
Adam et al. (2012)	SMARTC	Facilitates the sharing of knowledge and offers support for logical reasoning in addition to dynamic response organization discovery	Automating the process of combining several operational systems of response groups is not feasible.
Marrella et al. (2017)	SmartPM	Supporting automatic knowledge-intensive process adaption at runtime	It cannot handle hierarchical processes or evolve the process model from captured exceptions.
Afzal et al. (2021)	ASSEMBLE	Outperforms pure attribute-based mapping without time overhead	Service mapping is designed for atomic services only.
Assy et al. (2015)	Aggregated neighbourhood context graph	Produces comprehensible configurable fragments	Only the relationship between an activity and its immediate neighbors is included in the fragments.
La Rosa et al. (2013)	Merged models and digest	Multiway merging	Does not support the coevolution of process variants based on a merged model.

intersecting models. Merged models are designed for analysts who seek to develop a comprehensive model that encompasses a set of process models. These models often reflect different versions of the same underlying process. The objective is to replace the individual variants with the merged model. In contrast, digests serve the purpose of helping analysts in their endeavors to discover the most often occurring fragments within a set of process models. This feature enables them to concentrate their efforts on optimizing these particular fragments.

All the existing algorithms do not address the semantically rich resource identification. Moreover, decision-making is not efficient for resource allocation to the user. The proposed algorithm addresses the solution to the aforementioned problems.

PROPOSED WORK

The proposed system framework consists of two phases: ontology-based reasoning and process composition modeling. The semantic-based emergency response plan recommendation system develops an executable action plan gradually in multiple steps. The input is the collection of attributes or user contextual information (incident type, location, severity, personal details, etc.). The output is the resource availability status from the user contextual information. Initially in information retrieval process, the features are assigned based on the returned recommended default actions and are used as input in the process of discovering and selecting operating systems/service APIs. The APIs of the relevant response agencies and resource providers are discovered and selected during this process. A composition of services that satisfy the objective state is discovered during the CPN-based service selection process. In the final phase, reachability analysis for selected services is performed, and a sequence of transitions is triggered to reach the goal state from the beginning state.

Therefore, the working components used in the proposed system—namely, ontology-based reasoning and process composition modeling—are used in combination to develop a semantically rich system wherein the input knowledge is organized and processed. The proposed system provides optimized results to the user in the medical emergency conditions. This system is extremely important to the users who have medical urgency in priority and are unable to decide the responsive system immediately. The users are provided with good numbers of outputs, and the system is iterated until the user is completely satisfied with the set of results displayed.

Based on the given contextual details of the incident (for example, the type, severity, and location; the predetermined actions or response plans for specific emergency events, the involved response organizations, their jurisdictional boundaries, mutual aid agreement regulations, and the resources they can offer; and the accessible Web services/APIs of the operational systems of these response organizations for resource requests), constructing a response process that is both executable and adaptable to the current incident is necessary. This response process should be capable of evolving as the incident progresses or as the environmental circumstances alter.

The proposed recommendation system can be defined based on four different perspectives:

- What: The proposed system defines the complete set of basic symptoms, such as fever, cold, or chills, which are found to be an alarming situation, especially for children less than 5 years old and people older than 65.
- Why: The system must be a perfect recommendation system because the workflow initiates from the user and then flows through the modules of semantic understanding, discovery of services, selection of services, reachability analysis for dynamic services selection, service allocation, and so on. The final available resources are presented to the user quickly. All the components are actors, and the interaction must be clearly defined.
- Who: The stakeholders and the system components are defined according to the universal vocabulary. Some of the contextual attributes used in the vocabulary of the proposed system are incident type, severity, location, state, city, and patient ID.
- When: A medical emergency can occur at any time. Even the simplest form of sickness, such as fever, cold, a drop in blood sugar level, or a spike in blood pressure, can be treated as emergency situations for children less than 5 years old and people older than 65, or physically and mentally challenged people.

The major focus of the proposed system's first and the last perspective of the definition given above. Because it is a medical emergency system, the services or the resources must be allocated to the individuals quickly. Moreover, if the user is dissatisfied with the existing resources, the system must reiterate the same process for the discovery of a new set of resources related to the user query. The ontology-based matching and process composition modeling activities are shown in Figure 2.

