Representation of Knowledge by Temporal Cases in Humanitarian Response

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Abstract

The article examines the issue of presenting knowledge of temporal cases when providing humanitarian aid to the population in cases of critical situations. To meet the needs of humanitarian response, modelling of problem solving was applied based on the experience of past situations under time constraints determined by a real controlled process. To implement the derivation mechanism based on temporal cases, qualitative point time logic and metric time logic are applied. Extended nearest neighbour method, improved CBR loop, added critical response block. Case-based knowledge presentation methods allow to increase the efficiency of decision-making in various problem situations.

Keywords

Case-based reasoning, temporal reasoning, humanitarian response, temporal logic, machine learning, decision making.

1. Introduction

Humanitarian aid is a type of assistance with remedies for living, which are provided free of charge to the population of areas affected by a humanitarian disaster. Humanitarian aid is characterized by its urgent nature and the necessity for continuous monitoring of the population's needs. The challenges of recent years, such as the COVID-19 epidemic, military actions in Ukraine, a powerful earthquake in Turkey (2023) and others, have shown the inability of state institutions and humanitarian organizations to support the large-scale humanitarian needs of the population. Which identifies necessary to transform the entire system of peacekeeping and humanitarian activities, including its social and humanitarian component [1].

Humanitarian response to the needs of the population of areas affected by cataclysms is a complex and multi-stage process, where the most important criterion is the time of providing the necessary assistance. The need for humanitarian response may take place over a long period of time, from months to years, or even decades. In addition, there are many unplanned factors in the implementation of humanitarian projects, the situation in the disaster zone can change rapidly, which leads to new requirements for the provision of assistance. Also important are the logistics of delivering aid, which is critical, for example, in war zones or in earthquake-prone areas where there are risks of repeated aftershocks.

In the process of decision-making in humanitarian response, the following should be taken into account:

- the best possible solution is selected, because there is no guaranteed solution to the problem;

COLINS-2023: 7th International Conference on Computational Linguistics and Intelligent Systems, April 20–21, 2023, Kharkiv, Ukraine
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- accumulated experience of solving similar situations is used as the main source for decision-making;
- obtained solutions can be used in the future with the possibility of their adaptation to new situations.

The model of knowledge representation of the subject area determines the efficiency of decision-making. The specificity of humanitarian response requires simple and adaptive models that are easy to apply in rapidly changing situations. Case-based Reasoning (CBR) [2] can be used to solve this cluster of problems, it has proven itself well in situations where the principle of regularity is fulfilled and the tasks that have to be solved are repeated. The knowledge accumulated by the system can be used to process new scenarios. The question arises of adapting the case base to cases where it is not possible to extract a similar template. In this case, it is possible to combine CBR with other machine learning methods precisely at the stage of cases adaptation.

The purpose of this study is to analyse and develop knowledge representation models for humanitarian response. Within the framework of the study, the following tasks are being solved: analysis of the possibility of using CBR to present knowledge in humanitarian response; extension of classical CBR with consideration of time factors; determination of procedures for adaptation and training of developed models to the current situation.

2. literature review

Many studies have been devoted to the problems of providing humanitarian aid, which can tentatively be classified in the following areas:

- analysis of humanitarian regulation experience;
- disasters forecasting and predicting their consequences;
- development of models and methods of humanitarian response.

Based on the analysed literature, it was determined that the process of distributing humanitarian aid is the most critical. The issue of logistics of humanitarian chains is considered in [3]. As part of the study following needs were determined: the need for further study of the interrelationships of the set of actors, redistribution of aid by nodes, study of the vulnerability of transport routes. Problems of measuring the effectiveness of the humanitarian supply chain are considered in [4]. Based on the analysis of publications for the years 2007-2021, it was concluded that "empirical evidence of the implementation of the efficiency measurement system is limited". In this regard, this direction needs further research.

[5] studies the process of placing objects for the chain of humanitarian aid in case of disasters that start quickly. The proposed model of maximum coverage is intended to provide humanitarian aid to the population. The model takes into account budget constraints and capacity constraints, but does not foresee a response to the time factor – a rapid change in the situation and the emergence of new humanitarian needs.

