Received December 1, 2019, accepted January 2, 2020, date of publication January 7, 2020, date of current version January 16, 2020.

Digital Object Identifier 10.1109/ACCESS.2020.2964710

Text Quality Analysis of Emergency Response Plans

WENYAN GUO[1], QINGTIAN ZENG[2], HUA DUAN[3], WEIJIAN NI[1], TONG LIU[1], CONG LIU[4], AND NENGFU XIE[5]

[1]College of Computer Science and Engineering, Shandong University of Science and Technology, Qingdao 266590, China
[2]College of Electronic and Information Engineering, Shandong University of Science and Technology, Qingdao 266590, China
[3]College of Mathematics and System Science, Shandong University of Science and Technology, Qingdao 266590, China
[4]School of Computer Science and Technology, Shandong University of Technology, Zibo 255300, China
[5]Institute of Agricultural Information, Chinese Academy of Agricultural Science, Beijing 100081, China

Corresponding authors: Qingtian Zeng (qtzeng@163.com), Hua Duan (huaduan59@163.com), and Weijian Ni (niwj@foxmail.com)

This work was supported in part by the NSFC under Grant 61472229, Grant 61602278, Grant 61602279, Grant 71704096, Grant 61702306, Grant 31671588, and Grant 61902222, in part by the Science and Technology Development Fund of Shandong Province of China under Grant 2016ZDJS02A11, Grant ZR2017BF015, and Grant ZR2017MF027, in part by the Humanities and Social Science Research Project of the Ministry of Education under Grant 16YJCZH154, Grant 16YJCZH041, Grant 16YJCZH012, and Grant 18YJAZH017, in part by the Taishan Scholar Climbing Program of Shandong Province, in part by the Taishan Scholar Program of Shandong Province under Grant tsqn201909109, in part by the SDUST Research Fund under Grant 2015TDJH102, and in part by the Graduate Science and Technology Innovation Program of Shandong University of Science and Technology under Grant SDKDYC190223.

ABSTRACT Emergency response plans are regarded as effective guidance for natural disasters and these plans describe emergency response processes in natural language. More specifically, they are textual process descriptions and describe not only how all departments perform their own response tasks, but also how different departments interact with each other. Analyzing text quality of emergency response plans as a typical evaluation approach is an important concern in emergency responses. Because of the flexibility of natural language, emergency response plans normally contain unwanted ambiguities, and it is difficult to check consistency and completeness. Automatic text quality analysis of emergency response plans written in Chinese from the perspective of process descriptions is proposed in this paper. Firstly, three types of response tasks including message sending tasks, message receiving tasks and regular tasks are extracted through Bi-LSTM-CRF networks (a Conditional Random Fields network is combined with a Bidirectional Long Short-Term Memory network). Then, a series of text quality analysis rules associated with extracted response tasks are created. These rules focus on the progressive relationship of four levels of emergency responses, completeness of response tasks, ambiguity and redundancy of emergency response plans. Finally, real-world data is collected to validate the proposed approach, which consists of four types of emergency response plans of natural disasters including district, municipal, provincial and national emergency response plans. It is demonstrated that the proposed approach can be used to facilitate revisions and improvements of emergency response plans.

INDEX TERMS Emergency response plans, process information extraction, text quality analysis, emergency plan evaluation, textual process descriptions.

I. INTRODUCTION

Emergencies threaten public life and property and require rapid responses in a complex and stressed context [1]. In emergency responses, the government and relevant departments work together and cooperate with the military and armed police forces as necessary. So, emergency response is a complex process involving the collaboration and interaction of multiple partners [1], [2]. A typical emergency response process includes not only how all departments perform their own response tasks (inner-processes), but also how different departments interact with each other (interactive processes) [3]. In general, it is comprised of four levels of emergency responses namely I-response, II-response, III-response and IV-response. Emergency response plans are used as effective instructions for emergency responses [4].

The associate editor coordinating the review of this manuscript and approving it for publication was Jenny Mahoney.

This work is licensed under a Creative Commons Attribution 4.0 License. For more information, see http://creativecommons.org/licenses/by/4.0/

An emergency response plan written in natural language describes how an emergency response process can be performed [5], [6]. Thus, an emergency response plan can be regarded as an instance of textual process descriptions.

Evaluating emergency response plans is of great significance to guarantee response efficiency. It can locate defects and provide specific suggestions to revise and improve emergency response plans [7]. Analyzing text quality of emergency response plans as a typical evaluation approach focuses on the development process of the emergency response plan and whether its content is complete and the text format is normative [8]. It is possible to analyze the text quality of the emergency response from the perspective of text description content (i.e. an emergency response process). Our previous work extracted emergency response process models from emergency response plans [5], [6]. The extracted emergency response process makes it possible to perform text quality analysis of emergency response plans from the perspective of process descriptions. In the emergency response plan written in Chinese, a process element is described as a continuous word sequence. The performance of the Chinese language processing tool is much worse than that of English, which limits the performance of extracting process information from Chinese emergency response plans. Therefore, a neural network instead of rule-based approach is used to identify process elements and process element identification is regarded as a sequence tagging problem.

Emergency response plans are documented in natural language to allow for multiple emergency partners to easily understand each other and share the document with each other. However, there exist two key issues with using natural language to describe emergency response processes. Firstly, the flexibility of natural language imposes unwanted ambiguities in emergency response plans. Ambiguity in natural language refers to a type of uncertainty in which several interpretations of the same text can be produced [9], [10]. Choosing the right and reasonable interpretation requires departments and roles with rich experience and domain knowledge. Ambiguous descriptions in emergency response plans are unfriendly to inexperienced departments and roles and prevent them from accurately and quickly understanding their responsibilities. For example, the sentence "*Relevant departments carry out rescue tasks*" does not make it clear which department needs to perform this task. Unfortunately, there are many such ambiguous descriptions in emergency response plans because of their style of writing. Secondly, different from formal process models, emergency response plans written in natural language cannot be verified for consistency and completeness [11]. For example, it is difficult to determine whether the response process described in the emergency response plan is complete or whether there is a lack of department and response task. Hence, text quality analysis of emergency response plans from the perspective of process descriptions has always been an important concern in emergency responses.

According to the extracted emergency response process, emergency response plans have the following quality issues from the perspective of process descriptions.

- Emergency response plans, as official documents issued by the government, require rigorous and standardized descriptions such as complete sentence structure.
- Not only inner-processes of all departments but also interactive processes among multiple departments described in emergency response plans should be correct and complete.
- Emergency response plans should describe differences and correlation of four levels of emergency responses through response tasks and their roles and departments.
- Process descriptions in emergency response plans should be unambiguous, concise and easily understandable.

In this paper, an emergency response plan is regarded as a kind of textual process description and its quality analysis is performed from the perspective of process description. An automatic analysis approach of emergency response plans written in Chinese is proposed to provide text quality assurance. Emergency response processes including three types of response tasks are extracted from emergency response plans through a neural network. Quality metrics of emergency response plans focus on the progressive relationship of the four levels of emergency responses, completeness of response tasks, ambiguity and redundancy of emergency response plans. Four types of emergency response plans for natural disasters in China are collected to validate the proposed approach. Text quality analysis results can provide support for revisions and improvements of these emergency response plans.

The rest of this paper is organized as follows. Section II evaluates related work. Section III introduces emergency response plans. Section IV describes emergency response processes. Section V presents emergency response process extraction. Section VI gives the text quality analysis of emergency response plans from the perspective of process description. Section VII evaluates the proposed approach. In section VIII, we discuss our research while section IX draws some conclusions and presents future work.

II. RELATED WORK

A. EVALUATION OF EMERGENCY RESPONSE PLANS

Two types of evaluation approaches have been widely used.

(1) Evaluate the implementation process of emergency response plans after emergencies. The evaluation of the effectiveness of emergency response plans can avoid reusing poor-quality plans and causing unnecessary losses. In the evaluation process, difficult issues including incomplete and inaccurate evaluation information and subjective perception of the evaluator have attracted a lot of attention. Zhang [8] applied multi-level and grey evaluation method to evaluate implementation effect of hazardous chemical spill plans. Han [12] comprehensively used the methods of Delphi, AHP and FCE and gave an index system to evaluate the operational

performance of emergency response plans. Girard *et al.* [13] proposed a method to evaluate the performance of local emergency response plan under multiple states of its resource degradation. Long *et al.* [14] proposed an integrated assessment method by incorporating an improved technique for order preference by similarity to ideal solutions, Shannon entropy and a coordinated development degree model to evaluate emergency plans.

(2) Evaluate the text quality of emergency response plans before emergencies. However, a properly evaluated response plan before emergencies cannot guarantee an efficient response process. Yang and Rong [7] utilized the matching of knowledge supply and demand to evaluate the capability of emergency plans aiming at providing specific suggestions for relevant departments to revise and improve emergency plans. Chen and Zhang [15] put forward a performance assessment method for emergency planning through the combination of analytic hierarchy process (AHP) and fuzzy theories. The index system of emergency planning performance assessment involved completeness of document system, logicality of content description, operability of the planning and directive attribute of emergency decision-making. Yu and Chi [16] regarded the procedure of an emergency plan as a project and the steps in emergency plans as working procedure and evaluated the operability of emergency plans by a comprehensive index system. Huang [17] established a hierarchical indicator system to comprehensively evaluate the completeness of emergency plans.

To sum up, existing approaches have mostly established indicator systems through statistical analysis of historical data and have produced subjective expert evaluation results. It is difficult to establish an appropriate indicator system because of the variety of emergency types and complex response plan systems. In addition, the psychological factors, knowledge experience and decision-making level of decision makers make it difficult to quantify indicators. Until now, there is also a lack of theoretical evaluation of the text quality of emergency response plans before emergencies.

B. PROCESS MODEL EXTRACTION

The textual description of the emergency response process is a type of intuitive process representation form and is easily understood by emergency partners [5], [18]. Differently, the emergency response process model is rigorous and is mainly used to analyze and verify the emergency response process [19], [20]. Generally speaking, an emergency response process was modeled as a Petri Net or its variants to effectively analyze time performance and detect resource conflicts [3], [21]–[25]. These analysis and verification approaches are mainly dependent on structure characteristics of emergency response process models. Moreover, for business process models, text label analysis and terminological ambiguity checking were also used to provide quality assurance [26]–[29]. Process model extraction mainly deals with the transformation from textual process descriptions to business process models. In totally, process model extraction has two key steps: process element identification and process model generation. Friedrich [30] proposed a rule-based method to extract BPMN process models from English natural language text based on syntactic parsing tree and typed dependencies of Stanford Parser. Dufour-Lussier [31] introduced a method to automatically extract a rich case representation from cooking recipes for process-oriented case-based reasoning. Zolotarew [32] proposed a method for extracting business process from natural language text through intermediate process model using the spreadsheet-based representation. Renato [33] established a set of mapping rules associated with natural language processing techniques to identify process elements used for modeling business processes. Halioui [34] introduced an ontology-based workflow extraction framework to acquire processual knowledge from texts.

