



HAL
open science

AutoMC: Learning Regular Expressions for Automated Management Change Event Extraction from News Articles

Murat Kalender

► **To cite this version:**

Murat Kalender. AutoMC: Learning Regular Expressions for Automated Management Change Event Extraction from News Articles. 18th IFIP International Conference on Artificial Intelligence Applications and Innovations (AIAI), Jun 2022, Hersonissos, Greece. pp.289-300, 10.1007/978-3-031-08337-2_24 . hal-04668662

HAL Id: hal-04668662

<https://inria.hal.science/hal-04668662v1>

Submitted on 7 Aug 2024

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License



This document is the original author manuscript of a paper submitted to an IFIP conference proceedings or other IFIP publication by Springer Nature. As such, there may be some differences in the official published version of the paper. Such differences, if any, are usually due to reformatting during preparation for publication or minor corrections made by the author(s) during final proofreading of the publication manuscript.

AutoMC: Learning Regular Expressions for Automated Management Change Event Extraction from News Articles

Murat Kalender¹[0000-0002-9088-2582]

IgniteTech, Austin, TX, USA murat.kalender@ignitetech.com
<https://ignitetech.com>

Abstract. Event extraction is one of the challenges to be tackled in order to extract valuable insight from unstructured text. The process of automatically identifying events in a corpus of text and extracting comprehensive information about them is called event extraction. Although a number of systems have been proposed for event extraction, there is currently no publicly available system specific to management changes. This paper presents a novel event extraction system - AutoMC - that identifies management change events from business news articles. Specifically, we propose a novel regular expressions based management change event extraction algorithm. The effectiveness of AutoMC is validated empirically over generated data sets. The experimental results show that our system performs competitively in comparison to management change event detection studies in the literature. High event detection performance (78.72% accuracy score) is achieved by the proposed event extraction rule learning method.

Keywords: Event extraction · Information extraction · Natural language processing.

1 Introduction

In the new era of internet news publishing, hundreds of business articles are being published every day by popular news organizations. Business decision makers require an intuitive understanding of the health of their market, which is typically particularly sensitive to breaking news about economic events like acquisitions, management changes, stock splits, and dividend announcements [11].

It is a difficult task for business decision makers to process a continuous flow of news articles through various internet sources. Therefore, automated solutions that can analyze internet news articles in natural language are becoming increasingly valuable in today's information-driven business ecosystem [2]. Automating information extraction and knowledge acquisition processes can help decision-makers to save time and assist them to make better decisions by providing valuable input.

In this context, the identification of events can guide decision making processes, as these events provide means of structuring information using concepts,

with which knowledge can be generated by applying inference. Automating information extraction and knowledge acquisition processes can facilitate or support decision makers in fulfilling their cumbersome tasks, as faster processing of aggregated data from various sources enables one to make better informed decisions [3].

Formally, event extraction is defined as the process of automatically identifying events in a corpus of text and extracting comprehensive information about them [7]. In this study, we introduce AutoMC, a system that identifies the management change events from business news articles using natural language processing (NLP) and machine learning based techniques.

There are two main aspects of an event detection system: the detection of the event and the extraction of the entities associated with the respective event. We address the first part with a supervised text classifier to detect business news articles that contain a management change event. The second part is addressed with a named entity recognizer and auto generated regular expressions. Fig. 1 shows an example of a management change event that can be detected automatically using an event detection system.

<p>James Black has been appointed as the new Director Person Title</p> <p>at ABC Inc. London office effective January 14 2022. Organization Location Date</p> <p>He replaces Jamey Brown, who resigned late last year. Person Date</p>					
Event Type	Person	Organization	Title	Location	Date
Hire	James Black	ABC Inc.	Director	London	Jan 2022
Departure	Jamey Brown	ABC Inc.	Director	London	Dec 2021

Fig. 1. An example extraction of the management change event and its linking of a piece of textual content to event entities.

The effectiveness of AutoMC is validated empirically by using evaluations over generated data sets. The experimental results show that AutoMC performs competitively in comparison to the previous methods in the literature. The main contributions of this paper are summarized as follows.

- A novel event detection system is proposed to extract management change events from unstructured text. AutoMC relies on the automated extraction of management change rules compared to manually constructed rules-based event detection studies in the literature.

- A new data set was created to evaluate the performance of the proposed system.

