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Research on the Impact of Entities' Cooperation Ability of Emergency Entities

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Abstract: *To improve the cooperation ability of emergency entities, in this research, the emergency activities model, skill contribution degree, entity-relationship strength, activity continuity, and emergency entity cooperation degree were defined. Emergency entity cooperation degree and emergency activity continuity table were constructed with emergency cases, emergency plans, and emergency drill plans, and factors were further excavated which affected them. In this paper, we focus on the factors which affect the cooperation ability of emergency entities, the relationship between the emergency cooperation ability and the number of cooperation, entity-relationship intensity, emergency activity frequency, and skill contribution of fire entities and medical entities were obtained. These data results are of great significance to decision-makers in formulating emergency rescue and emergency plans.*

Keywords: Entities; Cooperation; Degree; Activities.

1. Introduction

In recent years, frequent emergencies in the world, such as public safety and COVID-19, have put forward higher requirements for emergency rescue and emergency disposal. There have been many achievements in the research of emergency teams. Wang Wenjun's team [1,2] studied the core elements of emergency based on human dynamics and used community detection and other methods to deal with complex situations such as emergency situations, subjects, resources, objects. Liu D et al. [3] studied the relationship between entities and entities in complex situations in the detection of complex communities. Many research teams have made achievements in the field of member allocation and team generation [4]. Ly proposed to use the decision tree learning method [5] to allocate members from the perspective of artificial intelligence. Liu YB [6]extracted members' skill characteristics based on machine learning, to complete skill matching in team generation. Xu RB et al. proposed a membership allocation model based on the attributes of subject members, resource objects, and related constraints, taking into account a variety of execution modes, then good results have been achieved in team-building [7,8].

In the aspect of the activity-based cooperation model, many research teams put forward the team cooperation model. Meddah proposed a process-based mining collaboration model [9]. Based on social network theory, Lappas took the cost of cooperation among members as an operator to increase the efficiency of team cooperation [10]. Kargar proposed the Top-k team to replace the best team in the past based on the sum of distance and leader distance [11,12].

Many achievements have not been studied on the optimal allocation of entity members in emergencies and coordination among emergency teams. The main task of this paper is to join the essential factors and attributes of an emergency rescue system in the specific environment of emergencies, which is valuable work.

2. Concepts and Problem Description

2.1 Related Concepts

Definition 1. Emergency Event (*EE*) includes the Emergency Event Start Time (*EEst*) or can be the start time of sub-events. The Emergency Event scene (*EEs*) can be the collection of the place where the event occurred and transferred, and the end time of the event (*EEet*). Emergency Event Subject (*EEsub*), Emergency Event Object (*EEobj*), Emergency Event Name (*EEname*) has uniqueness, Emergency Event Activity (*EEact*). *Ee* is a subset of *EE*. The formal descriptions are as follows.

Ee={*Eest*($t_1,t_2,...t_n$), *Ees*($s_1,s_2,...s_n$), *Eeet*($et_1,et_2,...\ et_n$), *Eesub*(*oil,hotwater,trucks...*), *Eeobj*(*human, animal*), *Eename*(*explosion,collapse,fire...*), *Eeact*(*Sprinkle, bury,hoist...*) }.

EE_1={(*2018/2/5/17:18, Fuxintang Bath Shop, Chicheng Street, TiantaiCounty, Taizhou City, Zhejiang Province, 2018/2/5/24:00, fire, people, fire, EEact* (*flushing, rescuing, emergency rescue, explosion-proof, lifting and transporting*), *emergency execution entity* (*Entity person, Ep*) = (*firefighters, medical personnel, material management, and other emergency personnel*)}.

Definition 2. Emergency Rescue Process Model (*ERPM*). Emergency coordination departments allocate their resources according to emergency needs after receiving the alarm. The resulting sequence of rescue activities, the formal description is (Activity[*n*], A) = {a_1, a_2, a_3 ... a_n}. The set represents an orderly pair tuple of priorities between activities, S(A*A), Rules represents the order between rescue sub-activities, which is defined as *ERPM* = (A, S, R).

Definition 3. Emergency activity model. Procedures for the environmental treatment of emergency sites(*EvP*). For instance, a_1 denotes “gas isolation and purification activities”; a_2 denotes“disposal of collapses”; a_3 denotes “disposal of power outages in an electrified environment”, etc.

