

# Adapting Tools for Text Monitoring and for Scenario Analysis Related to the Field of Social Disasters

Svetlana Cojocaru, Mircea Petic, Inga Titchiev

**Abstract**—Humanity faces more and more often with different social disasters, which in turn can generate new accidents and catastrophes. To mitigate their consequences, it is important to obtain early possible signals about the events which are or can occur and to prepare the corresponding scenarios that could be applied. Our research is focused on solving two problems in this domain: identifying signals related that an accident occurred or may occur and mitigation of some consequences of disasters. To solve the first problem, methods of selecting and processing texts from global network Internet are developed. Information in Romanian is of special interest for us. In order to obtain the mentioned tools, we should follow several steps, divided into preparatory stage and processing stage. Throughout the first stage, we manually collected over 724 news articles and classified them into 10 categories of social disasters. It constitutes more than 150 thousand words. Using this information, a controlled vocabulary of more than 300 keywords was elaborated, that will help in the process of classification and identification of the texts related to the field of social disasters. To solve the second problem, the formalism of Petri net has been used. We deal with the problem of inhabitants' evacuation in useful time. The analysis methods such as reachability or coverability tree and invariants technique to determine dynamic properties of the modeled systems will be used. To perform a case study of properties of extended evacuation system by adding time, the analysis modules of PIPE such as Generalized Stochastic Petri Nets (GSPN) Analysis, Simulation, State Space Analysis, and Invariant Analysis have been used. These modules helped us to obtain the average number of persons situated in the rooms and the other quantitative properties and characteristics related to its dynamics.

**Keywords**—Lexicon of disasters, modelling, Petri nets, text annotation, social disasters.

## I. INTRODUCTION

IN the world, many emergencies occur daily. They are of different nature, for example, natural disasters, technogenic disasters, or those executed by people. During the disasters, people expose their life to the dangerous impact of the environment and the economic factors. To mitigate the destructive results of the disaster, the functionality of communication during the response in such situations should be ensured.

In our actual society, a very important role is played by the

information networks. It is the place where we can learn about most recent news on different subjects. Especially, the Internet has become the place where the latest information about emergencies that have occurred in the world is placed. That is why it is used to help and mitigate the social consequences of disasters.

Huge amount of text data from the Internet becomes a valuable source of research towards the elaboration of a tool that will help to prevent the catastrophic consequences of disasters. The Internet users share their information about the emergencies by means of mass-media, social networks or blogs in the form of news, discussions, expressed views etc. The main characteristic of this type of information is its unstructured form. Taking it into consideration, we think that special analytical tools are needed that would give decision-makers support for a second opinion. Nowadays, there is no such kind of practical tools, with the exception of forest fire monitoring and forecasting applications.

Our paper is written within a project [1] whose main goal is to elaborate instruments, methods and algorithms that would be capable to determine various kinds of emergencies. The purpose is to track the online media sources in three neighbouring countries (Ukraine, Romania, and the Republic of Moldova), to find suitable texts in four languages: Ukrainian, Russian, Romanian and English, to analyse them within the Situation Analytical Centre established in Kiev, to recommend the opportune resilience solution to decision makers. In this paper, we intend to analyse a number of Romanian text data that are accessible on the Internet and are unstructured.

In order to mitigate the consequences of disasters, this paper illustrates an approach, using Petri Nets (PNs) formalism, to model the sequence of steps necessary for successful evacuation of people in case of a disaster. PNs are considered as an effective tool for modelling these requirements. They can be used for structural modelling of the system at the state level and quantitative analysis, behaviour simulation and good graphical representation of the elementary components.

The paper is organized as follows. First, existing approaches related to the process of identification in the social media the signals related to social disaster that occurred or may occur and to modelling disaster and emergency management activities will be presented. Section II concerns with the general approach in the collection of news articles obtained manually and the description of the two processing stages. In Section III, we treated the topic of the process of automatic retrieving and processing of online articles. Section IV deals with the requirements of modelling. In Section V, the

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proposed model for the evacuation of people in case of disaster will be introduced, including a small example. The paper is finalized with conclusions and future work suggestions.