C. PROCESS ELEMENT IDENTIFICATION

In emergency response plans, each process element to be extracted is described as a sequence of words. Hence, process element identification can be regarded as a sequence tagging problem. Statistical learning models including Hidden Markov Models (HMM), Maximum Entropy Markov Models (MEMMs) [35] and Conditional Random Fields (CRF) [36] have been widely used to solve the sequence labeling problem in natural language processing. In general, CRF performs better than the other two models. In recent years, neural networks such as the Long Short-Term Memory network (LSTM) and the bidirectional Long Short-Term Memory network (Bi-LSTM) have been widely used in natural language processing [37]. For a sequence tagging problem, neural networks require word sequence as input layer and tag sequence of process elements as output layer. Huang proposed the Bi-LSTM-CRF network (a CRF network is combined with a Bi-LSTM network) and compared its performance with that of CRFs and Bi-LSTM [38]. Three advantages of the Bi-LSTM-CRF network were also pointed out: (1) both past and future input features are added through bidirectional LSTM; (2) sentence level tag information is added through the CRF layer; (3) the Bi-LSTM-CRF network is robust and has less dependence on word embedding. Hence, the Bi-LSTM-CRF network is selected to identify process elements from the emergency response plan.

III. EMERGENCY RESPONSE PLANS

An emergency response plan typically contains four sections which are corresponded to four levels of emergency responses, i.e. first level emergency response, second level emergency response, third level emergency response and fourth level emergency response as shown in Fig. 1. The first level emergency response is for the most serious emergencies and the fourth level emergency response is for the least serious emergencies. In order to improve the efficiency of disaster relief resources, different levels of emergency responses are assigned to different levels of response tasks, departments and roles. The first level emergency response has higher priority

x Emergency response
x.1 First level emergency response
x.1.1 Starting procedure
After the disaster occurs, the Provincial Disaster Reduction Committee Office analyzes and evaluates to determine that the disaster situation have reached the starting standard, and ……
x.1.2 Emergency response measurement
The director of the Provincial Disaster Reduction Committee guides and supports provincial natural disaster relief work in the affected city.
(1) After receiving the disaster report, the Provincial Civil Affairs Department reports it to the provincial government and the Ministry of Civil Affairs within 2 hours.
……
(10) ……

x.2 Second level emergency response
x.2.1 Starting procedure
……
x.2.2 Emergency response measurement
……

x.3 Third level emergency response
x.3.1 Starting procedure
……
x.3.2Emergency response measurement
……

x.4 Fourth level emergency response
x.4.1 Starting procedure
……
x.4.2 Emergency response measurement
……

FIGURE 1. An example of emergency response plans.

in response tasks, departments and roles than other three levels of emergency responses.

In each section of the emergency response plan, the parts of "*starting procedure*" and "*emergency response measurement*" describe the emergency response process in detail. Each sentence describes two types of response tasks including regular tasks and interactive tasks. Interaction tasks often involve two types of departments and roles, i.e. message sender and message receiver. A coordinated interaction among different roles and departments is critical for a timely response to emergencies. For example, the 1st sentence of Fig. 2 describes an interactive task which involves the department "the Provincial Disaster Reduction Committee Office" (message sender) and the role "the director of the Provincial Disaster Reduction Committee"(message receiver). Regular tasks describe which role or department is responsible for which task. For instance, the 3rd sentence of Fig. 2 describes the task "decides to enter II-response state" for the role "the Director of the Provincial Disaster Reduction Committee".

Text quality analysis of the emergency response plan from the perspective of process descriptions includes the following four aspects:

(1)The progressive relationship among four levels of emergency responses should be correct. For example, the

1. The Provincial Disaster Reduction Committee Office proposes to the Director of the Provincial Disaster Reduction Committee to enter II- response.
2. The Provincial Disaster Reduction Committee Office proposes to the Deputy Director of the Provincial Disaster Reduction Committee to enter III- response.
3. The Director of the Provincial Disaster Reduction Committee decides to enter II-response state.
4. The Deputy Director of the Provincial Disaster Reduction Committee decides to enter III-response state.
5. The relevant member units of the Provincial Disaster Reduction Committee carry out comprehensive assessment and verification of disaster losses in accordance with the relevant provisions.

FIGURE 2. Five sentence examples of the emergency response plan.

1st sentence of Fig. 2 describes an interactive task of the second level emergency response and the 2nd sentence of Fig. 2 describes an interactive task of the third level emergency response. The two interactive tasks correspond to the same tasks and message senders and different message receivers. The message receiver of the second level emergency response " the Director of the Provincial Disaster Reduction Committee" is the superior of the message receiver of the third level emergency response "the Deputy Director of the Provincial Disaster Reduction Committee". Similarly, the 3rd sentence of Fig. 2 describes a regular task of the second level emergency response and the 4th sentence of Fig. 2 describe a regular task of the third level emergency response. The two regular tasks correspond to a same task and different executive roles. The executive role of the 3rd sentence of Fig. 2 is the superior of the executive role of the 4th sentence of Fig. 2. Different levels of emergency response are assigned to different levels of response tasks and high response levels of response tasks correspond to high levels of roles and departments. In addition, the overlaps of response tasks imply the correlation of four levels of emergency responses.

(2) Response task descriptions should be complete. For emergency response interactive processes, complete descriptions of interactive tasks contribute to guarantee coordination and cooperation among multiple departments. A complete interactive task involves both message senders and message receivers such as the 1st sentence and 2nd of Fig. 2. In addition, complete descriptions of regular tasks are critical to explaining a particular department or role should perform which task. A complete regular task involves both tasks and their executive departments or roles such as the 3rd and 4th sentences of Fig. 2.

(3) Response task descriptions should be accurate. Ambiguous descriptions of response tasks prevents departments and roles from understanding emergency response processes accurately. For example, in the 5th sentence of Fig. 2, the department "the relevant member units of the Provincial Disaster Reduction Committee" cannot be mapped to the emergency response organization system. This type of

sentence cannot accurately describe which department or role is responsible for the task "carry out comprehensive assessment and verification of disaster losses".

(4) Process descriptions of the emergency response plan should be concise. The part "in accordance with the relevant provisions" of the 5th sentence of Fig. 2 is irrelevant with response task completion. The high proportion of irrelevant parts in the sentence will inevitably affect the understanding of the emergency response plan.

IV. EMERGENCY RESPONSE PROCESSES

An emergency response process consists of I-response, II-response, III-response and IV-response sub-processes depending on the severity of emergencies. The priority relation among the four response sub-processes is written as $IV < III < II < I$. Each response sub-process is denoted as a collection of response tasks. There exist three types of response tasks, i.e. regular task, message sending task and message receiving task. Message sending tasks and message receiving tasks are called interactive tasks and mainly used to perform interactive processes of emergency responses.

Definition 1: A regular task is a 4-tuple $T =< level, tRole, tDep, tTask >$ *where (1) level denotes response level to which the regular task belongs; (2) tRole and tDep denote executive roles and departments of the regular task; and (3) tTask denotes task description of the regular task.*

Definition 2: A message sending task is a 6-tuple $S =< level, sRole, sDep, eRole, eDep, sTask >$ *and a message receiving task is a 6-tuple* $E =< level, sRole, sDep, eRole, eDep, rTask >$*, where (1) level denotes response level to which the message sending and receiving tasks belong; (2) sRole and sDep denote message sending roles and departments; (3) eRole and eDep denote message receiving roles and departments, and (4) sTask and rTask denote task descriptions of the message sending and receiving tasks.*

Definition 3: An emergency response process $\Sigma = \Sigma_T \cup \Sigma_S \cup \Sigma_E$*, where* $\Sigma_T = \{T_1, T_2, T_3, \ldots, T_M\}$*,* $\Sigma_S = \{S_1, S_2, S_3, \ldots, S_N\}$*,* $\Sigma_E = \{E_1, E_2, E_3, \ldots, E_P\}$*, and T, S and E denote regular tasks, message sending tasks and message receiving tasks, respectively.*

Each emergency response plan corresponds to an emergency response organization system which describes all departments and roles of the emergency response and their hierarchical relation as shown in Fig. 3. There exists superior-subordinate relation among different departments or roles. In Fig. 3, the command center is the superior of member units and the subordinate of superior departments. The member units $M_1, M_2, \ldots, M_n$ are at the same level.

Definition 4: A set of departments is written as $D = \{d_1, d_2, d_3, \ldots, d_m\}$*.* $\forall d_i, d_j \in D$ *and* $F = \{\rightarrow, \Rightarrow, \doteq, \leftarrow, \Leftarrow\}$ *denotes the relation of the two departments.*

(1) If $d_i \rightarrow d_j$*,* d_i *is the subordinate of* d_j*.*
(2) If $d_i \Rightarrow d_j$*,* d_i *is not the superior of* d_j*.*
(3) If $d_i \doteq d_j$*,* d_i *and* d_j *are at the same level.*
(4) If $d_i \leftarrow d_j$*,* d_i *is the superior of* d_j*.*
(5) If $d_i \Leftarrow d_j$*,* d_i *is not the subordinate of* d_j*.*

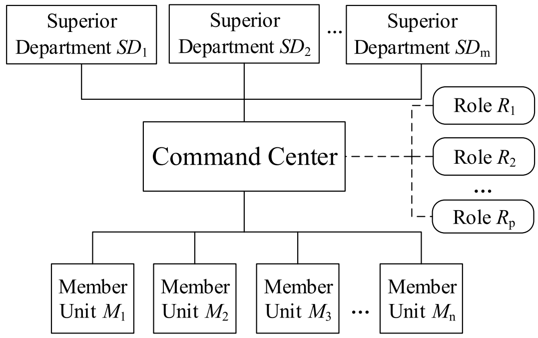

FIGURE 3. An emergency response organization system.