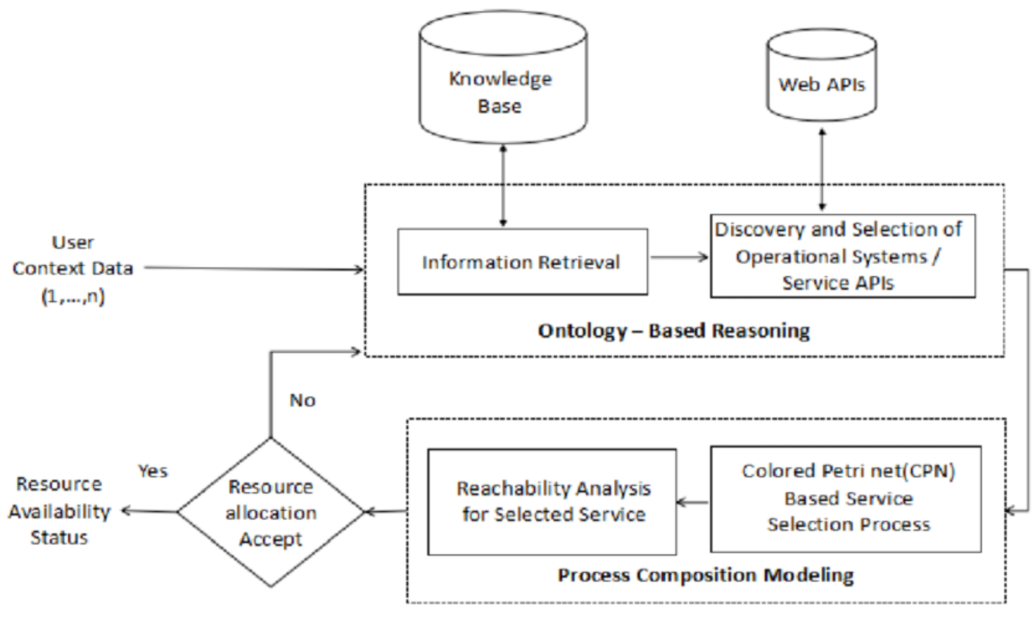
Ontology-Based Reasoning

The system uses an ontology and reasoning engine to prepare a response to a specific situation. The ontology classifies incidents according to their nature, severity, and geographical location, as well as the agencies and organizations responsible for responding to each. The first phase, ontology-based reasoning, consists of two major submodules—information retrieval and discovery and selection of operational systems/service APIs.

Information Retrieval

The system necessitates fundamental incident information in the form of contextual information or contextual attributes during the initial input. Preprocessing is performed to eliminate stop words, and stemming is executed to extract noun entities exclusively from the contextual information provided. Then the noun entities are semantically represented, and the similarity between the knowledge base (which stores several default actions) and the given semantic representation of the noun entities is

Figure 2. Proposed system architecture



evaluated. In a nutshell, the similarity scores can be employed to determine which default actions are most pertinent to the provided contextual information. The system then suggests to the user the top k most pertinent default actions.

Semantic-Based Information Retrieval Model Algorithm

In this section we discuss the steps pertaining to the semantic-based information retrieval model algorithm.

Input: User context data
Output: Recommended default actions
Step 1: Preprocess: Gather a list of recommended actions from a reliable source. Preprocess the text data by removing stop words, stemming or lemmatizing the words, and converting everything to lowercase.
Step 2: Semantic analysis: Semantic analysis involves extracting meaning words and understanding from the data using natural language processing (NLP) techniques.
Step 3: Storing data in a knowledge base: A knowledge base contains information about the default actions that are available to the user.
Step 4: Matching: The algorithm matches the user's context data and intent with the information in the knowledge base using cosine similarity [15] as shown in equation (1) to identify the relevant default actions that are available to the user.

$$\text{Cosine similarity } (Q, K) = (Q * K) / (||Q|| * ||K||) \quad (1)$$

In equation (1), Q and K are the two vectors being compared. (Q * K) is the dot product of Q and K (i.e., the sum of the element-wise products of Q and K). (||Q|| * ||K||) are the Euclidean magnitudes (lengths) of the two vectors that are calculated as sqrt(sum of squares of the elements of Q) and sqrt(sum of squares of the elements of K), respectively.