## II. LITERATURE REVIEW

Emergency warnings and decision making are popular topics of research, and there are many papers that elucidate them. Internet resources are considered a rapid information spreading tool for people to be informed about recent emergencies [2], [3]. This fact makes social networks to be the most frequent instrument in disaster monitoring and mitigation [4]. Moreover, there are possibilities to locate the place of a disaster in the social network [5], [6]. In addition, the smart phones have become more frequent for application of the disaster response [7]. However, the above-mentioned possibilities do not take into account the regional particularities. For example, the region consisting of Romania, Ukraine and the Republic of Moldova has its own specifics [3], [8]. These particularities are described in [3], where the notion of Romanian Controlled Vocabulary is defined. This vocabulary was conceptualized based on the studies of a number of other professional controlled vocabularies [3]. In [9], another professional vocabulary is presented, which was developed in the USA and is divided in 17 categories. Each category was developed by the authorities that are interested in the usage of this terminology.

In the Republic of Moldova, there is a Service of Civil Protection and Exceptional Situation that has its own classifier [10]. It has the description of possible exceptional situations in the Republic of Moldova. That is why we used this resource in our research to classify the emergencies.

As the problem of permanent enrichment of the Controlled Vocabulary is authentic, the keywords that should complete this vocabulary are extracted from texts of social media [11].

With the purpose of analyzing, the existing approaches used for detecting, monitoring, modelling, and mitigating of social disasters caused by actions of different nature, articles related to the management, strategy development, methods of recovery and the possibility of their automatic processing were studied. An activity management system for the temporal coordination of disaster response activities is presented in [12]. In [13], Generalized Stochastic PNs were used in order to model a traffic accident rescue process with the aim of identifying weaknesses and optimizing rescue teams. Also, Stochastic PNs can be used to analyse and simulate a coal mine emergency process [27] and to model an emergency response decision-making process [28] for performance analysis. In [29], colored PNs were used in order to model an emergency plan business process. The way of transferring a text into a formal model together with the encountered difficulties has been studied and reported in [14]. The analysis and simulations of a coal mine emergency process by means of Stochastic PNs were presented in [15]. In [16], a practical tsunami refuge PN simulation system for independent disaster prevention organizations was developed, as a tool for heightening the awareness of potential tsunami damage. The

simulation system of spreading urban fire in an earthquake using PN was developed in [17], which can be applied to the case of fire occurring simultaneously in many places. In this context, the formal method like PN becomes a powerful and an important tool for detecting, monitoring, modelling, and mitigating of disasters caused by actions of different nature.

## III. ONLINE MEDIA PROCESSING STEPS

From the beginning, we tried to supervise social networks and news sites to understand which the keywords of the emergency events are. As we mentioned two main sources of information, it is important to underline that they are treated in different manners [18]. In the following sections, we limited our research only to news sites.

The elaboration of the tools that are intended to be created is supposed to be accomplished in two main stages: a preparatory one and the processing one. The steps for the first stage is presented in Fig. 1 and for the second stage in Fig. 2.

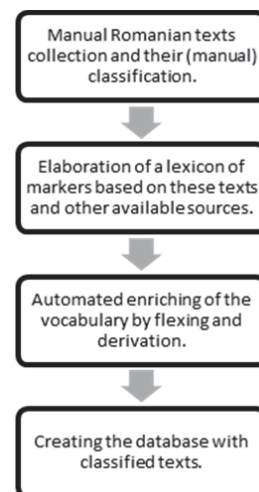


Fig. 1 Steps in preparatory stage

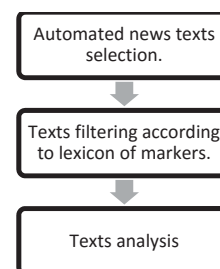


Fig. 2 Steps in the processing stage

During our research, we have monitored several sites from the Republic of Moldova and Romania and manually collected 724 texts in Romanian concerning the topic of our research. All the collected texts have more than 150 000 words that were lemmatized and annotated with the part of speech tagger. After the texts were pre-processed, we manually classified them into 10 categories of exceptional situations which are present in the Service of Civil Protection and Exceptional

Situation classifier (Fig. 3). One text can be considered as part of several categories. These selected categories include approximately 84% of situations that are described in the classifier [10]. The other situations have insignificant frequency for our research. Every specific social situation has its own set of lexical keywords.