Definition 5: $\forall d \in D$ *and* $d = \{r_1, r_2, r_3, \ldots, r_n\}$ *denotes the department d is consist of n roles.* $\forall r_i, r_j \in d$ *and* $F = \{\prec, \ll, \cong, \succ, \gg\}$ *denotes the relation of the two roles who belong to the same department.*

(1) If $r_i \prec r_j$*,* r_i *is the subordinate of* r_j*.*
(2) If $r_i \ll r_j$*,* r_i *is not the superior of* r_j*.*
(3) If $r_i \cong r_j$*,* r_i *and* r_j *are at the same level.*
(4) If $r_i \succ r_j$*,* r_i *is the superior of* r_j*.*
(5) If $r_i \gg r_j$*,* r_i *is not the subordinate of* r_j*.*

To determine the superior-subordinate relation of the two roles r_k and r_t, there exist two cases: (1) If r_k and r_t belong to the same department, their superior-subordinate relation can be directly determined according to the emergency response organization system. (2) If r_k and r_t belong to different departments, the superior-subordinate relation between their departments can represent the relation between the two roles themselves.

Messaging and collaboration guarantee interactions among different departments and roles. Messaging often occurs between superior and subordinate departments or roles. For example, subordinate departments or roles report disaster information to their superiors while superior departments or roles give disaster relief order to their subordinates. Collaboration usually occurs among the peer departments and roles who need to perform a common task. Generally, the interactive process of the emergency response is centrally controlled by a command center, multiple superior departments and member units [40]. The command center is responsible for asking for instructions from its superior departments and collecting information from its member units to make decisions.

V. EMERGENCY RESPONSE PROCESS EXTRACTION

In order to analyze text quality of emergency response plans from the perspective of process descriptions, extracting emergency response processes is a critical step. Firstly, emergency response process elements are identified and extracted through a neural network. Then, three types of response tasks are generated from the extracted process elements.

A. PROCESS ELEMENTS IDENTIFICATION

An emergency response plan is composed of a number of sentences named long sentences, and each long sentence contains

TABLE 1. An example of tagging process elements.

Tokens	The	Provincial	Disaster	Reduction	Committee	publishes	disaster	losses	based	on	regulations
POS	DT	NNP	NNP	NNP	NNP	VBZ	JJ	NNS	VBG	TO	NNS
Tags	B-D	I-D	I-D	I-D	B-T	I-T	I-T	I-T	O	O	O

TABLE 2. Process element tags.

Process elements	Roles	Departments	Regular tasks	Message sending tasks	Message receiving tasks	Others
Tags	B-R/I-R	B-D/I-D	B-T/I-T	B-S/I-S	B-E/I-E	O

several subordinate clauses named short sentence [6]. The short sentence is an independent sentence or clause that contains only one subject-predicate structure. Particularly, a long sentence is separated into multiple short sentences by commas in emergency response plans written in Chinese. In word segmentation and part-of-speech tagging, a sentence is divided into several tokens and each token is assigned with a unique tag that indicates its syntactic role. In our preprocessing, each short sentence is followed by a punctuation mark to indicate the end of the short sentence and an emergency response plan text is decomposed into a set of short sentences by these punctuation marks. Then, each short sentence is divided into several tokens with their part-of-speech tags by jieba library.[1] For example in Table 1, the first and second rows represent tokens of original short sentence and their part-of-speech tags, respectively. The short sentence "The Provincial Disaster Reduction Committee publishes disaster losses based on regulations" is divided into "The-DT, Provincial-NNP, Disaster-NNP, Reduction-NNP, Committee-NNP, publishes-VBZ, disaster-JJ, losses-NNS, based-VBG, on-TO, regulations-NNS".

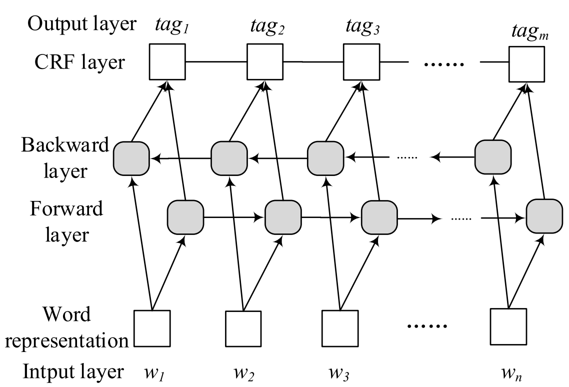

FIGURE 4. A Bi-LSTM-CRF network.

In this paper, we use the Bi-LSTM-CRF network (a Conditional Random Fields network is combined with a Bidirectional Long Short-Term Memory network) [38] to identify process elements from emergency response plans. Fig 4 gives a framework of the Bi-LSTM-CRF network which requires a token sequence as the input layer and a tag sequence of process elements as the output layer. At the input layer, each word is represented as a random higher-dimensional vector. Through the Bi-LSTM-CRF network, each token is assigned a tag of process elements depending on lexical morphology and context. Five types of process elements, i.e. regular task descriptions (tagged with "T"), roles (tagged with "R"), departments (tagged with "D"), message sending task descriptions (tagged with"S"), message receiving task descriptions (tagged with "E") and irrelevant elements (tagged with "O") are identified as shown in Table 2. In addition, BIO encoding (B-begin, I-inside, O-outside) is used to tag each token. At the output layer of the neural network, a sequence of process elements is generated from the same type of tags. For example in Table 1, the third row represents tag results of process elements and the sequence of a department "The Provincial Disaster Reduction Committee" consists of one tag of "B-D" and four tags of "I-D".

[1] https://pypi.org/project/jieba

B. RESPONSE TASK GENERATION

Following the previous step, message sending tasks descriptions, message receiving task descriptions, regular task descriptions, roles and departments are identified from each short sentence of emergency response plans. In order to generate the three types of response tasks, it is necessary to further identify the relation between role/department and task descriptions. In other words, the sender and the receiver of interactive tasks and the executor of regular tasks need to be distinguished from identified roles and departments. Twelve types of combination patterns of process elements are given in Table 3 where executor denotes executive role and department, sender denotes message sending role and department and receiver denotes message receiving role and department. In emergency response plans written in Chinese, the subject often appears in the first short sentence and the other short sentences lack subjects after their separating from the long sentence. In this case, it is usually necessary to supplement their subjects according to the subject of the long sentence. For pattern 1 Table 3, "executor" is the subject to be supplemented. For patterns 5 and 7, "sender" is the subject to be supplemented. For pattern 9, "receiver" is the subject to be supplemented. Before generating response tasks, the process element of role or department is supplemented at the beginning of the short sentence if its subject is missing. In addition, the sequential relation of short sentences determines the execution relation of response tasks.

TABLE 3. Combination patterns among process element in short sentences.

Response tasks	No	Patterns
Regular tasks	0	executor + regular task
	1	regular task
	2	executor
Message sending tasks	3	sender + message sending task
	4	sender + message sending task + to + receiver
	5	message sending task + to + receiver
	6	sender + to + receiver + message sending task
	7	to + receiver + message sending task
Message receiving tasks	8	receiver +message receiving task
	9	message receiving task
	10	receiver + from + sender + message receiving task
	11	receiver + message receiving task+ from + sender+ message sending task

Algorithm 1 To Generate a Regular Task

1: Input: a short sentence with identified process elements (sen)
2: Output: a regular task (T)
3: **if** $sen.MSD = \phi$ && $sen.MRD = \phi$ **then**
4: $\quad T.level \leftarrow response\ level$; $T.tTask \leftarrow \phi$;
5: $\quad T.tRole \leftarrow \phi$; $T.tDep \leftarrow \phi$
6: $\quad$ **if** $sen.RTD \neq \phi$ **then**
7: $\quad\quad T.tTask \leftarrow sen.RTD$
8: $\quad$ **end if**
9: $\quad$ **if** $sen.ROLE \neq \phi$ **then**
10: $\quad\quad T.tRole \leftarrow sen.ROLE$
11: $\quad$ **end if**
12: $\quad$ **if** $sen.departments \neq \phi$ **then**
13: $\quad\quad T.tDep \leftarrow sen.DEP$
14: $\quad$ **end if**
15: **end if**
16: Return T

Algorithm 1 illustrates how to generate a regular task from a short sentence. It requires a short sentence with identified process elements including message sending task descriptions ($sen.MSD$), message receiving task descriptions ($sen.MRD$), regular task descriptions ($sen.RTD$), roles ($sen.ROLE$) and departments ($sen.DEP$) as input and outputs a regular task. If message sending and receiving tasks are not described in the short sentence, a regular task is generated (line 3-5). If the identified process element of the short sentence is task descriptions of the regular task, it is assigned to $T.tTask$ (line 6-8). If the identified process element in the short sentence is executive role of the regular task, it is assigned to $T.tRole$ (line 9-11). If the identified process element in the short sentence is executive department of the regular task, it is assigned to $T.tDep$ (line 12-14). A set of regular tasks is generated from all short sentences of an emergency response plan.

Combination patterns of process elements and the keyword "to" are used to distinguish sender and receiver from identified roles and departments. Algorithm 2 illustrates how to generate a message sending task from a short sentence.

Algorithm 2 To Generate a Message Sending Task

1: Input: a short sentence with identified process elements (sen))
2: Output: a message sending task (S)
3: **if** $sen.MSD \neq \phi$ **then**
4: $\quad S.level \leftarrow response\ level$
5: $\quad S.sTask \leftarrow sen.MSD$
6: $\quad S.sRole \leftarrow \phi$; $S.eRole \leftarrow \phi$
7: $\quad S.sDep \leftarrow \phi$; $S.eDep \leftarrow \phi$
8: $\quad$ **if** "to" $\in sen$ **then**
9: $\quad\quad S.sRole \leftarrow sen.ROLE$ before "to"
10: $\quad\quad S.eRole \leftarrow sen.ROLE$ after "to"
11: $\quad\quad S.sDep \leftarrow sen.DEP$ before "to"
12: $\quad\quad S.eDep \leftarrow sen.DEP$ after "to"
13: $\quad$ **end if**
14: $\quad$ **if** "to" $\notin sen$ **then**
15: $\quad\quad S.sRole \leftarrow sen.ROLE$ before $sen.MSD$
16: $\quad\quad S.sDep \leftarrow sen.DEP$ before $sen.MSD$
17: $\quad$ **end if**
18: **end if**
19: Return S

It requires a short sentence with identified process elements as input and outputs a message sending task. If a message sending task is described in the short sentence, a message sending task is generated (line 3-7). If the short sentence contains the keyword "to", the identified role (department) before "to" is assigned to $S.sRole$ ($S.sDep$) and the identified role (department) after "to" is assigned to $S.eRole$ ($S.eDep$) (line 8-13). If the short sentence does not contains the keyword "to", the identified role (department) before the message sending task is assigned to $S.sRole$ ($S.sDep$) (line 14-19). A set of message sending tasks is generated from all short sentences of an emergency response plan.