The remainder of this paper is organized as follows. Section 2 reviews related work. Section 3 presents a detailed model of the AutoMC system. Experimental results are shown in Section 4 and we conclude in Section 5.

2 Related Work

Many researchers have made extensive efforts to develop a variety of methods [5, 9, 18, 20] for extracting events from news articles. In this section, we review related work on business event extraction and analysis. The differences between existing work and our approach are then presented.

In recent years, most event extraction studies use deep learning methods to extract general events [6, 14, 19]. Specifically, Wang et al. [19] propose a document-level joint event extraction model, TDJEE, to extract financial events from numerous financial announcements. TDJEE uses BERT and CRF methods for event argument extraction and role labeling. To capture the semantic information of the document-level context, a relation-aware Transformer and attention network are used.

A large-scale training corpus is essential for deep learning models. Since it is challenging to create a large-scale training corpus many approaches to the detection of business events are template-based and rule-based methods [1, 7, 15]. These studies use rule-sets or ontology knowledge-bases that are largely or entirely constructed by hand, rather than fully relying on manually annotated supervised datasets [8].

Arendarenko et al. [1] proposed BEECON, an information and event extraction system for business intelligence. It is an ontology-based system for business documents analysis that can detect 41 different types of business events from unstructured documents using NLP techniques, pattern recognition algorithms, and hand-written detection rules.

Hogenboom et al. [7] proposed SPEED that identifies the concepts defined in a semantic lexicon (WordNet [13]) related to economic events and applies rule based algorithms to detect economic events, which are defined in a domain ontology. In order to maximize recall of their proposed system, the authors match lexical representations of concepts retrieved from the text with event-related concepts that are available in WordNet.

Sahnoun et al. [15] presented an ontology-based system for management change event extraction. The authors defined a management change event ontology and a set of event rules manually and then consumed it using regular expressions, named entity recognition, and reasoning methods to extract management change events.

The creation of rules is a complicated process that requires a significant degree of domain knowledge, which makes rule based information extraction approaches less desirable. We propose a novel approach for automated extraction

of management change rules using a human-annotated ground-truth data and n-gram technique. The annotated ground truth data is created manually by the business experts over years in the scope of IgniteTech’s Business Intelligence (BI) solution named FirstRain¹. AutoMC utilizes this annotated dataset to learn the event extraction rules in the form of regular expressions. Then our rule based algorithm uses those rules in the event extraction process.

3 AutoMC

AutoMC is an event extraction tool designed for detecting management changes from business news articles. AutoMC can identify 4 types of management change events:

- Internal Move: Change in position of an individual within the same organization.
- Move: A person switches from one organization to another one.
- Hire: Organization announces a new hire event and the story does not mention the previous organization.
- Departure: A person leaves an organization and no information is available about his/her new position.

AutoMC has been realized through the design and implementation of two major modules: AutoMC Workbench and Management Change Extraction Pipeline.

The AutoMC Workbench is used for presenting the identified events and allowing domain experts to fix if there are incorrect or missing event extractions. The AutoMC Workbench is a web application where users can also input text content and view the event extraction results. Fig. 2 shows an example of extracted events from a news article². In the workbench, the news article content is presented with highlighted person entities. Then all the extracted event related entities are listed. At the bottom, all the extracted events are listed in text fields so that the operator can update them when it is needed.

Management Change Extraction Pipeline is the core module that extracts management change events from a given input text. This module is composed of three submodules: Regex Learner, News Classifier, and Management Change Extractor. In the following sections, these sub-modules will be analyzed comprehensively.

3.1 Regex Learner

The Regex Learner module generates a list of regular expression rules for a given annotated dataset. Specifically, this task consists of; (i) entity annotation step where management change event named entities are annotated; (ii)

¹ <https://ignitetechnology.com/softwarelibrary/firstrain>

² <https://theproducenews.com/people/walmart-produce-exec-named-ceo-farm-fresh-direct>

Walmart produce exec named CEO of Farm Fresh Direct

Farm Fresh Direct, a leading conventional and organic potato organization, has named **Mike Hulett** as the company's new CEO. Hulett joins **Farm Fresh Direct** from Walmart, where he was most recently **Merchandising Director** for apples, pears and cherries.