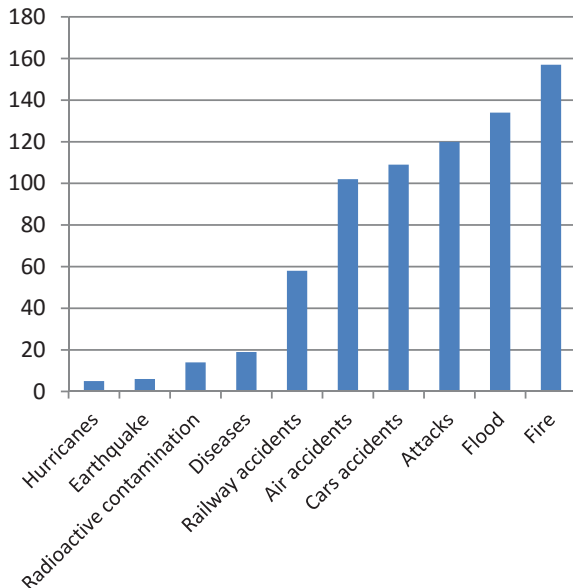


Fig. 3 Statistics on collected news article by categories

#### IV. AUTOMATE RETRIEVING AND PROCESSING OF ONLINE ARTICLES

In order to monitor different news articles on the Web, download and extract the necessary texts and store documents in the database, we have elaborated a crawler-base application [19]. As every site has its proper structure, plug-ins were elaborated for every site separately. Articles are downloaded based on the specific set of keywords from the lexicon of markers. We consider the lexicon of markers being the classifier attributes for those 10 categories. The classification is performed with the help of j48tree classifier that is included into the Weka application. Our methodology managed to obtain 76% of accuracy. After the process of filtration, only the text of the article is obtained.

The process of automation of news collecting from the Web is very important. That is why we started with Natural kit for NodeJS that has several tools for text processing; particularly Naive Bayes and logistic regression are of importance for us. Based on those 10 categories, we completed a database with the downloaded news texts following the format of data in the database. In this manner, we classified all the collected texts in different topics. The process of analysis consists in the comparison of the target text with the texts from the database. The tool offers the score of similarity that indicates how close the text is to a selected topic.

The experiments showed that if the database grows by  $n$ ,

then the processing time is growing by  $2n$ . That is why our research is directed to streamline the process. We want to find a methodology to decrease the processing time of the texts. The first idea is to make optimizations for the data from the database. The optimization concerns the contents of the database. We excluded those sentences or only words that are not relevant to the topic of our research. The remained text would be sufficient for processing and classification of new downloaded articles and the analyzing time is less than previous. However, these optimizations in database should be made carefully in order not to omit important sequences of texts. Obviously, the text reducing is made only in patterns and news should not be modified, where, all the details of the articles are not omitted, for example the place of the emergency. It will be useful for mitigation scenarios.

#### V. KEYWORDS OF THE TOPICS

The annotation of the collection of texts is followed by extraction of keywords of the topics, from which we created a special lexicon. The words or expressions related to emergency were manually extracted and included into our lexicon. As we mentioned before, there are some fundamental resources that served as basis for our lexicon [20]. These are the site of Service of Civil Protection and Exceptional Situation and Romanian Controlled Vocabulary, developed in [3]. These two resources, in combination with the keywords from the collected particles, constitute the basis of our lexicon of keywords. Actually we have a lexicon with more than 380 keywords. Nevertheless, the lexicon needs to be always completed with new keywords. The first idea is to process new articles and to extract new keywords. The other solution is to exploit the generative particularities of Romanian language morphology. In this case, we may increase the number of keywords from the existent set of keywords from our lexicon. That is the reason of this component of the final system.

For our research purpose, we work with stems. Romanian language corresponds to inflectional class of languages and the process of inflection and derivation supposes to take into consideration the vowel or consonant alternations. For example, there are several stems because of vowel alternation for the verb “a dărapăna” (to run-down): dărapăn, dărapăn, dărapen. With the help of our in-house tool, we inflected the keywords from the lexicon. The tool was elaborated by taking into account the grammar rules with scattered contexts [22]. The process of inflection uses the morphological knowledge corresponding to a concrete keyword. The algorithm includes the word to a morphological group [23]. Obviously, every ending has its own morphological characteristics of the word-form; thus, we obtain morphological annotation of the keyword.