Emergency Subject Processing(*SP*). a_1 denotes “sprinkle water on the ignition point”; a_2 denotes “dry ice treatment on the ignition point”.

Emergency Object Processing(*OP*). For instance, a_1 denotes “rescuing trapped persons”; a_2 denotes “ using detection”; a_3 denotes “rescuing other materials”.

Procedures for fixing sudden scene situations(*SaP*). For instance, a_1 denotes “field assessment”; a_2 denotes “confirmation of explicit trigger termination”; a_3 denotes “confirmation of implicit trigger termination”.

Emergency Rescue Result Assessment (*RA*): a_1 = Rescue Economic Value Assessment, a_2 = Rescue Number Assessment. Eventually generated Activity[n] = {*EvP, SP, OP, SaP, RA*}, where the relationship between activities and activities can be duplicated, such as Activity[n] = {*EvP, SP, OP, SP, OP, SaP, RA*}, which indicates that the priority of *SP*, *OP* does not have a clear priority relationship and needs to be carried out concurrently. This corresponds to the characteristics of emergencies. A lot of activities are executed concurrently, and S = {<*EvP, SP*>, <*SP, OP*>, <*OP, SaP*>, <*SaP, RA*>} is obtained. Emergency rescue events enter the emergency case base with a process template to generate case knowledge.

Definition 4. Emergency database represented by EE_{CB}, the formal description is EE_{CB} = {Ee_1, Ee_2, Ee_3... Ee_i, ... Ee_n}, it categorized by event subject. A_{ee} = {a_1, a_2, a_3... a_i, ... a_n} appears in the set of activities in EE_{CB1}. $T_i = <Ee_{i,0}; Ee_{i,1}; ... ; Ee_{i,j}>$ denotes *a* time series of all events in the emergency case database, where $E_{ei,j}$ denotes the *j*th event in the *i*th emergency case. Activity denotes the trajectory $T_i = <a_{i,0}; a_{i,1}; ...; a_{i,j}>$.

Definition 5. Emergency entity $Ep = \{(a_i\_Ep_i), ai \quad A_{ee}, Epi \quad Ep\}$, which indicates that *Epi* performs rescue activity a_i in an emergency; Then the entity track is defined as $EpT_i = <a_{i,0}|Ep_{i,0}; a_{i,1}|Ep_{i,1};...; a_{i,j}|Ep_{i,j}>$, which denotes the sequential sequence of activities of an emergency rescue entity. An emergency execution entity can also be an emergency group, which contains several entity sequences.

Definition 6. The skill contribution of the emergency entity is the ratio of the number of times Ep_i uses a skill in an activity to the total number of times this skill is used in EE_{CB}, which is U_{Epi} (0,1), which reflects a skill proficiency of an entity.

Definition 7. The continuity of emergency activities is expressed by $contin_{ai,aj}$, and $contin_{ai,aj}$ [0,1], indicates the degree of continuity and synergy between a_i and a_j in emergency execution[13].

$$contin_{a_i,a_j} = \{1+e^{-\theta(fa_i,a_j - f')}\}^{-1} \tag{1}$$

Where $f_{ai,aj}$ indicates the frequency of occurrence in emergency activities, f' represents the frequency at which all activities appear in the case base, and θ is a tuning parameter.

Definition 8. Relationship Strength (*RS*) of emergency entities is determined by the attribute similarity between entities. Assuming that there are *m* interactive relationships between Ep_i and Ep_j, $m \quad N$, x (Ep_i) and $x(Ep_j)$ represent entity attributes respectively, $RS<Ep_{i,j}>$represents the potential relationship strength between two entities, and $S(x(Ep_i), y(Ep_j))$ represent entity similarity.

$$P(RS < Ep_{i,j} >, m \mid x(Ep_i), y(Ep_j)) = P(RS < Ep_{i,j} > \mid x(Ep_i), y(Ep_j)) \prod_{1}^{m} P(m \mid RS < Ep_{i,j} >) \quad (2)$$

$$P(RS < Ep_{i,j} > \mid x(Ep_i), y(Ep_j)) = N(S(x(Ep_i), y(Ep_j)), v) \quad (3)$$

The v can be less than 1. If the team belongs to the same team, the value of v is slightly larger.

$$P(\mathrm{m} = 1 \mid RS < Ep_{ij} >) = \{1 + e^{-(RS+b)}\}^{-1} \quad (4)$$

RS is the strength of the relationship and gets a value P .