Step 5: Ranking and recommendation: Finally, the system recommends the top-k relevant default actions to the user, based on the matching results.

Discovery and Selection of Operational Systems/Service APIs

In this process, discovery and selection of the APIs of the operational systems/Web services of the relevant response agencies and resource providers are based on their jurisdictions, rules, and policies using the semantic-based matching algorithm. The input to this algorithm is the recommended relevant default actions. The default actions represented in semantic representation help to find the web APIs represented in API representation, and then the algorithm measures the similarity between the default actions and web APIs (stored several web APIs) using equation (1). The similarity scores rank the APIs based on their relevance to the given default actions. Finally, the web services of the relevant response agencies and resource providers are then recommended.

Process Composition Modeling

The second phase involves process composition modeling, which consists of two primary submodules: colored petri net (CPN)-based service selection process and reachability analysis for the selected services.

CPN-Based Service Selection Process

The CPN (Jensen, 2013) is defined as CPN = (S, P, T, A, N, C, G, E, I). The elements of this formula are defined as follows:

- S is a finite set of non-empty types called color sets.
- P is a finite set of places.
- T is a finite set of transitions.
- A is a finite set of arcs such that: P n T = P n A = T n A = Ø.
- N is a node function. It is defined from A into $P \times T \cup T \times P$.
- C is a color function. It is defined from P into S.
- G is a guard function. It is defined from T into expressions such that: $\forall t \in T$: [Type (G (t)) = Bool$\wedge$ Type (Var (G (t))) $\subseteq$ S].
- E is an arc expression function.
- I is an initialization function.

The method initially calculates the initial and objective states necessary for service composition. Table 2 shows the elements used to determine the starting state of the system by using the provided contextual attributes C. Table 3 lists the elements to compute the goal state by applying the default action as G. Performing reachability analysis involves analyzing the beginning state and goal state, as well as the available service activities represented by CPNs. The method is designed to locate a series of service activities that have the capability to transition the system from its starting state to the desired goal state. Finally, the algorithm returns R, the workflow of the concrete response process.

The response agencies maintain a set of services in the form of inputs and their corresponding outputs, as shown in Tables 2 and 3. The web interfaces are designed in such a way that, once the inputs values are fed by the user through their login, the values are reflected and processed by the internal system of the responsive agencies. The interfaces provide a set of user-friendly attributes that display the inputs and their corresponding outputs so that the user can easily identify them. Moreover, the medications, tests, and the treatments are also shared for the user for easy access and knowledge.

Table 2. Start state computation

Contextual attributes	Initial state
Incident_type = 'Cancer'; Severity = 'High'; Location = 'India'; State = 'TamilNadu'; City = 'Chennai'; Patient_id = 'ABC123'	Incident_type = 'not-null'; Severity = 'not-null'; Location = 'not-null'; State = 'not-null'; City = 'not-null'; Patient_id = 'not-null';

However, this implementation is not shown in the proposed work simulation because the proposed system is well connected to the users who are interested in using the services alone. However, when the user is dissatisfied with the display results, the next process of the reachability analysis module is iterated to choose the best optimized services.

Reachability Analysis for Dynamic Selection of Services

The reachability analysis algorithm is used to do the reachability analysis by creating the CPN occurrence graph after it receives a start state, a goal state, and the CPN model of the available service operations. This technique aims to identify a service composition. The service composition that is returned is shown as a series of transitions that are executed to go from the beginning state to the desired goal state. If the reachability analysis technique yields a sequence of transitions that is not empty, then the related sequence of services can be regarded as a valid service composition workflow R for the specified default action. In the event that the desired state cannot be reached, the algorithm will yield an empty sequence as its output.

Given this CPN, you can apply the reachability analysis algorithm to find a sequence of transitions that can transform the CPN from an initial state to a goal state. For example, suppose, you want to find a sequence of transitions that can take you from the initial state where Location = 'India', Weather = 'Clear', and Appointment = {}, to a goal state where Appointment is a non-empty value. If no solution is found, return an empty sequence. This process is an iterative approach to recommendation systems, where the system recommends organizations to the user, and if the user is not satisfied with the recommendations, the system reprocesses and recommends another set of organizations. This process continues until the user is satisfied with the recommendations.