Combination patterns of process elements and the keyword "from" are used to distinguish sender and receiver from identified roles and departments. Algorithm 3 illustrates how to generate a message receiving task from a short sentence. It requires a short sentence with identified process elements as input and outputs a message receiving task.

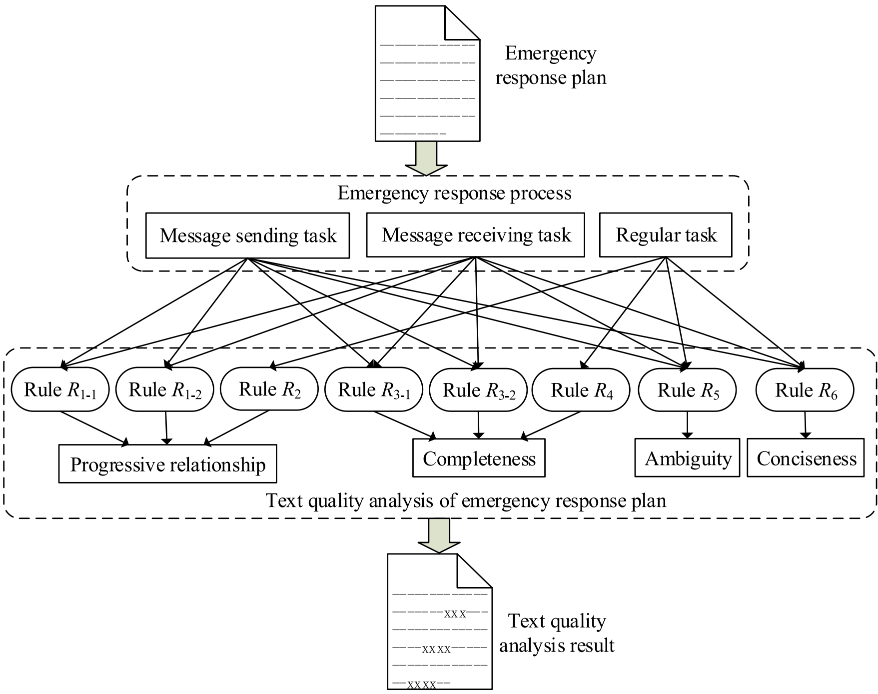

FIGURE 5. A framework of text quality analysis of emergency response plans.

Algorithm 3 To Generate a Message Receiving Task

1: Input: a short sentence with identified process elements (sen)
2: Output: a message receiving task (E)
3: **if** $sen.MRD \neq \phi$ **then**
4: $\quad E.level \leftarrow response\ level$
5: $\quad E.sTask \leftarrow sen.MRD$
6: $\quad E.sRole \leftarrow \phi$; $S.eRole \leftarrow \phi$
7: $\quad E.sDep \leftarrow \phi$; $S.eDep \leftarrow \phi$
8: $\quad$**if** "$from$" $\in sen$ **then**
9: $\quad\quad E.sRole \leftarrow sen.ROLE$ after "from"
10: $\quad\quad E.eRole \leftarrow sen.ROLE$ before "from"
11: $\quad\quad E.sDep \leftarrow sen.DEP$ after "from"
12: $\quad\quad E.eDep \leftarrow sen.DEP$ before "from"
13: $\quad$**end if**
14: $\quad$**if** "$from$" $\notin sen$ **then**
15: $\quad\quad E.eRole \leftarrow sen.ROLE$ before $sen.MRD$
16: $\quad\quad E.eDep \leftarrow sen.DEP$ before $sen.MRD$
17: $\quad$**end if**
18: **end if**
19: Return E

If a message receiving task is described in the short sentence, a message receiving task is generated (line 3-7). If the short sentence contains the keyword "from", the identified role (department) after "from" is assigned to $E.sRole$ ($E.sDep$) and the identified role (department) before "from" is assigned to $E.eRole$ ($E.eDep$) (line 8-13). If the short sentence does not contains the keyword "from", the identified role (department) before the message receiving task is assigned to $E.eRole$ ($E.eDep$) (line 14-19). A set of message receiving tasks is generated from all short sentences of an emergency response plan.

VI. TEXT QUALITY ANALYSIS OF EMERGENCY RESPONSE PLANS

This section introduces the approach to analyze text quality of emergency response plans from the perspective of process descriptions. Fig. 5 gives a framework of text quality analysis of emergency response plans. Six rules of text quality analysis associated with the extracted response tasks are proposed and then are used to evaluate the progressive relationship of four levels of emergency responses, completeness analysis of emergency response tasks, and ambiguity and redundancy of emergency response plans. Finally, text quality analysis results are generated and provide support for revisions and improvements of emergency response plans.

A. PROGRESSIVE RELATION ANALYSIS OF FOUR LEVELS OF EMERGENCY RESPONSES

Progressive relation analysis focuses on the correctness of difference descriptions of four levels of emergency responses. Different levels of emergency response are assigned to different levels of response tasks. Departments and roles involved in response tasks correspond to different levels of the emergency response organization system. For the interactive process of multiple departments, high response levels of interactive tasks correspond to high levels of message senders and receivers. For inner-processes of all

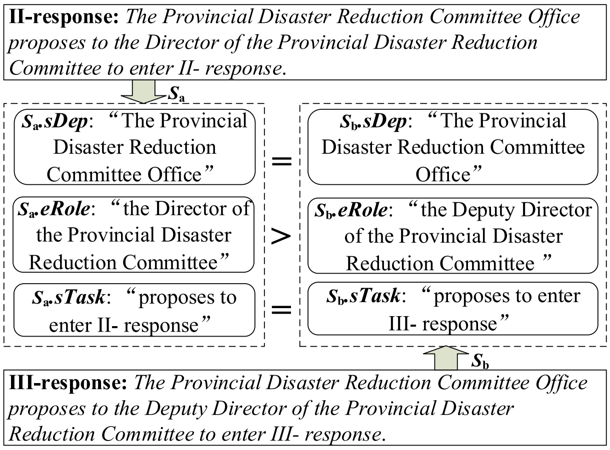

FIGURE 6. An example of Rule R_{1-1}.

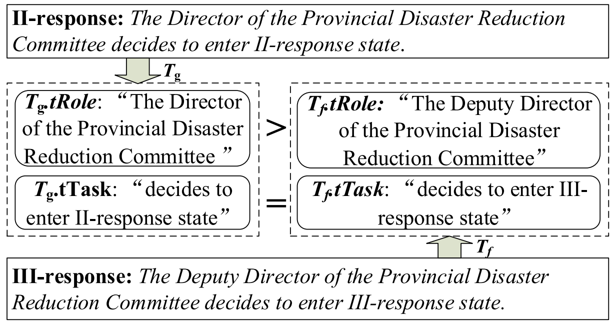

FIGURE 7. An example of Rule R_2.

departments, high response levels of regular tasks correspond to high levels of executive roles and departments.

Rule R_{1-1} (R_{1-2}) illustrates that if the message sending (receiving) task S_i (E_i) has the same task description with S_j (E_j) and the response level of S_i (E_i) is higher than that of S_j (E_j), the levels of message sender and receiver of S_i (E_i) are both same with those of S_j (E_j) or higher than those of S_j (E_j). Fig. 6 shows an example of Rule R_{1-1}. The message sending task S_a is extracted from the part of second emergency response and S_b is extracted from the part of third emergency response. The task description of S_a is same with that of S_b. The sender of S_a is same with that of S_b. The receiver of S_a "the Director of the Provincial Disaster Reduction Committee" is the superior of the receiver of S_b "the Deputy Director of the Provincial Disaster Reduction Committee". Analysis result shows that the two message sending tasks are correct for describing progressive relation between III-response and II-response processes.

Rule $\boldsymbol{R_{1-1}}$: $1 \le i, j \le N$, $S_i, S_j \in \Sigma_S$, $\forall rsi \in S_i.sRole$, $\forall dsi \in S_i.sDep$, $\forall rei \in S_i.eRole$, $\forall dei \in S_i.eDep$, $\forall rsj \in S_j.sRole$, $\forall dsj \in S_j.sDep$, $\forall rej \in S_j.eRole$, $\forall dej \in S_j.eDep$, $(S_i.sTask = S_j.sTask) \wedge (S_i.level > S_j.level) \rightarrow (dsi \Leftarrow dsj) \wedge (dei \Leftarrow dej) \wedge (rsi \gg rsj) \wedge (rei \gg rej)$.

Rule $\boldsymbol{R_{1-2}}$: $1 \le i, j \le P$, $E_i, E_j \in \Sigma_E$, $\forall rsi \in E_i.sRole$, $\forall dsi \in E_i.sDep$, $\forall rei \in E_i.eRole$, $\forall dei \in E_i.eDep$, $\forall rsj \in E_j.sRole$, $\forall dsj \in E_j.sDep$, $\forall rej \in E_j.eRole$, $\forall dej \in E_j.eDep$, $(E_i.eTask = E_j.eTask) \wedge (E_i.level > E_j.level) \rightarrow (dsi \Leftarrow dsj) \wedge (dei \Leftarrow dej) \wedge (rsi \gg rsj) \wedge (rei \gg rej)$.

Rule R_2 illustrates that if the regular task T_i has the same task descriptions with T_j and the response level of T_i is higher than that of T_j, the levels of executive roles and departments of T_i are same with those of T_j or higher than those of T_j. Fig. 7 shows an example of Rule R_2. The regular task T_g is extracted from the part of second emergency response and T_f is extracted from the part of third emergency response. The task description of T_g is similar with that of T_f. The executive role of T_g "the Director of the Provincial Disaster Reduction Committee" is the superior of the executive role of T_f "the Deputy Director of the Provincial Disaster Reduction Committee". Analysis result shows that the two regulars tasks are correct for describing progressive relation between III-response and II-response processes.

Rule $\boldsymbol{R_2}$: $1 \le i, j \le M$, $T_i \in \Sigma_T$, $\forall ri \in T_i.tRole$, $\forall di \in T_i.tDep$, $\forall rj \in T_j.tRole$, $\forall dj \in T_j.tDep$, $(T_i.task = T_j.task) \wedge (T_i.level > T_j.level) \rightarrow (di \gg dj) \wedge (ri \Leftarrow rj)$.