"This is a terrific opportunity with a great organization," said Hulett. "Farm Fresh is well established, a strong player in conventional potatoes and is widely recognized in the industry as a market **Leader** in organic potatoes."

Of his 22 years of experience in the produce industry, Hulett spent the last 11 years with Walmart. He **worked** in the Bentonville, AR, headquarters since 2014. Prior to that Hulett was **Director** of sourcing for **Walmart** U.S. and international, working from the field offices in Yakima, WA.

Person: **Janey Higham** **Mike Hulett** **Vijal Valdez**

Company: **Ed Property Holding Inc.** **FreshDirect LLC** **Walmart Inc.**

Title: **Board** **Board of Directors** **Chairman** **Chairman of Board**

Groups: **Customer Service** **Merchandising** **Retail**

Regions: **Bentonville** **Idaho** **U.S.** **Valdez** **Vista** **Yakima**

Type	Name	New Company	New Pos. Title	New Group	New Region	Old Company	Old Pos. Title	Old Group	Old Region	Event Time
										01/18/2022 <input type="checkbox"/>
move	Mike Hulett	Farm Fresh Direct Lic. -- 4	Chief Executive			Walmart, Inc. -- 34227 -- V	Director	Merchand		01/18/2022 <input type="checkbox"/>

Fig. 2. The event extraction result of a news article is shown through the AutoMC Workbench.

natural language processing step where the input text is split into sentences, stop and infrequent words are removed; (iii) rule generation step where possible rules are generated using n-grams; (iv) rule filtering step where too generic and infrequently matching rules are filtered out.

In the entity annotation step, the event entities are replaced with special tokens of organization, title, and person. Management change events contain 6 different entity types (person, organization, title, group, region, and date) and the move event type has two instances of event entities; previous and new. In order to reduce the complexity of generated rules and to increase the detection rate, Regex Learner module is designed to generate rules which can detect the core entity types of person, title, and organization.

In the NLP step, we split documents into sentences and tokenize each sentence using Stanford's CoreNLP [12]. Regex Learner only retains words appearing more than 100 times in the dataset and removes the words that appear less. Regex Learner also removes stop words along with special words (as, to, of, new, etc.) that are observed frequently in management change events.

In the rule generation step, Regex Learner filters out the sentences if it does not contain all the event tokens of organization, title, and person. Then for each remaining sentence, Regex Learner generates all possible rule combinations using the n-gram technique with the restriction of retaining all entity tokens, a sentence verb, and at least one word between entity tokens. Regex Learner also adds the matches any number of characters regular expression token between each word in order to learn more generic rules. For example, Table 1 shows the generated rules for a given example sentence from a document annotated with a hire type of event. The event rule learning algorithm is applied for each management change event type and distinct rules are learned. In order to detect the previous position entities of move or internal move events, Regex Learner also learns rules using the same approach.

Table 1. An illustration of the Regex Learner Module on a sample sentence that contains management change events.

Input Text	James Black has been appointed as the new Director at ABC Inc.
Annotated Text	_Person_ has been appointed as the new _Title_ at _Organization_
Processed Text	_Person_ appointed as new _Title_ at _Organization_
Extracted Rules	_Person_ .* appointed .* _Title_ .* at .* _Organization_ _Person_ .* appointed .* as .* _Title_ .* at .* _Organization_ _Person_ .* appointed .* new .* _Title_ .* at .* _Organization_ _Person_ .* appointed .* as .* new .* _Title_ .* at .* _Organization_

In the rule filtering step, Regex Learner filters out too generic and infrequently matching rules. If a rule is generated less than 100 times in the whole dataset, then it is considered infrequent and discarded. A rule is also discarded if it is too generic that it might cause false event detection. We label rules as too generic unless it is not generated 2 times more than the summation of its extracted subset rules. For example, the firstly listed extracted rule in Table 1 is a generic rule that would cover all the possible event extractions of the other three subset rules.

The proposed rule learning method is one of the key contributions of this study. We have utilized our method on the annotated data, which is created manually by the business experts of IgniteTech to learn the management change event rules. The annotated dataset contains 30,106 published news articles in 2021 about management change events. Table 2 shows the number of news articles and the number of distinct event types in our final training dataset.

Table 2. Regex Learner training dataset characteristics.