The recommendation system first collects data about the user's preferences and needs through various methods, such as surveys, past behavior, and demographic information. This information is then used to generate a set of recommendations based on algorithms and models that analyze the user's data and compare it with the data of other users with similar preferences. If the user is not satisfied with the initial recommendations, the system may prompt the user to provide feedback on why the recommendations were not suitable. The feedback may include information on specific organizations that the user would like to see recommended, or the user's preferences may change based on the recommendations that the user has already seen. The system then takes this feedback and reprocesses the data to generate a new set of recommendations based on the updated user preferences. The process repeats until the user is satisfied with the recommendations. Using this iterative approach

Table 3. Goal state computation

Default action	Goal state
1. Request resource provided hospitals. 2. Check hospital availability status. 3. Get confirm appointment.	Resources: 'not-null'; Hospital: 'not-null'; Availability: 'not-null'

Table 4. Comparison with existing systems

Technique/algorithm	Information Sharing	Dynamic discovery of organization	Automated process composition	Semantic rich retrieval
Smart-C	Yes	Yes	No	No
DCERP	Yes	Yes	Yes	No
SBERPRS (proposed work)	Yes	Yes	Yes	Yes

to recommendation systems has several benefits. First, it allows the system to continually improve and learn from user feedback, leading to more accurate recommendations over time. Additionally, it ensures that the users' needs are met and that they are satisfied with the recommendations, leading to increased user engagement and retention.

PERFORMANCE EVALUATION

The development of the web-based application was carried out using the C# programming language and the Visual Studio web server. The incident commander is presented with an interface that enables the generation of a new incident within the ontology. The initial input to the system necessitates fundamental incident information, as outlined in the incident report, including the incident type, date, and location, among other relevant details. Based on the provided information, the system generates recommendations for default reaction actions; it also identifies the specific sorts of resources that are necessary. The user can make modifications to the suggested tasks and resources as needed. The system uses the user's decision and the information included in the ontology to identify prospective response organizations and the APIs of their operational systems or services. This process enables the system to facilitate the request for the necessary resources.

Table 4 and Figures 3–6 show that the proposed system outperforms the existing systems, Smart-C and DCERP, owing to the factor that the semantics of the inputs text are processed efficiently using semantic retrieval techniques in the proposed system. Moreover, the dynamicity of the resources selection and allocation is provided using efficient algorithms, and this is evident from the performance metric factors such as precision, recall, and F-measure.

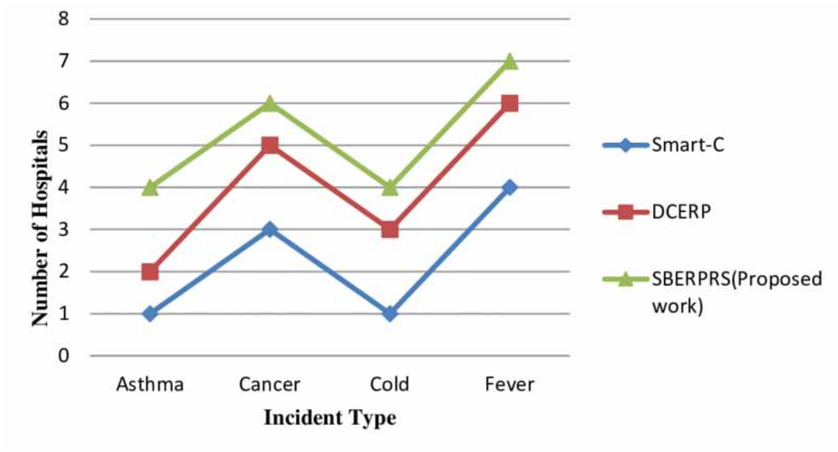
In light of the user's dissatisfaction with the organizations provided, we revisit the preceding steps and subsequently propose an alternative selection of organizations. Table 4 compares the proposed work, Semantic Based Emergency Response Plan Recommendation System (SBERPRS), with other works. The proposed work is validated for the number of hospitals recommended to the users and the number of iterations need to user-satisfied hospitals recommended to them. The performance analysis of the proposed work is shown in Figure 3. This figure shows that our proposed work suggests a higher number of hospitals when compared with other systems.