B. COMPLETENESS ANALYSIS OF EMERGENCY RESPONSE TASKS

Completeness analysis pays attentions to response task descriptions of short sentences. Thus, it is necessary to check whether the extracted response tasks are complete. For emergency response interactive processes, complete descriptions of message sending and receiving tasks contribute to guarantee coordination and cooperation among multiple departments. So, each message sending and receiving task extracted from emergency response plans should have both senders and receivers. In addition, clear responsibility descriptions are the basic requirement for each department and role of the emergency response organization system. Complete descriptions of regular tasks are critical to explaining which department or role should perform which task. Therefore, each regular task extracted from emergency response plans should have both task descriptions and their executive roles or departments.

Rule R_{3-1} (R_{3-2}) illustrates that message senders and receivers of the message sending (receiving) task S_i (E_i) cannot be empty. Fig. 8 shows an example of Rule R_3 in which the message sending task S_c is complete and the message receiving task E_c lacks senders.

Rule $\boldsymbol{R_{3-1}}$: $1 \le i \le N$, $S_i \in \Sigma_S$, $\neg(S_i.sRole = \phi \wedge S_i.sDep = \phi) \wedge \neg(S_i.eRole = \phi \wedge S_i.eDep = \phi)$.

Rule $\boldsymbol{R_{3-2}}$: $1 \le i \le P$, $E_i \in \Sigma_E$, $\neg(E_i.sRole = \phi \wedge E_i.sDep = \phi) \wedge \neg(E_i.eRole = \phi \wedge E_i.eDep = \phi)$.

Rule R_4 illustrates that executors (executive roles or departments) and task descriptions of the regular task T_i cannot be empty. Fig. 9 shows an example of Rule R_4. The regular task T_v is complete and the regular task T_u lacks executive roles and departments.

Rule $\boldsymbol{R_4}$: $1 \le i \le M$, $T_i \in \Sigma_T$, $\neg(T_i.tRole = \phi \wedge T_i.tDep = \phi) \wedge \neg(T_i.task = \phi)$.

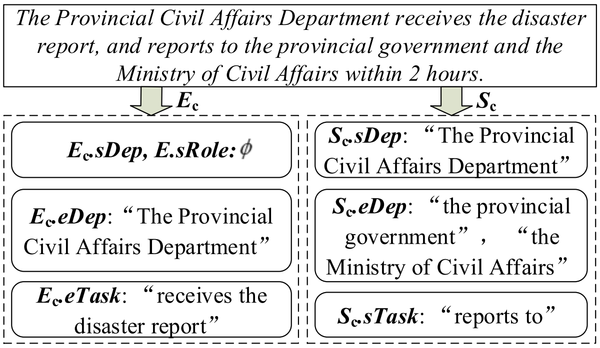

FIGURE 8. An example of Rule R_3.

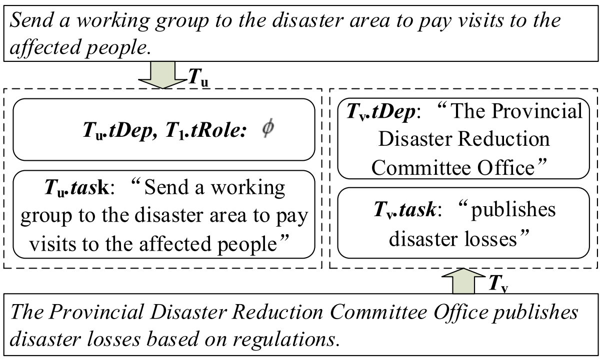

FIGURE 9. An example of Rule R_4.

C. AMBIGUITY ANALYSIS OF EMERGENCY RESPONSE PLANS

Each department and role involved in response tasks should belong to an instance of the emergency response organization system. However, some extracted roles and departments from the emergency response plan often have ambiguous descriptions such as ''other relevant departments'' and ''provincial leaders'' and these roles and departments can not be mapped to the emergency response organization system. This type of ambiguous descriptions confuses roles and departments of emergency responses and make them unable to accurately know their responsibilities. A well-written emergency plan should accurately describe response tasks and their roles and departments.

Unambiguous departments and roles refer to specific instances of the emergency response organization system. Response tasks with ambiguous roles or departments are regarded as ambiguous response tasks. Rule R_5 illustrates that the ambiguity of emergency response plan is the ratio of ambiguous tasks to all response tasks and it should be less than the threshold α where ATN denotes the number of ambiguous tasks, and M, N, and P denote the number of regular tasks, message sending tasks and message receiving tasks respectively. The value of ambiguity denotes the degree of inaccurate descriptions in the emergency response plan.

Rule $\boldsymbol{R_5}$:

$$Ambiguity = \frac{ATN}{M+N+P} \leq \alpha, 0 < \alpha < 1.$$

FIGURE 10. Experimental data of emergency response plans of natural disasters.

D. REDUNDANCY ANALYSIS OF EMERGENCY RESPONSE PLANS

Emergency response participants pay more attentions to information that is directly related to response task completion [39]. The part which is irrelevant to response tasks interferes with the understanding of emergency response plans. The redundancy is used to measure the conciseness of process descriptions of the emergency response plan.

In the stage of process elements identifying, irrelevant elements are tagged with ''O''. Irrelevant elements usually refer to unnecessary modifiers. For each long sentence of the emergency response plan, irrelevant elements often appears between the role/department and the task description, or among multiple task descriptions, or before the first process element, or after the last process element. The redundancy of each long sentence is the ratio of irrelevant tokens to all tokens and the redundancy of the emergency response plan is the average redundancy of all long sentences. Rule R_6 illustrates the redundancy of the emergency response plan should be less than the threshold β where the emergency response plan has n long sentences. Appropriate thresholds (α and β) provide a balance between the flexibility and the rigorousness of process descriptions of the emergency response plan.

Rule $\boldsymbol{R_6}$:

$$Redundancy = \frac{1}{n}\sum_{i=1}^{n}\frac{Others}{All\ tokens} \leq \beta, (0 < \beta < 1).$$

VII. EXPERIMENTAL EVALUATION

A. EXPERIMENTAL DATA

Emergency response plans of natural disasters consist of district, municipal, provincial and national levels according to emergency scope. In our experiments, real-world data which consists of 49 emergency response plans has been collected as shown in Fig. 10 where the four columns represent national, provincial, municipal and district plans from left to right, respectively. The solid boxes of Fig. 10 are for the emergency response plans that have been collected. The solid line of Fig. 10 indicates the reference relation among different types of emergency response plans in boxes. These plans are regulatory documents and the reference relation among them is consistent with the administrative division. For example, Shandong province emergency plan refers to the national emergency response plan. Qingdao municipality emergency response plan refers to national and Shandong province emergency response plans. Shinan district emergency response plan refers to national, Shandong province and Qingdao municipality emergency response plans. According to these reference relations, the national emergency response plan is regarded as a reference standard for the other three types of emergency response plans.

TABLE 4. Overview of experimental data characteristics.

Plans	NL	CL	NS	CS
Nation	61	42	144	18
Province	56	46	150	17
Municipality	56	46	142	18
District	52	43	144	15

Syntactic characteristics including the length of sentences and the number of clauses are employed to evaluate the complexity and understandability of emergency response plans. Table 4 shows the syntactic features of emergency response plans in experimental data set. There are four key parameters in Table 4, i.e. average number of long sentences per emergency plan (''*NL*''), average number of characters per long sentence (''*CL*''), average number of short sentences per emergency plan (''*NS*'') and average number of characters per short sentence (''*CS*''). Complexities of four types of emergency response plans are very similar. The number of long sentences is more than 50 and the average length of long sentences is more than 40. The number of short sentences is more than 140 and the average length of short sentences is more than 15. From the table, it turns out that the emergency response plans are relatively complex and difficult to understand. Manually analyzing text quality of emergency response plans is a time-consuming and labor-intensive task.

B. PROCESS EXTRACTION RESULTS

The Bi-LSTM-CRF network is implemented by python 3.6.2 and TensorFlow platform. The optimization algorithm is Adam Optimizer with the learning rate of 0.1. The hidden layers of 100, the batch size of 64 and the epoch of 40 are used to train models. The dimension of word vector is set as 300. The experimental data is split into training dataset (80%) and testing dataset (20%). The precision, recall and F1 are selected as metrics to evaluate the quality of extracted process elements. Four types of elements including roles/departments, regular tasks, interactive tasks, and irrelevant elements, are identified and extracted by the Bi-LSTM-CRF network. Table 5 shows extraction results of process elements. In the experimental data set, the number of different process elements are different. The extraction result of regular tasks is best (precision: 82.47%, recall: 88.12%). The number of message sending and receiving tasks is the least which results in high precision (91.95%) and low recall (34.26%).

TABLE 5. Process element extraction results.

Process elements	Precision(%)	Recall(%)	F1(%)
Roles/departments	80.32	79.21	79.76
Regular tasks	82.47	88.12	85.20
Interactive tasks	91.95	34.26	49.92
Others	88.28	85.12	86.67

TABLE 6. Characteristics of the extracted emergency response processes.

Plans	Regular tasks	Interactive tasks	Departments	Roles
Nation	132	6	26	5
Province	134	14	41	17
Municipality	133	14	39	16
District	130	15	44	18

Table 6 shows characteristics of emergency response processes extracted from district, municipal, provincial and national emergency response plans. For the four types of emergency response plans, the number of regular tasks is far more than that of interactive tasks. The number of departments is larger than that of roles. The scale of the emergency response process extracted from the national emergency response plan is similar to those of the other three types of emergency response plans except for interactive tasks and roles. For the national emergency response plan, the number of interactive tasks is only 6 and the number of roles is only 5. However, the average number of interactive tasks extracted from other three types of emergency response plans are all more than 14. It turns out that the other three types of emergency response plans describe more frequent interactions among departments and roles than the national emergency response plan.

C. TEXT QUALITY ANALYSIS RESULTS

1) ANALYSIS RESULTS OF TEXT QUALITY OF PROVINCIAL EMERGENCY RESPONSE PLANS

Not all response tasks need to be checked for the correctness of progressive relation among four levels of emergency responses. For Rule R_{1-1} and Rule R_{1-2}, message sending and receiving tasks with same task descriptions and different sender and receiver from different response levels need to be checked. For Rule R_2, regular tasks with same task descriptions and different executive roles and departments from different response levels need to be checked. The ratio of checked response tasks (''*CRT*'') to all response tasks implies the correlation among four levels of emergency responses (''*Correlation*'') and the specific calculation formula is as follows where M, N, and P denote the number of regular tasks, message sending tasks and message receiving

TABLE 7. Analysis results of Rule R_{1-1}, R_{1-2} and R_2 of provincial emergency response plans.