Definition 9. Cooperation degree of emergency entities. $Coop_{ai,aj}$ represents the cooperation ability of two entities in emergency activities. Where $t_{ai,aj}$ represents the average time required by the entities to execute a_i and a_j.

$$coop_{a_i, a_j} = \{RS_{a_i, a_j} + e^{-\theta(t_{a_i, a_j})}\}^{-1} \quad (5)$$

2.2 Data Sets

The data sets consist of a network case database and an artificial case database. Network case data is the news data of emergencies in a city from 2010 to 2019. The amount of news data collected in this paper is large, and the news with less content is removed, leaving more than 800 pieces of data describing the time, place, emergencies, rescue subjects, and so on. In this paper, 140 selected case data from one of the administrative divisions were conducted. There are 94 corresponding artificial data, accounting for 40%, as shown in Table1.

Table 1. Description of data

Data sets		Number	Field properties
News data		140	Start time, place, emergency event,
Artificial data	Emergency plan	42	name of the emergency entity,
	Emergency drill plan	52	emergency activity, end time ……

Source: Self-made table based on Data sets

The artificial case refers to the emergency plans and emergency drill plans. The emergency plans describe the sequence of emergency activities in detail, and the emergency drill plans describe the emergency subject and the sequence of emergency activities in detail. Taking a community as an example, the emergency plans formulated by enterprises, service industries, and other units in the community are carried out around the emergency rescue subjects within the administrative division, which provides a data basis for studying the degree of cooperation between emergency subjects and the continuity of emergency activities.

3. Methods

3.1 Optimization of Emergency Entities and Activities

The processing of emergency entities and emergency activities are optimized by emergency case and emergency plan data set. The overall framework shows in Figure 1. The emergency case base and plan base are preprocessed. Eliminate unnecessary fields in the database. Classify them by region and deal with the boundaries of administrative regions.

When a and B are the center of the region, the geographic location threshold is the highest. The farther away from the center, the smaller the geographical threshold, which is called weak boundary. Events distributed in the weak boundary can belong to two administrative regions, which are based on distance intensity.

Calculate the trajectory of emergency entities in cases within the same administrative division. The empty data in the matrix is corrected with the artificial case base data to eliminate the noise data and redundant data. In this paper, through the labeling method, the emergency time and attributes are standardized to eliminate the abnormal data, which is realized by the classical Needleman-Wunsch algorithm [14].

For example, *S=<EP, SP>, <SP, OP>, <OP, SaP>, <SaP, RA>*, in which *SP* is missing. When the activity field is aligned, fill it with "Λ", then *S=<EP, Λ>, <Λ, OP>, <OP, SaP>, <SaP, RA>*. This is conducive to the optimization of emergency execution entity activity sequence.

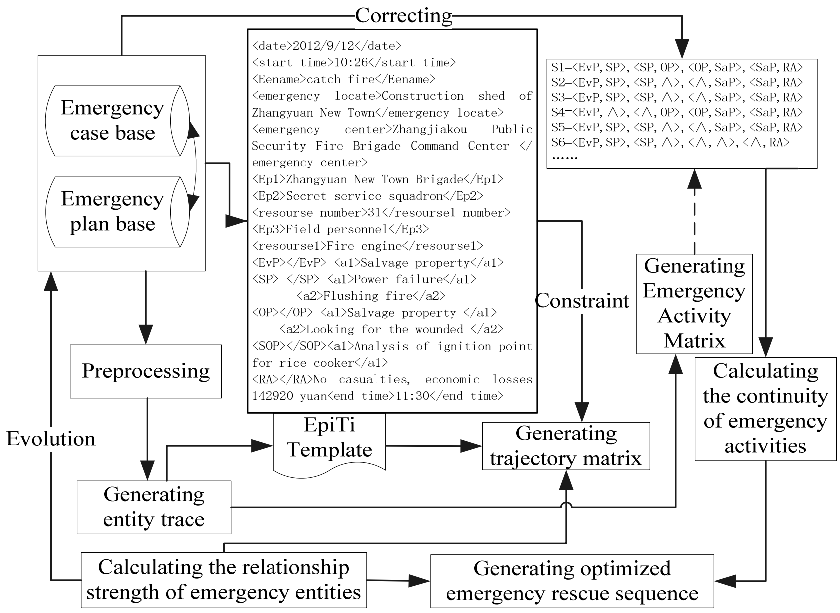

Figure 1. Optimization framework of emergency entities

The continuity of emergency activities and the relationship strength of emergency entities are by the data above. The entity cooperation ability and the optimized emergency activity sequence are obtained, which are calculated by skill contribution.