Precision, Recall, and F-Measure

The evaluation of semantic rich approaches usually measures their effectiveness rather than their efficiency. Precision is a quantitative measure that assesses the accuracy of positive predictions by determining the number of correct ones as given in equation (2).

The accuracy is determined by dividing the number of accurately predicted positive cases by the total number of positive examples that were anticipated. The precision values are evaluated for the semantic rich system, and it is compared with that of other systems as shown in Figure 4.

Figure 3. Performance analysis



$$Precision = \frac{TP}{TP + FP} \tag{2}$$

In equation (2), TP represents when the recommended hospital is indeed relevant for the given situation. FP represents when the recommendation system incorrectly suggests a hospital that is not relevant to the situation.

The recall metric is determined by dividing the count of correctly categorized positive predictions by the total count of positive predictions as given in equation (3). The recall metric evaluates the model's capacity to correctly identify positive predictions. The recall values of the semantic-rich system are assessed and compared with those of other systems, as shown in Figure 5.

$$Recall = \frac{TP}{TP + FN} \tag{3}$$

In equation (3), TP represents when the recommended hospital is indeed relevant for the given situation. FN represents when the recommendation system fails to suggest a hospital that is actually relevant for the situation.

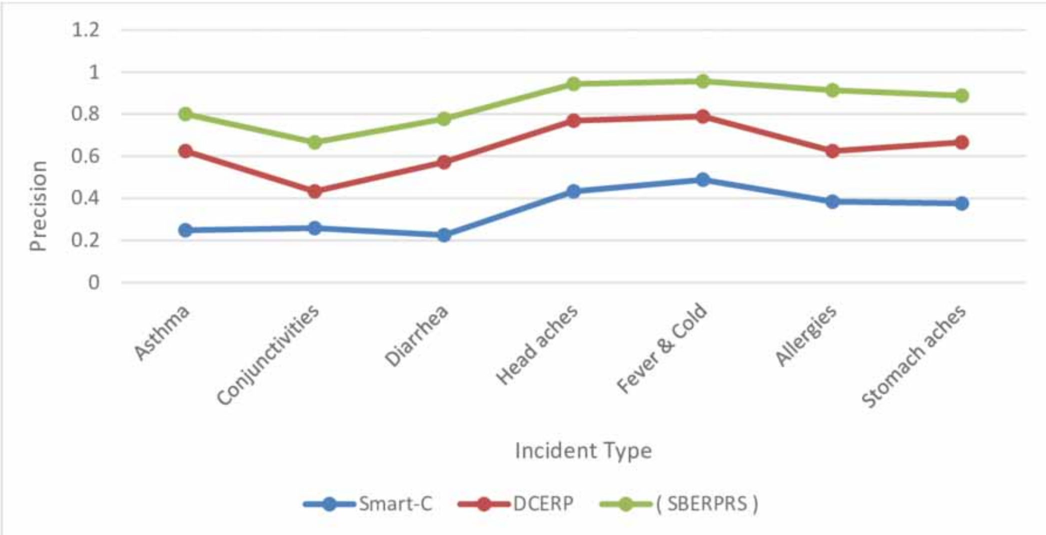
The F-measure offers a method to integrate precision and recall into a unified metric that encompasses both characteristics as given in equation (4). The F-measure values of the semantic-rich system are assessed and compared with those of other systems, as shown in Figure 6.

$$F - measure = 2 * \frac{Precision * Recall}{Precision + Recall} \tag{4}$$

CONCLUSION

An integrated approach for a semantic-based emergency response plan recommendation system is developed for medical applications. The primary element of the methodology is in its

Figure 4. Precision values



independence from preexisting interconnections among the information systems employed by various response organizations. In contrast, ontology-based reasoning is employed to ascertain the essential response activities, requisite resources, and pertinent response organizations. This functionality allows for the creation of a practical response strategy that promotes effective coordination between the incident command system and response organizations, thereby enhancing the management of resources during operations.