If, in the process of inflection, there is not any change in the meaning of the words [24], the process of derivation is more sophisticated. Our approach uses only information about letter representation, and in some cases, the part of the speech without any semantic information. As automatic derivation is an over-generative process, we need a stage of validation. In our case, we use the Internet filtration and then manual

validation for the generated keywords [25]. The approach can help in the vocabulary completion by more than 15%, with the accuracy of 89%.

## VI. PETRI NETS

In the following sections, we will solve the second problem enunciated in introduction and related to mitigation of some consequences of disasters.

Several methods can be used to check and analyse the properties of distributed systems. A formal method, like PNs, is one of the methods which demonstrated high power of modelling and good results in time. With the PNs sequential, asynchronous and parallel systems can be expressed accurately. The model should correspond to a certain performance restriction and it is required to define a configuration of the system, intended to work in a certain context. Performance restrictions aim to ensure functional characteristics in the current context related to response in time. In particular, this study is focused on quantitative investigations related to dynamics of the modelled system.

The occurrence of social disaster [13], [26] can lead to other kind of accidents and catastrophes and may be necessary to keep human health and in some cases, human life by timely evacuation of people. In order to determine important features related to the successful evacuation of people, formal method like PN is used. Modelling is held at state (named places in terms of PNs) level, are determined states where one can find out the system and actions (named transitions in terms of PNs) that can lead to its changing. They have intuitive graphical representation and are a bipartite graph with two types of nodes: places and transitions interconnected by arcs, but which connect only different types of nodes.

In theoretical and practical ways, the formalism of PN can be applied. In order to surprise, as close as possible, the modelled real systems, the classical PN has been extended with the notion of time [12], [13]. They are a powerful modelling technique because they can be used to model complex systems and to verify if the modelled systems satisfy some criteria.

## VII. GSPN

To perform quantitative analysis, GSPNs [26] will be used, because they can capture the aspects of production in time of actions and immediate producing of some actions.

GSPNs have been extended from the ordinary PNs and contain the same basic sets such as:

- set of places  $P$ ;
- set of transitions  $T$ ,  $P \cap T = \emptyset$ ;
- input, output and inhibition functions  $I$ ;  $O$ ;  $H$ :  $T \rightarrow N$  ( $N = P \cup T$ ).

They were extended by using of two types of transitions: *immediate transitions* which are produced immediately and *stochastic transitions* which are produced complying with an exponential distribution function.

Weighting function  $W$ :  $T \rightarrow R$ , were extended in the following way:

- for a timed transition (represented by a hollow rectangle),  $w(t)$  is a rate (possibly marking dependent) of a negative exponential distribution specifying the firing delay;
- for an immediate transition (represented by a filled rectangle),  $w(t)$  is a firing weight (possibly marking dependent).

Also a priority function  $\Pi$ :  $T \rightarrow N$  is added, which associates the lower priorities to timed transitions and higher priorities to immediate transitions.

The initial marking  $M_0$ :  $P \rightarrow N$  determines the initial state of the modelled system.

Transition is enabled, if and only if required tokens are available in the input places. The transition that will occur is based on the priorities and weights. First, the set of transitions with the highest priority is found and if it contains more than one enabled transition, the selection is based on the rates or weights of the transitions, according to:

$$P\{t\} = \frac{w(t)}{\sum_{t' \in E(M)} w(t')} , \quad (1)$$

where  $E(M)$  is the set of transitions enabled at the marking  $M$ , i.e. the set of enabled transitions with the highest priority.

The firing of a transition removes the tokens from input places. The distribution of tokens (denoted by dots), called GSPNs marking, defines the state of the modelled processes.

When a new marking is reached, if only timed transitions are enabled, this marking is called *tangible*; if at least one immediate transition is enabled, the marking is called *vanishing*.

In order to determine the time of evacuation of people from rooms, we will take into account the speed of one or more flows of people:

$$t_{ev} = \sum_{i=1}^n t_i \quad (2)$$

where  $n$  is the number of rooms,  $t_i$  is the travel time of the first flow, which depends on length of room and walking speed of people flow.