3.2 Mining Highly Cooperation Emergency Entities

In this paper, the high cooperation relationship between emergency entities is realized by analyzing the data in the entities cooperation degree table. According to the sequence of emergency events in the administrative region, in this paper, we establish the cooperation degree table between emergency entities and further analyze the influencing factors of the cooperation ability between emergency entities. As shown in Table2, the data were transformed into structured data through XML as input, the relevant parameters were initialized and the regional confidence threshold was set. First, the sequence of emergency entity trajectory and the sequence of emergency activities were established, and the relationship between emergency entities and activities was mapped.

Table 2. Constructing collaboration degree of entities

Algorithm 1: Constructing collaboration degree of entities

Input: Initialization *i,j,n,m,θ*; Dateset.
Output: Cooperation Degree of Entities.
1. Initialization *i,j,n,m,θ*;
2. Input Dataset;
3. For(int i; i<n; i++)
4. To construct Entity Trajectory Matrix;
4. To construct Active array Ea[*i*];
5. ActivitySeq Map[*i*] ← Get ActivitySeq(Ea[*i*]);
6. End For

7. For(int i; i<n; i++)
8. Get skills num[*i*],To calculate U_{Epi};
9. Calculate *RS* with formula (2-4);
10. End For
11. For (int i; i<n; i++)
    Calculate $Coop_{aiaj}$ with Formula (5);
12. Ep_iSeqMap[*i*] ← RS[*i*]*Coop[*i*]*U_{Epi};
13. End For
14 . If Ep_iSeqMap[*i*] ∈ ActivitySeqMap[*i*] Then
15. Output Cooperation Degree D[*i*];
17. End For

Source: Self-made table based on procedure flow

3.3 Mining High-continuity Activities

Based on the emergency case base and plan base, and combined with the cooperation degree of emergency entities in the previous section, the continuity table of emergency activities is constructed in the emergency event where the emergency entity is located, as shown in Table 3. The continuity of emergency activities was correctly analyzed. After parameter initialization, calculate the frequency *f'* of emergency activities, and then calculate the skill contribution of the corresponding emergency entity in the activity continuity, to make the relationship between the skill contribution and the strength of entity-relationship in the following, and then calculate the continuity of the activities executed by the emergency entity. Finally, the continuity table of emergency activities is obtained.

Table 3. Constructing continuity degree of activities

Algorithm 2: Constructing continuity degree of activities

Input: initialization i,j,n,θ.
Output: continuity degree of activities.
1. Initializationi,j,n,θ;
2. Input Dataset(collaboration degree of entities);
3. Get num(activities);
4. Get list(Ep_i);
5. For(int i; i<n; i++)
6. Calculate *f'*;
7. Calculate $contin_{ai,aj}$ with formula (1);
8. If $contin_{ai,aj}$ activity[i]∈Ep_iSeqMap[*i*] then
9. activities[i] ← $contin_{ai,aj}$ activity[i];
10. End For
11. For(int i; i<n; i++)
12. Output continuity degree of activities;
13. End For

Source: Self-made table based on procedure flow

4. Results

In the experiment, it took the data of a city in China as the research object. The data is composed of news, cases, and emergency plans with the result that19 cooperation tables of emergency entities and 27 high continuity tables of emergency activities were constructed. Some data are shown in Table 4 and Table 5.

When making emergency plans and emergency rescue plans, the core of emergency decision-makers is the emergency entity, and the degree of cooperation of emergency entities is the foundation of emergency rescue. The ability of cooperation of emergency entities directly affects the effect of rescue, in this paper, we focus on three indicators that affect the degree of emergency cooperation: the number of cooperation, relationship strength, and skill contribution.