# Article	# Event	# Move	# Departure	# I_Move	# Hire
30,106	47,387	5,947	8,532	9,878	23,030

Regex Learner is able to learn three types of rules; new, previous, and departure. New rules help us to extract new positions, new organizations, and person entities for the hire and move event types. Previous rules help us to extract previous positions, previous organization, and person entities for the move event types. Similarly, departure rules help us to extract previous position, previous organization, and person entities for the departure event types. Table 3 shows the total number of auto generated rules along with 3 sample rules for each rule type as a result of the rule learning step using our training dataset.

Table 3. Auto generated management change event rules statistics along with sample ones.

Type	Size	Samples
New	207	_Organization_ .* announce .* promotion .* _Person_ .* to .* _Title_ _ _Person_ .* is appointed .* to .* _Title_ .* of .* _Organization_ _ _Organization_ .* replaced .* _Title_ .* with .* _Person_ _
Previous	164	_Person_ .* prior .* joining .* , .* _Title_ .* at .* _Organization_ _ _Person_ .* served as .* _Title_ .* of .* _Organization_ _ _Person_ .* was .* _Title_ .* at .* _Organization_ _
Departure	45	_Organization_ .* announces .* _Person_ .* resigned .* _Title_ _ _Organization_ .* of .* _Person_ .* resigned .* as .* _Title_ _ _Organization_ .* retire .* _Person_ .* from .* _Title_ _

3.2 News Classifier

The News Classifier module aims to solve a binary classification problem by detecting news articles about management change events. This module is realized in two steps: the creation of training data and the development of a fast and accurate supervised text classification algorithm.

The first step, creating a training set is achieved by combining the articles about management change events used in the rule learning step and other business news articles, which are collected using the FirstRain solution for the same period of 2021. We have created a balanced dataset, where each target class is represented by the equal number of input samples. The dataset contains totally 60,000 published news articles.

In the second step, we have used FastText [10] as a linear text classifier on the created dataset. FastText considers distributed word representation and word order using a variety of methods while utilizing computationally efficient algorithms. It converts documents to vectors by averaging the word embeddings that correspond to their words and is used as the input to train linear classifiers with a hierarchical softmax function [10]. In recent studies [16, 17], it is reported that FastText outperforms the traditional machine learning algorithms such as Logistic Regression, Support Vector Machines (SVM), Random Forests, and it is frequently used for text classification [4]. For that reason, FastText is used in this study as the text classifier to detect news articles about management change events.

3.3 Management Change Extractor

Management Change Extractor module is used for extracting the events from news articles by utilizing a rule based approach. Specifically, our approach consists of three main steps that are described in Algorithm 1.

In the first step, the input text is processed with Stanford’s CoreNLP tool [12] to extract named entities, sentences, and words. Then the extracted entities are replaced with special tokens of organization, title, and person. In the second

```

events = [];
sentences, entities = stanford_corenlp_service(document);
for sentence in sentences do
    annotated_sentence = annotate_entities(sentence, entities);
    new_matchings = match_rules(annotated_sentence, new_rules);
    previous_matchings = match_rules(annotated_sentence, previous_rules);
    departure_matchings = match_rules(annotated_sentence,
        departure_rules);
end
events.add(new_matchings);
for new_match in new_matchings do
    for previous_match in previous_matchings do
        if new_match.person = previous_match.person then
            unified_event = unify(new_match, previous_match);
            events.remove(new_match);
            events.add(unified_event);
            break;
        end
    end
end
events.add(departure_matchings);
for departure_match in departure_matchings do
    for new_match in new_matchings do
        if new_match.person = departure_match.person then
            unified_event = unify(new_match, departure_match);
            events.remove(departure_match);
            events.add(unified_event);
            break;
        end
    end
end
return events;

```

Algorithm 1: The algorithm for a rule based management change event extraction for an input document.

step, event extraction rules are applied to each sentence in the order of new, previous, and departure. In the final step, the matching rules are unified and interpreted to find the management change events that would be presented in the AutoMC Workbench. The possible event unification cases per event type are listed below:

- Hire: If there is only a new rule matching for a person entity then it is classified as a hire event type.
- Internal Move: When the same person entity is matched with a new and previous rule and organization names are identical for the new and previous matchings then an internal move event is created by combining the extracted entities.
- Move: When the same person entity is matched with a new and previous rule and organization names are different for the new and previous matchings then a move type of event is created by combining the extracted entities.
- Departure: If there is only a departure rule matching for a person entity then it is classified as a departure event type.