The transfer function is used, which takes into account the time spent in the queue (moving time of human in the room) and the density and flow rate. The walking speed on the first flow depends on people's density in the rooms. The maximum density of inhabitants in every room is assumed to be 6.5 people/m<sup>2</sup>.

$$D_1 = \frac{N_1}{(l_1 + w_1)} \quad (3)$$

where  $N_1$  is the number of people in the first room,  $l_1$  is the length of the first room, and  $w_1$  is the width of the first room.

The maximum number of persons who can enter each room is:

$$N_{max} = l * w * 6.5$$

where  $l$  is the length of the room, and  $w$  is the width of the



room.

The walking speed on the next rooms depends on the flow rate, which depends, in turn, on the flow rates of the previous flows.

$$r_i = \frac{\sum r_{i-1} * w_{i-1}}{w_i} \quad (4)$$

where  $r_i$ ,  $r_{i-1}$  are the flow rates in  $i$ ,  $i-1$  rooms, and  $w_{i-1}$ ,  $w_i$  are the width of the  $i-1$ ,  $i$  rooms, respectively.

By a GSPN structure, only the static properties of a system can be determined, and the dynamic system properties result from the execution of GSPN.

### VIII. EVACUATION SYSTEM

In order to model an evacuation system, we will respect the following algorithm [21]:

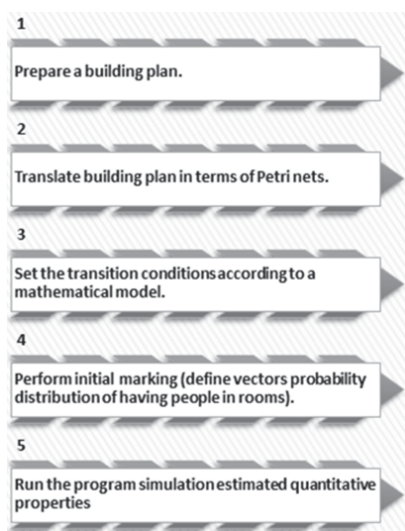


Fig. 4 Necessary steps to model evacuation system

In every building, the evacuation plan is given to make the translation easier in terms of PNs. We will mark the rooms and doors. Suppose that there is a building as it is specified in Fig. 5. By R1-R9, the rooms are denoted, and the doors are denoted by D1-D9. In Fig. 6, the PN of this building is given.



Fig. 5 Building plan

The rooms are modelled by using the places R1-R9, doors

are modelled by using the places D1-D9, movements from the rooms to the doors takes time and are modelled by the timed transitions  $t_0$ - $t_8$ , and movements from the doors into the rooms are modelled by immediate transition  $t_9$ - $t_{15}$ . Each inhabitant is modelled by one token, respectively. The people are moving according to evacuation plan from room to room until they exit the building. They are accumulated in the place which represents the last door (D9). The initial marking is  $M_0 = (2, 1, 2, 1, 1, 2, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0)$ .

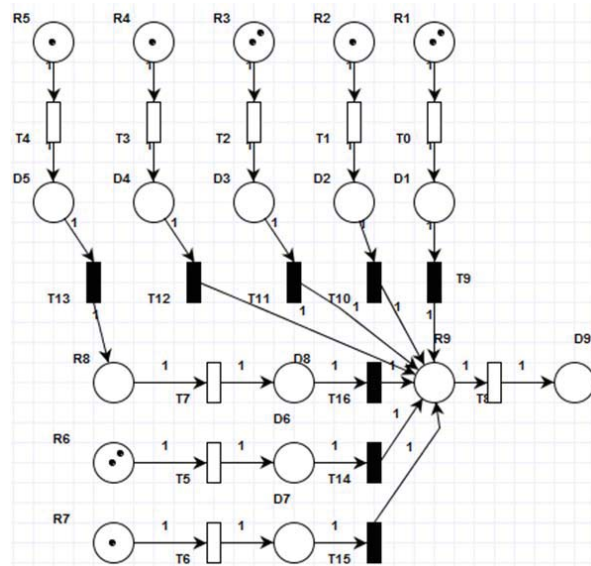


Fig. 6 GSPN which models the building from Fig. 5

After the translation of the building plan in terms of PNs, the setup conditions for firings of transitions (speed of flows, walking speed, people's density in the rooms, transfer function, flow rate) are described in the previous paragraph.