According to table 4 and table 5, it is calculated that there are 9 fire fighting entities and 8 medical entities in the same administrative division. The degree of cooperation between them is analyzed below.

Table 4. Partial Cooperation degree of entities

Entity→Entity	Cooperation degree	Emergency event
$Ep_1\|a_1 \rightarrow Ep_2\| a_2$	0.304	$Ee_{1,1}$
$Ep_3\|a_1 \rightarrow Ep_4\| a_2$	0.451	$Ee_{1,1}$
$Ep_2\|a_2 \rightarrow Ep_3\| a_3$	0.367	$Ee_{1,2}$
$Ep_2\|a_2 \rightarrow Ep_4\| a_3$	0.000	$Ee_{1,2}$
$Ep_3\|a_2 \rightarrow Ep_4\| a_3$	0.345	$Ee_{1,2}$
……	……	……

Source: Self-made table based on partial data

Table 5. Partial of Continuity degree of activities

Activity→Activity	Continuity degree	Entity
$a_1 \rightarrow a_2$	0.601	Ep_1, Ep_2
$a_2 \rightarrow a_3$	0.751	Ep_2, Ep_3
$a_1 \rightarrow a_3$	0.267	null
$a_1 \rightarrow a_4$	0.132	null
……	……	……

Source: Self-made table based on partial data

As shown in Figure 2, the number of entity cooperation is the superposition of the number of actual implementations and the number of implementations in the plans. The curve shows that the cooperation degree of fire entities increases significantly with the increase of the number of cooperations. When the number of cooperation reaches 40, the rising slope of cooperation ability becomes larger. With the increasing number of collaborations, the entity collaboration degree can exceed 1. Therefore, to improve the cooperation degree of entities, fire fighting entities must be implemented through professional entities, and fire drill becomes particularly important.

The cooperation degree of medical entities also increased significantly with the increase of cooperation times. This shows that medical entities need professional entities to implement and carry out strict emergency drills, to improve their cooperation ability. In some places, medical care entities are mobile and can not give full play to the maximum ability of medical entities.

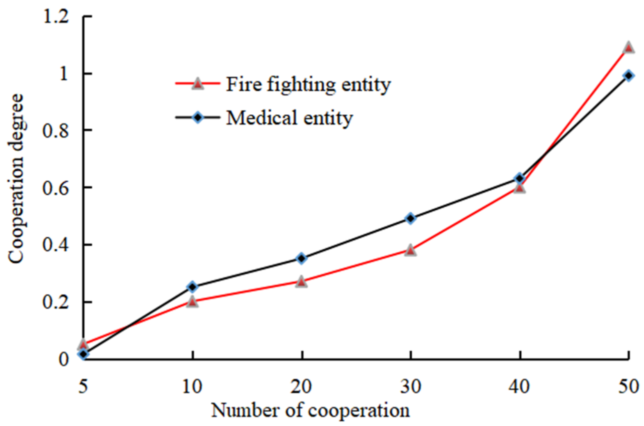

Figure 2. Relationship between the number of cooperation and cooperation degree.

According to the degree of continuity of activities and the degree of cooperation of the entity, calculate the strength of the relationship between entities. As shown in Figure 3, the curve represents the relationship between entity-relationship strength and cooperation degree. When the relationship strength coefficient is less than 0.4, the cooperation degree of fire entities remains at a relatively low level and changes little; When the relationship strength coefficient is greater than 0.4, the cooperation degree of entities begins to rise; When the relationship strength continues to increase, the degree of entities cooperation tends to be stable. This shows that the skill distribution of fire-fighting entities directly affects the degree of cooperation of entities. However, if only the skills of fire-fighting entities are pursued, the degree of cooperation of entities can be no longer improved. Therefore, the commander needs to have higher emergency command ability, take the commander's command as the guidance, comprehensively consider the rescue characteristics of the fire entity, and improve the adaptability of the fire entity.

The cooperation degree of medical entities continues to increase with the increase of relationship strength. It shows that the stronger the rescue skills of medical entities, the better the cooperation ability. This shows that medical entities need to have a higher skill level to improve the overall rescue level.