4 Evaluations and Experiments

The primary goal of this work is to create a system for extracting management change events from texts automatically. To evaluate the performance of the proposed system, a corpus is formed as described below.

News articles about the management change event has been collected using the FirstRain product in January 2022. FirstRain collects hundreds of articles published every day by popular news agencies like CNN, BBC, etc. Then, 500 different English news articles about a management change event are selected randomly and annotated manually by business experts to create the final testing dataset. The characteristics of the generated dataset are described in Table 4.

Table 4. AutoMC management change event dataset characteristics.

Total Event	Hire	Move	I_Move	Departure	
578	335	55	100	88	
Total Entity	Person	New_Org	New_Title	Prev_Org	Prev_Title
2003	578	490	490	243	202

To evaluate the performances of the proposed AutoMC system, accuracy metric is used as in the following formula:

$$Accuracy = \frac{\# \text{ correct predictions}}{\# \text{ total events or entities}} \quad (1)$$

The results of the overall performance on the test dataset are illustrated in Table 5 and Table 6. As Table 5 shows AutoMC has achieved 78.22% accuracy. The highest performance 90.75% accuracy is measured with the detection of the hire event type. We also observed the lowest performance of 54.55% accuracy with the detection of the move event type.

Table 5. Comparison of the performance values of AutoMC event extraction with varying event types.

Hire	Departure	I_Move	Move	Total
90.75%	65.91%	63.00%	54.55%	78.72%

Table 6 shows the performance values of AutoMC entity detection with varying entity types. The highest performance 93.25% accuracy is observed with the detection of the person entity, which can be also be interpreted as event detection performance of AutoMC. We observed the lowest performance of 44.55% accuracy with the detection of the previous title entity. Similarly, low performance (59.26%) is observed for the previous organization entity too.

Table 6. Comparison of the performance values of AutoMC entity detection with varying entity types.

Person	New_Org	New_Title	Prev_Org	Prev_Title	Total
93.25%	84.90%	79.80%	59.26%	44.55%	78.88%

Low performance on detection of the previous entities has caused AutoMC to perform worse compared to hire event type as we see in Table 5. The main reason for this low performance is that previous position information is mostly given partially in a sentence of management change article and it can be extracted by interpreting the whole document content. Since the AutoMC system extracts events at the sentence level, it doesn't perform well to extract previous entity types for certain cases.

For example, for the passage below, AutoMC recognizes that this passage contains a management change event. It would identify "John Black" as the person entity, "ABC Inc." as the new organization entity, and "Chief Executive Officer" as the new title entity of the event. However, AutoMC fails to detect the previous organization entity since there is no sentence that contains the previous organization and previous title entities. Therefore, AutoMC classifies the event as a hire event type rather than an internal move event, which can be interpreted only from the second sentence.

"ABC Inc. announces the appointment of John Black as the Company's Chief Executive Officer. Jim Nolan, Chairman of ABC Inc., commented,

We are excited to welcome John as the CEO of Diamond Wipes, who has been with the company for several years."

One of the management change event detection studies in the literature is proposed by Sahnoun et al. [15], which is also a rule based system. Our work differs from this study in the aspect of rule creation, which is automated in our proposed study. The authors have evaluated their system on a manually annotated dataset of 40 news articles. They reported a 79.34% F1 score in their evaluation results and closer performances for new and previous organization and title entity types. Even though our performance results are closer to this study, we can deduce that we arrived at an acceptable rate for a fully automated system to extract management change events from unstructured text.

5 Conclusion

This study presents - AutoMC - a management change event detection system that can extract management change event entities for a given unstructured text by using NLP and machine learning based techniques. The creation of the extraction rules is one of the key challenges addressed in the proposed system. To address this problem, a rule based algorithm is proposed, which leverages NLP methods. Moreover, a series of experiments are conducted to evaluate the performance of the system. Evaluations show that the proposed system has a satisfactory performance (78.72% accuracy score) for the task and it performed competitively in comparison to the previous methods in the literature.

In future work, the proposed management change event detection system could be improved by learning rules at the document level rather than the sentence level by incorporating the state of the art document level event extraction algorithms.