Figure 5. Recall values

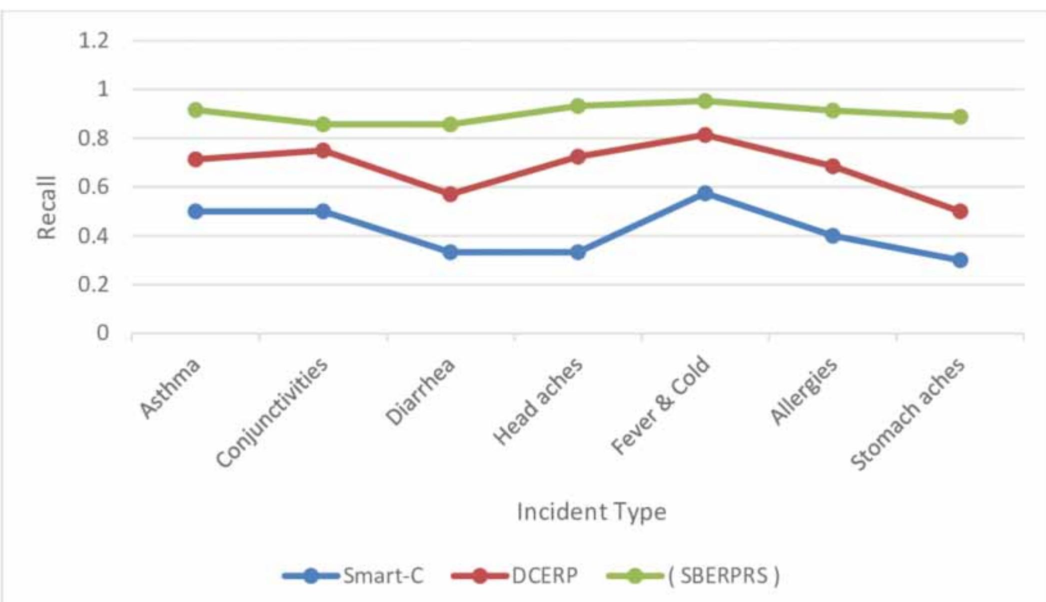
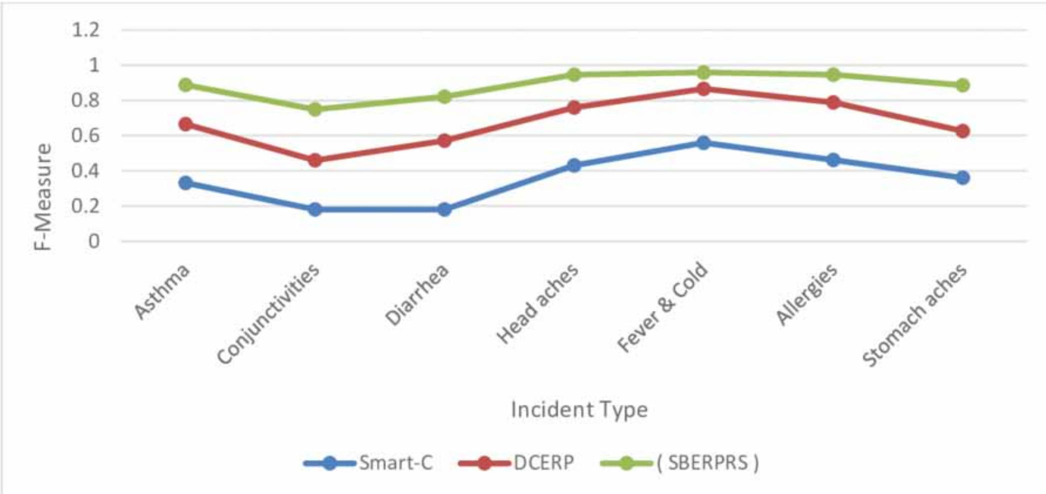


Figure 6. F-Measure values



The results of our study suggest that the inclusion of a comprehensive ontology in the system enables the dynamic composition of a response process that is responsive to the changing circumstances. Nevertheless, the efficacy of the outcomes is significantly contingent upon the caliber and precision of the foundational ontology. The assessment of the ontology's efficacy necessitates thorough examination and critical evaluation by domain specialists who possess profound expertise in the pertinent discipline.

CONFLICTS OF INTEREST

The authors of this publication declare there are no competing interests.

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