Plans	R_{1-1}, R_{1-2}			R_2		
	SE	$\overline{SE}$	YN	T	$\overline{T}$	YN
Anhui	9	5	Y	84	24	Y
Fujian	18	18	Y	70	47	Y
Gansu	8	6	Y	80	51	Y
Hainan	27	24	Y	144	91	Y
Heilongjiang	7	7	Y	123	65	Y
Henan	13	12	Y	135	90	Y
Hubei	13	13	Y	154	95	Y
Hunan	10	9	Y	114	56	Y
Jiangsu	3	2	Y	127	50	Y
Jiangxi	15	14	Y	98	56	Y
Qinghai	12	12	Y	95	49	Y
Shandong	12	10	Y	138	73	Y
Shanxi	15	14	Y	133	88	Y
Sichuan	6	5	Y	136	69	Y
Yunnan	10	8	Y	131	61	Y
Zhejiang	10	8	Y	126	66	Y

TABLE 8. Analysis results of Rule R_{3-1}, R_{3-2} and R_4 of provincial emergency response plans.

Plans	R_{3-1}, R_{3-2}		R_4		
	CI	NI	CT	NT_1	NT_2
Anhui	7	2	56	15	27
Fujian	11	7	66	22	3
Gansu	4	4	68	16	8
Hainan	29	7	149	31	0
Heilongjiang	7	0	107	13	10
Henan	9	4	132	15	5
Hubei	9	5	152	20	0
Hunan	4	6	104	17	3
Jiangsu	3	0	117	11	2
Jiangxi	9	6	78	15	20
Qinghai	6	7	76	12	20
Shandong	7	5	125	17	8
Shanxi	10	6	128	21	0
Sichuan	6	0	122	13	7
Yunnan	10	0	120	15	6
Zhejiang	10	0	112	17	7

tasks, respectively.

$$Correlation = \frac{CRT}{M+N+P}$$

Table 7 shows analysis results of Rule R_{1-1}, R_{1-2} and R_2 of provincial emergency response plans. "SE" denotes the number of message sending and receiving tasks and "$\overline{SE}$" indicates the number of message sending and receiving tasks that need to be checked for Rule R_{1-1} and Rule R_{1-2}. "T" represents the number of regular tasks and "$\overline{T}$" denotes the number of regular that need to be checked for Rule R_2. "YN" indicates the analysis results of Rule R_{1-1}, Rule R_{1-2} and Rule R_2 where "Y" means that the checked response tasks are correct and "N" means the opposite. In average, 85.201% of message sending and receiving tasks need to be checked for Rule R_{1-1} and Rule R_{1-2} and all of them are correct. In average, 54.364% of regular tasks need to be checked for Rule R_2 and all of them are correct.

To analyze the completeness of emergency response plans, there are two key characteristics of response tasks for Rule R_{3-1} and Rule R_{3-2} including the number of the complete message sending and receiving tasks ("CI") and the number of message sending and receiving tasks without senders or receivers ("NI"). For Rule R_4, there are three key characteristics of response tasks, i.e. the number of complete regular tasks ("CT"), the number of regular tasks with only executor ("NT_1"), and the number of regular tasks with only task descriptions ("NT_2"). The ratio of complete response tasks ("CCT") to all response tasks means comprehensive completeness analysis of emergency response plans ("*Completeness*") and the specific calculation formula is as follows.

$$Completeness = \frac{CCT}{M+N+P}$$

Table 8 shows analysis results of Rule R_{3-1}, R_{3-2} and R_4 of provincial emergency response plans. In average, 31.925% of message sending and receiving tasks lack senders or receivers, 4.090% of regular tasks have only executive roles or departments and no task descriptions, and 11.145% of regular tasks have only task descriptions and no executive roles and departments. To sum up, 31.925% of message sending and receiving tasks and 15.235% regular are not complete.

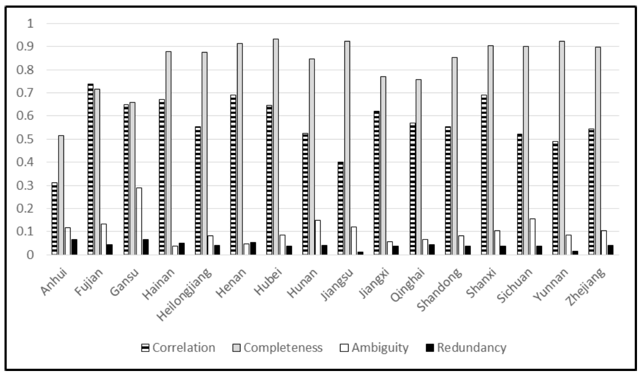

FIGURE 11. Analysis results of correlation, completeness, ambiguity and redundancy of provincial plans.

Fig.11 shows analysis results of correlation, completeness, ambiguity and redundancy of provincial emergency response plans. The average correlation is 57.321%. The correlation of 7 provincial emergency response plans exceeds the average. The maximum correlation is 73.864% and the minimum correlation is 31.183%. The average completeness is 82.922%. The completeness of 11 provincial emergency response plans exceeds the average. The maximum completeness is 93.413% and the minimum completeness is 51.613%. The average ambiguity is 10.658%. The ambiguity of 10 provincial emergency response plans is less than the average. The largest ambiguity is 28.846% and the least ambiguity is 3.704%. The average redundancy is 4.082%. The redundancy of 10 provincial emergency response plans is less than the average. The largest redundancy is 6.645% and the least redundancy is 1.109%.

2) ANALYSIS RESULTS OF TEXT QUALITY OF MUNICIPAL EMERGENCY RESPONSE PLANS

Table 9 shows progressive relation analysis results of municipal emergency response plans for Rule R_{1-1}, Rule R_{1-2} and Rule R_2. In average, 86.713% of message sending and receiving tasks need to be checked for Rule R_{1-1} and Rule R_{1-2} and all of them are correct. In average, 50.013% of regular tasks need to be checked and all of them are correct for Rule R_2.

TABLE 9. Analysis results of Rule R_{1-1}, R_{1-2} and R_2 of municipal plans.

Plans	R_{1-1}, R_{1-2}			R_2		
	SE	$\overline{SE}$	YN	T	$\overline{T}$	YN
Chengdu	6	5	Y	91	42	Y
Dongying	8	5	Y	155	80	Y
Haikou	24	24	Y	141	95	Y
Hangzhou	10	8	Y	148	71	Y
Hefei	7	4	Y	78	17	Y
Jinan	7	8	Y	130	54	Y
Lianyungang	3	2	Y	132	52	Y
Nanjing	2	2	Y	119	35	Y
Qingdao	16	16	Y	123	41	Y
Quanzhou	22	22	Y	72	59	Y
Sanming	17	17	Y	70	46	Y
Shenyang	3	2	Y	103	56	Y
Weifang	12	9	Y	146	82	Y
Xiamen	22	22	Y	85	57	Y
Xian	20	20	Y	147	86	Y
Zibo	11	9	Y	171	59	Y

TABLE 10. Analysis results of Rule R_{3-1}, R_{3-2} and R_4 of municipal plans.

Plans	R_{3-1}, R_{3-2}		R_4		
	CI	NI	CT	NT_1	NT_2
Chengdu	6	0	97	6	33
Dongying	6	2	140	15	8
Haikou	29	4	142	34	0
Hangzhou	10	0	140	18	0
Hefei	5	2	49	12	28
Jinan	7	3	129	8	3
Lianyungang	3	0	121	11	3
Nanjing	2	0	113	6	0
Qingdao	11	5	89	18	32
Quanzhou	7	2	80	13	7
Sanming	13	7	69	21	0
Shenyang	3	0	91	4	11
Weifang	9	4	133	18	8
Xiamen	19	3	77	30	3
Xian	18	7	146	26	0
Zibo	11	3	144	19	8

Table 10 shows analysis results of Rule R_{3-1}, R_{3-2} and R_4 of municipal emergency response plans. In average, 24.544% of message sending and receiving tasks in average lack senders or receivers. In average, 4.953% of regular tasks have only executive roles or departments and no task descriptions, and 9.893% of regular tasks have only task descriptions and no executive roles and departments. To sum up, 75.455% of message sending and receiving tasks and 85.154% of regular tasks are complete.

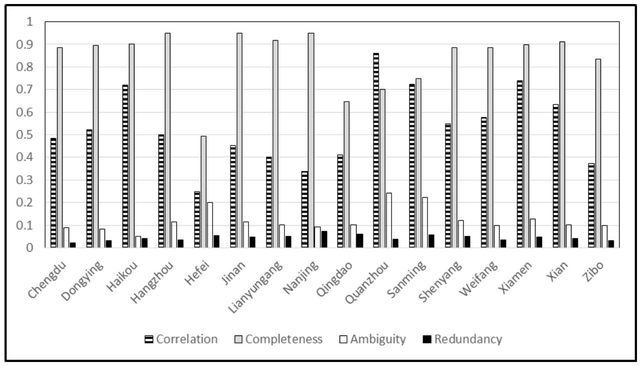

FIGURE 12. Analysis results of correlation, completeness, ambiguity and redundancy of municipal plans.

Fig.12 shows analysis results of correlation, completeness, ambiguity and redundancy of municipal emergency response plans. The average correlation is 53.321%. The correlation of 7 municipal emergency response plans exceeds the average. The maximum correlation is 86.170% and the minimum correlation is 24.706%. The average completeness is 84.118%. The completeness of 11 municipal emergency response plans exceeds the average. The maximum completeness is 95.041% and the minimum completeness is 49.412%. The average ambiguity is 12.194%. The ambiguity of 12 municipal emergency response plans is less than the average. The largest ambiguity is 24.194% and the least ambiguity is 5.213%. The average redundancy is 4.53%. The redundancy of 8 municipal emergency response plans is less than the average. The largest redundancy is 7.452% and the least redundancy is 2.206%.