Using the analysis modules of PIPE [30], we have obtained the following results: the average number of tokens on a place, by exploring the state space of the PN, steady state solution of the model was determined.

### IX. QUANTITATIVE ANALYSIS

After the simulation, we obtained the results from which it is observed the exponential growth of the number of tangible states.

TABLE I  
NUMBER OF TANGIBLE STATES

Nr.	Number of people in rooms	Number of tangible states/states	Number of arcs in reachability graph
1.	5	111/352	560
2.	10	179/545	885
3.	15	587/2082	3516

The average number of tokens (people) in Fig. 7 was also obtained. The number of people from the initial state is constant.

Petri net simulation results		
Place	Average number of tokens	95% confidence interval (+/-)
D1	0.06061	0
D2	0.0303	0
D3	0.06061	0
D4	0.0303	0
D5	0.0303	0
D6	0.06061	0
D7	0.06061	0
D8	0.0303	0
D9	3.84848	1.03718
R1	0.75758	0.37638
R2	0	0.05819
R3	0.42424	0.52266
R4	0.51515	0.27243
R5	0.66667	0.5477
R6	0.90909	0.94627
R7	0.36364	0.16545
R8	0.09091	0.23338
R9	2	1.52509

Fig. 7 Average number of tokens

From the steady state analysis results in Fig. 8, it is observed that in the last tangible marking M179 accumulates all tokens in place D9 (which is the exit door from the building).

#### Steady State Analysis Results

	Set of Tangible States																		
	D1	D2	D3	D4	D5	D6	D7	D8	D9	R1	R2	R3	R4	R5	R6	R7	R8	R9	
M0	0	0	0	0	0	0	0	0	1	2	1	1	0	0	0	0	1	4	
M1	0	0	0	0	0	0	0	0	2	2	1	1	0	0	0	0	1	3	
M2	0	0	0	0	0	0	0	0	1	2	1	1	0	0	0	0	0	5	
...																			
M177	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	1	0	
M178	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	1	
M179	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	

Fig. 8 Steady State Analysis Results

The PN invariant analysis results in Fig. 9 show that the number of tokens is conservative.

#### Petri net invariant analysis results

##### T-Invariants

T0	T1	T10	T11	T12	T13	T14	T15	T16	T2	T3	T4	T5	T6	T7	T8	T9
The net is not covered by positive T-Invariants, therefore we do not know if it is bounded and live.																

##### P-Invariants

D1	D2	D3	D4	D5	D6	D7	D8	D9	R1	R2	R3	R4	R5	R6	R7	R8	R9
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
The net is covered by positive P-Invariants, therefore it is bounded.																	

##### P-Invariant equations

$$M(D1) + M(D2) + M(D3) + M(D4) + M(D5) + M(D6) + M(D7) + M(D8) + M(D9) + M(R1) + M(R2) + M(R3) + M(R4) + M(R5) + M(R6) + M(R7) + M(R8) + M(R9) = 10$$

Fig. 9 PN invariant analysis results

The net is bounded and has a finite set of states (545 states) which lead to a finite number of steps necessary for evacuation. Also, transitions do not influence each other, and each place works independently from another. It is conservative, the number of people is constant, new people do not appear; all 10 people from the initial state have been accumulated in the last place D9, which means that they all successfully evacuated.

#### X.CONCLUSION

Our experience has shown that the proposed tool provides acceptable results. In order to obtain a better classification, it is necessary to increase the number of collected texts, especially those related to the topics of hurricanes, earthquake, radioactive contamination, and diseases. Despite the optimization measures, the processing time tends to increase with the expansion of the database, and we decided to develop a distributed processing algorithm using the 64-node cluster from the Institute of Mathematics and Computer Science.

For the problem of mitigation of some consequences of disasters, a method of Generalized Stochastic PNs was proposed. They allow to model and simulate of the system that represent emergency evacuation of people in case of social disaster. By this method, can be checked such properties as boundedness, conservativeness, deadlock, safeness. Further research will be related to the increasing complexity of the modeled system using hierarchical PNs that will allow their expansion possibilities.

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