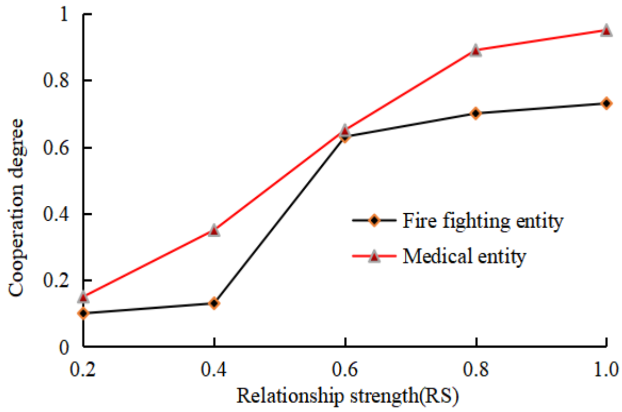

Figure 3. Relationship between RS and cooperation degree.

In algorithm 3, the skill contribution degree of the entity in participating activities is calculated, and the skill contribution degree corresponding to the above fire-fighting entity and the medical entity is found. The calculation method of skill contribution degree is described in definition 6. As shown in Figure 4, the curve shows the relationship between the entity's skill contribution and the frequency of emergency activities. The skill contribution of fire-fighting entities did not increase continuously with the increase of the frequency of emergency activities. When the frequency of emergency activities is less than 0.3, the skill contribution increases rapidly. However, with the increase of frequency, the skill contribution tends to be flat. When the frequency of emergency activities is 0.7, the curve shows an inflection point, and the skill contribution of fire-fighting entities shows a downward trend. This shows that increasing the number of emergency drills or emergency rescues can improve the skill contribution of fire-fighting entities in the early stage of team establishment. In the later stage, by adding different emergency scenarios in the emergency drill, the skill adaptability of the fire fighting entity is continuously improved.

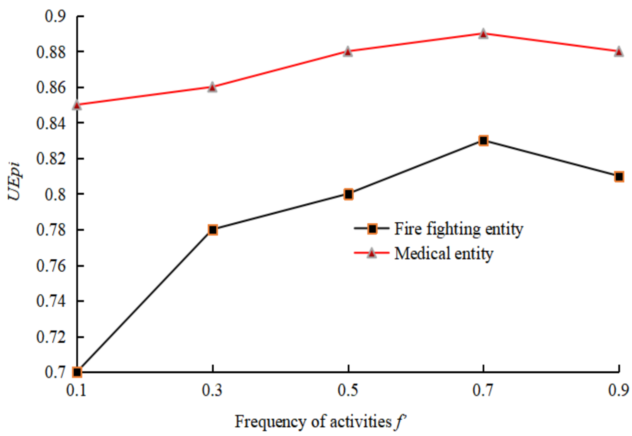

Figure 4. Relationship between frequency and skill contribution.

The skill contribution of medical entities changes little with the change of the frequency of emergency activities. The change range of emergency activity frequency is [0.1, 0.9], and the change range of skill contribution is [0.85, 0.88]. The skill contribution is always maintained at a relatively high level. The results show that there is a weak relationship between the skill contribution of medical entities and the frequency of emergency activities. When formulating the emergency plan or emergency rescue plan, the rescue ability of medical teams can be enhanced mainly by increasing the number of medical entities and improving the professional structure of medical entities.

5. Conclusions

To improve the cooperation ability of emergency entities, in this paper, we study the factors affecting the cooperation ability of emergency entities based on case base and plan base.

The performance of cooperation degree between fire-fighting entities and medical entities in the number of cooperation and the strength of entity-relationship is studied and analyzed. The relationship between the frequency of emergency activities and the skill contribution of emergency entities is analyzed. The research shows that in the early stage of fire-fighting entity, the skill contribution of the entity can be improved by increasing the frequency of emergency activities, while the skill contribution of the medical entity has a weak relationship with the frequency of emergency activities. These data will provide the basis for emergency decision-making. In the research, the fire entity and medical entity were studied only, and more emergency entities need to be analyzed to improve the accuracy of decision-making and achieve the role of emergency early warning.

In the next step, a variety of entities under the emergency scenario can be analyzed. Which is more effective for the data provided by emergency decision-makers. If a variety of real case data are used in the future, the mined entities and the relationships affecting the cooperation ability will be more accurate.

Conflicts of Interest: The authors declare no conflict of interest.

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