References

1. Arendarenko, E., Kakkonen, T.: Ontology-based information and event extraction for business intelligence. In: International Conference on Artificial Intelligence: Methodology, Systems, and Applications. pp. 89–102. Springer (2012)
2. Cao, L., Yang, Q., Yu, P.S.: Data science and ai in fintech: An overview. International Journal of Data Science and Analytics **12**(2), 81–99 (2021)
3. Chaturvedi, N., Dubey, J.: Study of state of arts methods for event extraction. In: Proceedings of International Conference on Advances in Computer Engineering and Communication Systems. pp. 117–126. Springer (2021)
4. Collobert, R., Weston, J., Bottou, L., Karlen, M., Kavukcuoglu, K., Kuksa, P.: Natural language processing (almost) from scratch. Journal of machine learning research **12**(ARTICLE), 2493–2537 (2011)
5. Elloumi, S., Jaoua, A., Ferjani, F., Semmar, N., Besançon, R., Al-Jaam, J., Hammami, H.: General learning approach for event extraction: Case of management change event. Journal of information science **39**(2), 211–224 (2013)
6. Han, Z., Jiang, J., Qiao, L., Dou, Y., Xu, J., Kan, Z.: Accelerating event detection with dgcnn and fpgas. Electronics **9**(10), 1666 (2020)

7. Hogenboom, A., Hogenboom, F., Frasinca, F., Schouten, K., Van Der Meer, O.: Semantics-based information extraction for detecting economic events. *Multimedia Tools and Applications* **64**(1), 27–52 (2013)
8. Jacobs, G., Hoste, V.: Extracting fine-grained economic events from business news. In: *Proceedings of the 1st Joint Workshop on Financial Narrative Processing and MultiLing Financial Summarisation*. pp. 235–245 (2020)
9. Jacobs, G., Lefever, E., Hoste, V.: Economic event detection in company-specific news text. In: *Proceedings of the First Workshop on Economics and Natural Language Processing*. pp. 1–10 (2018)
10. Joulin, A., Grave, E., Bojanowski, P., Mikolov, T.: Bag of tricks for efficient text classification. In: *Proceedings of the 15th Conference of the European Chapter of the Association for Computational Linguistics: Volume 2, Short Papers*. pp. 427–431. Association for Computational Linguistics (April 2017)
11. Konchitchki, Y., O’Leary, D.E.: Event study methodologies in information systems research. *International Journal of Accounting Information Systems* **12**(2), 99–115 (2011)
12. Manning, C.D., Surdeanu, M., Bauer, J., Finkel, J.R., Bethard, S., McClosky, D.: The stanford corenlp natural language processing toolkit. In: *Proceedings of 52nd annual meeting of the association for computational linguistics: system demonstrations*. pp. 55–60 (2014)
13. Miller, G.A.: *WordNet: An electronic lexical database*. MIT press (1998)
14. Peng, G., Chen, X.: Entity–relation extraction—a novel and lightweight method based on a gate linear mechanism. *Electronics* **9**(10), 1637 (2020)
15. Sahnoun, S., Elloumi, S., Ben Yahia, S.: Event detection based on open information extraction and ontology. *Journal of Information and Telecommunication* **4**(3), 383–403 (2020)
16. Salur, M.U., Aydin, I.: A novel hybrid deep learning model for sentiment classification. *IEEE Access* **8**, 58080–58093 (2020)
17. Stein, R.A., Jaques, P.A., Valiati, J.F.: An analysis of hierarchical text classification using word embeddings. *Information Sciences* **471**, 216–232 (2019)
18. Tong, M., Wang, S., Cao, Y., Xu, B., Li, J., Hou, L., Chua, T.S.: Image enhanced event detection in news articles. *Proceedings of the AAAI Conference on Artificial Intelligence* **34**(05), 9040–9047 (Apr 2020)
19. Wang, P., Deng, Z., Cui, R.: Tdjee: A document-level joint model for financial event extraction. *Electronics* **10**(7), 824 (2021)
20. Yang, H., Sui, D., Chen, Y., Liu, K., Zhao, J., Wang, T.: Document-level event extraction via parallel prediction networks. In: *Proceedings of the 59th Annual Meeting of the Association for Computational Linguistics and the 11th International Joint Conference on Natural Language Processing (Volume 1: Long Papers)*. pp. 6298–6308 (2021)