3) ANALYSIS RESULTS OF TEXT QUALITY OF DISTRICT EMERGENCY RESPONSE PLANS

Table 11 shows progressive relation analysis results of district emergency response plans for Rule R_{1-1}, Rule R_{1-2} and Rule R_2. In average, 71.327% of message sending and receiving tasks need to be checked for Rule R_{1-1} and Rule R_{1-2} and all of them are correct. In average, 38.585% of regular tasks need to be checked and all of them are correct for Rule R_2.

Table 12 shows analysis results of completeness analysis results of district emergency response plans for Rule R_{3-1}, Rule R_{3-2} and Rule R_4. In average, 17.008% of message sending and receiving tasks lack senders or receivers. In average, 10.081% of regular tasks have only executive roles or departments and no task descriptions and 6.497% of regular tasks have only task descriptions and no executive roles and departments. To sum up, 82.993% of message sending and receiving tasks and 83.422% of regular tasks are complete.

Fig 13 shows analysis results of correlation, completeness, ambiguity and redundancy of district emergency response plans. The average correlation is 41.957%. The correlation of 8 district emergency response plans exceeds the average. The maximum correlation is 70.588% and the minimum

TABLE 11. Analysis results of Rule R_{1-1}, R_{1-2} and R_2 of district plans.

Plans	R_{1-1}, R_{1-2}			R_2		
	SE	$\overline{SE}$	YN	T	$\overline{T}$	YN
Chenghua	6	5	Y	122	32	Y
Furong	13	3	Y	105	14	Y
Huangdao	8	7	Y	94	10	Y
Jianggan	9	6	Y	153	45	Y
Jimei	22	13	Y	81	50	Y
Laoshan	17	15	Y	107	46	Y
Longquanyi	6	6	Y	127	35	Y
Pukou	1	0	Y	117	53	Y
Shinan	12	4	Y	132	44	Y
Siming	19	12	Y	80	57	Y
Tongan	21	19	Y	81	53	Y
Wangcheng	23	23	Y	107	13	Y
Xiacheng	9	9	Y	151	56	Y
Xiangan	22	19	Y	106	51	Y
Xihu	10	8	Y	143	67	Y
Yuhang	10	8	Y	148	68	Y

TABLE 12. Analysis results of Rule R_{3-1}, R_{3-2} and R_4 of district plans.

Plans	R_{3-1}, R_{3-2}		R_4		
	CI	NI	CT	NT_1	NT_2
Chenghua	6	0	111	11	0
Furong	4	11	102	18	0
Huangdao	6	2	94	12	20
Jianggan	9	0	137	16	0
Jimei	19	3	106	22	21
Laoshan	14	3	107	20	17
Longquanyi	6	0	114	13	0
Pukou	1	0	114	4	0
Shinan	12	1	106	14	25
Siming	15	8	76	27	0
Tongan	18	3	73	29	3
Wangcheng	12	17	105	27	4
Xiacheng	9	0	131	20	0
Xiangan	19	3	76	27	3
Xihu	10	0	135	18	0
Yuhang	10	0	141	17	0

correlation is 14.407%. The average completeness is 86.016%. The completeness of 10 district emergency response plans exceeds the average. The maximum completeness is 95.570% and the minimum completeness is 66.667%. The average ambiguity is 12.753%. The ambiguity of 7 district emergency response plans is less than the average. The largest ambiguity is 19.753% and the least ambiguity is 3.636%. The average redundancy is 4.855%. The redundancy of 10 district emergency response plans is less than the average. The largest redundancy is 7.277% and the least redundancy is 2.722%.

4) COMPREHENSIVE ANALYSIS RESULTS

Fig.14 shows comprehensive analysis results of four types of emergency response plans. For the correlation of four levels of emergency responses, the national and provincial emergency response plans have greater correlation than other two types of emergency response plans. For completeness of response tasks, the national plan is better than other three types of emergency response plans. The ambiguity of the national plan is better than those of other three types of emergency response plans. The redundancy of the national emergency response plan is very close to those of other three types of emergency response plans. By comprehensive analysis, the text quality of the national plan is best in the four types of emergency response plans and can be regarded as a reference standard.

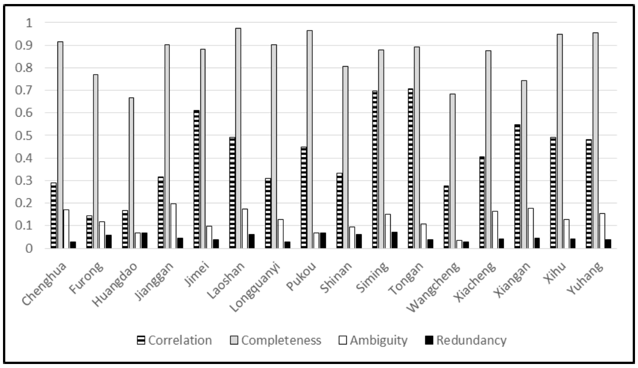

FIGURE 13. Analysis results of correlation, completeness, ambiguity and redundancy of district plans.

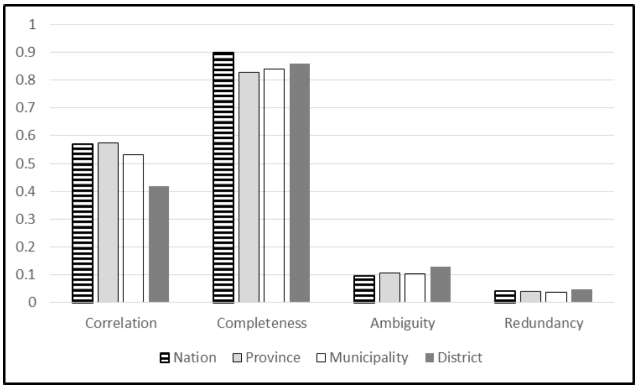

FIGURE 14. Comprehensive analysis results of four types of emergency response plans.

VIII. DISCUSSION

From process extraction results, the Bi-LSTM-CRF network performs well in identifying process elements described by continuous word sequences. However, process element identification requires a large amount of manually annotated data to guarantee accuracy which determines whether the extracted response tasks can be applied to text quality analysis of emergency response plans. From text quality analysis results, the proposed approach provide a way to find the defects of the emergency response plan before emergencies. Poor-quality emergency response plans are not friendly to roles and departments without rich experience and domain knowledge. Expert reviews are complicated and time-consuming tasks, and may tend towards a certain subjectivity. The proposed automated analysis approach can save evaluation cost and improve evaluation efficiency. Quantitative analysis results are used to compare the evaluated plan with other emergency response plans and facilitate experts to revise and improve emergency response plans.

The proposed approach cannot be used directly for other languages because of the uniqueness of Chinese language. When the proposed approach is used for English emergency response plans, appropriate modifications and improvements are necessary. On the one hand, the response process extraction has to be updated, which includes manually labeling additional English corpora and training the Bi-LSTM-CRF model. The response task generation approach has also to be updated because the combination patterns among process elements are different in English emergency response plans. If the word sequence describing process elements is not continuous, the process elements extracted by our approach may contain unnecessary modifiers. In this case, the rule-based extraction approach is more appropriate [30]. On the other hand, part of the text quality analysis also needs to be updated, which includes progressive relation analysis and ambiguity analysis. The four levels of emergency responses are described separately by different sections, which are the conditions for progressive relation analysis. Ambiguity in different types of natural language is diverse and requires specific analysis dependent on the characteristics of the language. Instead, completeness analysis of response tasks and redundancy analysis of emergency response plans can be directly used for other languages without updates.

IX. CONCLUSION

In this paper, a novel approach to analyze text quality of emergency response plans from the perspective of process descriptions is proposed. In order to generate emergency response processes, three types of response tasks are extracted from the emergency response plan through a deep neural network. The proposed approach of text quality analysis creates a series of rules to analyze progressive relation among four levels of emergency responses, completeness of response tasks, ambiguity and redundancy of the emergency response plans according to the extracted emergency response process. In addition, four types of emergency response plans of natural disasters, i.e. district, municipal, provincial and national emergency response plans, are collected to validate the proposed approach.

An emergency response process includes not only response tasks but also flow relation among response tasks. In the future, we aim to discuss process description quality about flow relation for emergency response plans. Flow relation extraction is a key step and there exists synchronous, exclusive, parallel and sequential relation to be extracted from emergency response plans. Text quality analysis of flow relation explores the completeness and ambiguity of flow relation. For example, the completeness analysis of flow relation is to determine which exclusive relation lacks branch condition. Ambiguous description of flow relation [9], [10] includes uncertain relation types and unclear reference about response tasks.

REFERENCES

[1] X.-Y. Li and C.-L. Luo, "Framework of the emergency management system for the mass emergency basing on preplan," in *Proc. Int. Conf. Manage. Sci. Eng.*, Moscow, Russia, Sep. 2009, pp. 2039–2044.
[2] R. W. Perry and M. K. Lindell, "Preparedness for emergency response: Guidelines for the emergency planning process," *Disasters*, vol. 27, no. 4, pp. 336–350, Dec. 2003.
[3] H. Duan, C. Liu, Q. Zeng, and M. Zhou, "A package reduction approach to modeling and analysis of cross-organization emergency response processes with privacy protected," *IEEE Access*, vol. 6, pp. 55573–55585, 2018.
[4] D.-Q. Zhu, L. Bin, and Y. Liu, "Research on ontology-based emergency response plan modeling," in *Proc. Int. Conf. E-Bus. E-Government (ICEE)*, May 2011, doi: 10.1109/icebeg.2011.5882647.
[5] W. Guo, Q. Zeng, H. Duan, G. Yuan, W. Ni, and C. Liu, "Automatic extraction of emergency response process models from Chinese plans," *IEEE Access*, vol. 6, pp. 74104–74119, 2018.
[6] W. Guo, Q. Zeng, H. Duan, G. Yuan, W. Ni, and N. Xie, "Extracting cross-organization process model of emergency response from plan text," in *Proc. IEEE Int. Conf. Saf. Produce Informatization (IICSPI)*, Dec. 2018, pp. 36–41.
[7] Y. Yang and L. Rong, "A method of evaluating the emergency response capability of emergency plans," in *Proc. 4th Int. Conf. Wireless Commun., Netw. Mobile Comput.*, Oct. 2008, pp. 1–4.
[8] Y. Zhang, "Research on implementation effect evaluation model of emergency plans based on multi-level and grey evaluation method," *Appl. Res. Comput.*, vol. 29, no. 9, pp. 3312–3319, 2012.
[9] H. Van der Aa, H. Leopold, and H. A. Reijers, "Dealing with behavioral ambiguity in textual process descriptions," in *Business Process Management* (Lecture Notes in Computer Science), vol. 9850, M. L. Rose, P. Loos, and O. Pastor, Eds. Cham, Switzerland: Springer, 2016, pp. 271–288.
[10] H. Van Der Aa, H. Leopold, and H. A. Reijers, "Checking process compliance against natural language specifications using behavioral spaces," *Inf. Syst.*, vol. 78, pp. 83–95, Nov. 2018.
[11] H. Van Der Aa, H. Leopold, and H. Reijers, "Detecting inconsistencies between process models and textual descriptions," in *Business Process Management* (Lecture Notes in Computer Science), vol. 9253, H. Motahari-Nezhad, J. Recker, and M. Weidlich, Eds. Cham, Switzerland: Springer, 2015, pp. 90–105.
[12] Q. Han, Z. Huang, and X. Fan, "Research on the evaluation method of operational performance of emergency response plan," in *Proc. Fourth Int. Conf. Multimedia Inf. Netw. Secur.*, Nov. 2012, pp. 786–789.
[13] C. Girard, P. David, E. Piatyszek, and J.-M. Flaus, "Emergency response plan: Model-based assessment with multi-state degradation," *Saf. Sci.*, vol. 85, pp. 230–240, Jun. 2016.
[14] Y. Long, Y. Yang, X. Lei, Y. Tian, and Y. Li, "Integrated assessment method of emergency plan for sudden water pollution accidents based on improved TOPSIS, Shannon entropy and a coordinated development degree model," *Sustainability*, vol. 11, no. 2, p. 510, Jan. 2019.
[15] G. Chen and X. Zhang, "Fuzzy-based methodology for performance assessment of emergency planning and its application," *J. Loss Prevention Process Ind.*, vol. 22, no. 2, pp. 125–132, Mar. 2009.
[16] Y. Yu and H. Chi, "Research on operability of emergency plans," *J. Public Manage.*, vol. 2007, no. 2, pp. 100–107, 2007.
[17] D. Huang, "Study on the evaluation method of emergency counterplan in petrochemical enterprise," *Petrochemical Saf. Technol.*, vol. 22, no. 5, pp. 17–20, 2006.
[18] G. Yuan, Q. Zeng, W. Ni, C. Liu, C. Li, and H. Duan, "Multi-view and multi-language description generation for cross-department medical diagnosis processes," *IEEE Access*, vol. 6, pp. 76741–76753, 2018.
[19] Q.-T. Zeng, F.-M. Lu, C. Liu, and D.-C. Meng, "Modeling and analysis for cross-organizational emergency response systems using Petri nets," *Chin. J. Comput.*, vol. 36, no. 11, pp. 2290–2302, Mar. 2014.
[20] F. Lu, Q. Zeng, Y. Bao, and H. Duan, "Hierarchy modeling and formal verification of emergency treatment processes," *IEEE Trans. Syst., Man, Cybern. Syst.*, vol. 44, no. 2, pp. 220–234, Feb. 2014.
[21] C. Liu, Q. Zeng, H. Duan, M. Zhou, F. Lu, and J. Cheng, "E-net modeling and analysis of emergency response processes constrained by resources and uncertain durations," *IEEE Trans. Syst., Man, Cybern. Syst.*, vol. 45, no. 1, pp. 84–96, Jan. 2015.
[22] Q. Zeng, F. Lu, C. Liu, H. Duan, and C. Zhou, "Modeling and verification for cross-department collaborative business processes using extended Petri nets," *IEEE Trans. Syst., Man, Cybern. Syst.*, vol. 45, no. 2, pp. 349–362, Feb. 2015.

[23] Q. Zeng, C. Liu, and H. Duan, "Resource conflict detection and removal strategy for nondeterministic emergency response processes using Petri nets," *Enterprise Inf. Syst.*, vol. 10, no. 7, pp. 729–750, 2016.
[24] Q. Zeng, "Resource conflict checking and resolution controller design for cross-organization emergency response processes," *IEEE Trans. Syst., Man, Cybern. Syst.*, vol. 10, no. 7, pp. 1491–1504, 2016.
[25] H. Duan, C. Liu, Q. Zeng, and M. Zhou, "Refinement-based hierarchical modeling and correctness verification of cross-organization collaborative emergency response processes," *IEEE Trans. Syst., Man, Cybern. Syst.*, to be published, doi: 10.1109/tsmc.2018.2838053.
[26] J. Mendling, H. Reijers, and J. Recker, "Activity labeling in process modeling: Empirical insights and recommendations," *Inf. Syst.*, vol. 35, no. 4, pp. 467–482, Jun. 2010.
[27] H. Leopold, S. Smirnov, and J. Mendling, "On the refactoring of activity labels in business process models," *Inf. Syst.*, vol. 37, no. 5, pp. 443–459, Jul. 2012.
[28] H. Leopold, R.-H. Eid-Sabbagh, J. Mendling, L. G. Azevedo, and F. A. Baião, "Detection of naming convention violations in process models for different languages," *Decis. Support Syst.*, vol. 56, pp. 310–325, Dec. 2013.
[29] F. Pittke, H. Leopold, and J. Mendling, "Automatic detection and resolution of lexical ambiguity in process models," *IIEEE Trans. Softw. Eng.*, vol. 41, no. 6, pp. 526–544, Jun. 2015.
[30] F. Friedrich, J. Mendling, and F. Puhlmann, "Process model generation from natural language text," in *Proc. Int. Conf. Adv. Inf. Syst. Eng.* Berlin, Germany: Springer, 2011, pp. 482–496.
[31] V. Dufour-Lussier, F. Le Ber, J. Lieber, and E. Nauer, "Automatic case acquisition from texts for process-oriented case-based reasoning," *Inf. Syst.*, vol. 40, pp. 153–167, Mar. 2014.
[32] O. Zolotarev, M. Charnine, and A. Matskevich, "Conceptual business process structuring by extracting knowledge from natural language texts," in *Proc. Int. Conf. Artif. Intell. (ICAI)*, vol. 1, 2014, pp. 21–24.
[33] R. C. B. Ferreira, L. H. Thom, J. P. M. de Oliveira, D. T. Avila, R. I. dos Santos, and M. Fantinato, "Assisting Process Modeling by Identifying Business Process Elements in Natural Language Texts," in *Advances in Conceptual Modeling*. Cham, Switzerland: Springer, 2017, pp. 154–163.
[34] A. Halioui, P. Valtchev, and A. B. Diallo, "Bioinformatic workflow extraction from scientific texts based on word sense disambiguation," *IEEE/ACM Trans. Comput. Biol. Bioinf.*, vol. 15, no. 6, pp. 1979–1990, Nov. 2018.
[35] A. McCallum, D. Freitag, and F. C. N. Pereira, "Maximum entropy Markov models for information extraction and segmentation," in *Proc. ICML*, 2000, pp. 591–598.
[36] J. D. Lafferty, A. Mccallum, and F. C. N. Pereira, "Conditional random fields: Probabilistic models for segmenting and labeling sequence data," in *Proc. 18th Int. Conf. Mach. Learn.* San Mateo, CA, USA: Morgan Kaufmann, 2001, pp. 282–289.
[37] G. Lample, M. Ballesteros, S. Subramanian, K. Kawakami, and C. Dyer, "Neural architectures for named entity recognition," in *Proc. Conf. North Amer. Chapter Assoc. for Comput. Linguistics, Hum. Lang. Technol.*, 2016, pp. 260–270.
[38] Z. Huang, W. Xu, and K. Yu, "Bidirectional LSTM-CRF models for sequence tagging," Aug. 2015, *arXiv:1508.01991*. [Online]. Available: https://arxiv.org/abs/1508.01991
[39] V. A. Diehl and C. B. Mills, "Procedural text structure and reader perceptions and performance," *J. General Psychol.*, vol. 129, no. 1, pp. 18–35, Jan. 2002.
[40] R. P. Padilha, M. R. S. Borges, J. O. Gomes, and J. H. Canos, "The design of collaboration support between command and operation teams during emergency response," in *Proc. 14th Int. Conf. Comput. Supported Cooperat. Work Design*, Apr. 2010, pp. 759–763.

WENYAN GUO received the M.S. degree in computer technology from Qingdao University, Qingdao, China, in 2016. She is currently pursuing the Ph.D. degree with the College of Computer Science and Engineering, Shandong University of Science and Technology. Her current research interests include process mining and business process management.

QINGTIAN ZENG received the Ph.D. degree in computer software and theory from the Institute of Computing Technology, Chinese Academy of Sciences, Beijing, China, in 2005. He was a Visiting Professor with the City University of Hong Kong, Hong Kong, in 2008. He is currently a Professor with the Shandong University of Science and Technology, Qingdao, China. His current research interests include Petri nets, process mining, and knowledge management.

HUA DUAN received the Ph.D. degree in applied mathematics from Shanghai Jiaotong University, Shanghai, China, in 2008. She is currently a Professor with the Shandong University of Science and Technology, Qingdao, China. Her current research interests include Petri nets, process mining, and machine learning.

WEIJIAN NI received the Ph.D. degree in computer application from Nankai University, Tianjin, China, in 2008. He was a Visiting Scholar with the State University of New York, New York, USA, in 2015. He is currently an Associate Professor with the Shandong University of Science and Technology, Qingdao, China. His current research interests include process mining, deep learning, and text mining.

TONG LIU received the Ph.D. degree in computer software and theory from the Shandong University of Science and Technology, Qingdao, China, in 2010. She is currently a Lecturer with the Shandong University of Science and Technology. Her current research interests include data mining, machine learning, and information retrieval.

CONG LIU received the B.S. and M.S. degrees in computer software and theory from the Shandong University of Science and Technology, Qingdao, China, in 2013 and 2015, respectively, and the Ph.D. degree in computer science and information systems from the Eindhoven University of Technology, Eindhoven, The Netherlands, in 2019. He is currently a Professor with the Shandong University of Technology, Zibo, China. His current research interests include business process management, process mining, and Petri nets.

NENGFU XIE received the Ph.D. degree in computer software and theory from the Institute of Computing Technology, Chinese Academy of Sciences, Beijing, China, in 2005. He was a Visiting Scholar with the City University of Hong Kong, in 2005. He is currently an Associate Researcher with the Institute of Agricultural Information, Chinese Academy of Agricultural Science, Beijing, China. His current research interests include agricultural knowledge management, large-scale agricultural knowledge processing, and the Internet of Things.