The direction of research on preliminary identification of future humanitarian response needs is promising. Machine learning methods are actively used to forecast natural disasters and potential damages from them, which makes it possible to predict the need for humanitarian response. In particular, CBR, which allows accumulating previous experience and adapting it to new conditions. But in some subject areas, in addition to accumulated experience, additional factors that are individual for each situation should be considered. In [6], a modified CBR, which takes into account the non-stationary spatial factors of geographic events, is used to map the susceptibility to landslides. Integrated CBR is considered in [7], where spatial proximity and spatial topological relations are defined as spatial characteristics. Influence factors related to the occurrence of landslides are considered as a sign of attributes. The obtained results make it possible to assess the scale of the natural disaster and implement preventive measures.

"A random coefficient model for anticipating the occurrence trend of earthquake fatalities" is proposed in [8] for a preliminary assessment of the scale of destruction and victims. But this model is not adapted to cases when there is a wave of shocks and the situation in the affected areas is rapidly deteriorating. [9] examines a fuzzy model for predicting seasonal rainfall, which enables the prediction of humanitarian response needs.

Studies [10-13] investigate the problems of building effective aid supply chains. Time limitations in humanitarian response are considered in [10]. Coordination of the humanitarian chain takes place with the help of a quantitative flexibility contract. A dual-objective mathematical model is proposed for the coordination of the supply and distribution of humanitarian aid, using the epsilon-constraint method or the NSGA-II and NRGA algorithms, depending on the scope of the task. The three-echelon model of the supply chain is considered in [11] and can be used in conditions of demand uncertainty. The model includes the relief organization, the relief item supplier, and the affected area. Each of the participants has its own profit functions, the model has been proven to prevent significant aid costs and shows a high level of satisfaction in the affected areas. In [12], the interaction between relief organizations and enterprises at the stage of preparation for a potential disaster is considered. The main factors are the uncertainty of the timing of a natural disaster and the criticality of the delivery time of humanitarian aid. In [13], the design of a humanitarian supply chain network is carried out by formulating a weighted objective programming model.

In this manner, the most critical parameter in the organization of humanitarian response is time. One of the approaches to modelling similar subject areas is the use of dynamic time graphs, which allow solving the problem of synchronization in time. In [14], a model of reasoning on temporal graphs is proposed, which contains different types of temporal logic rules and a strategy for their reduction by combining traversal and random selection. In [15], the problem of simultaneous processing of spatial and temporal data is solved by combining the concepts of fuzzy logic and SOLAP. The proposed model is extended by the possibility of logical inference for predictive analytics. In [16] control tasks in real-time systems are considered based on the synthesis of linear temporal logic and reinforcement learning.

In [17], a hybrid CBR with time dependencies is proposed for solving diagnostic problems. The determination of similarity is carried out in two stages: the first one uses the SME algorithm, the second one uses the NN algorithm to compare values. The use of temporal logic enables synchronizing events in time. In [18] a recovery model based on the reuse of knowledge through a combination of CBR and rule-based reasoning is considered.

Expanding the methods that solve the problem of rapid response and synchronization will allow to solve the problem of humanitarian response more effectively. The need for a comprehensive approach to choosing an effective humanitarian response scheme determines the urgency of building an intelligent real-time system for solving such problems

3. Development of temporal CBR method

Solution search methods using CBR can improve the efficiency of decision-making in various problem situations [2, 19]. To work in critical situations with a rapidly changing reality, the case must include not only the value of the parameters at the current time, but also their values for a certain period of time before that (their history).

First of all, it is necessary to determine the depth of analysis – period of time to analyse the problem situation. The interval under consideration is divided into N equal segments with a certain step (cycle). Further, in the generated data case, the values of the situation parameters are compared at each moment of time t_i, where $i = 1, \dots, N$.

The values of the cases parameters can be compared with each other using the nearest neighbour (NN) method, taking into account the selected Euclidean metric and the corresponding threshold value. We extend this method by adapting the solution search algorithm to temporal cases, using an approach based on the consideration and analysis of solutions obtained earlier. For all points i case variants are obtained with certain integral estimates, which can be chosen as corresponding to the situation at this point for the current similarity threshold value. At the next stage, according to integral estimates at points i the most likely case or a group of cases that satisfy the search condition can be selected. Each resulting case is associated with measure of similarity (Hamming distance) [19]: if all the parameters in the case and the current situation match, the degree of similarity is 1, and each matched parameter makes a contribution equal to $\frac{1}{\mathrm{K}}$, where K – number of parameters. Using the values of the parameters at points i, it is possible to build a forecast of the development of the problem situation using interpolation.

Since the implicit form of accounting for temporal characteristics does not allow explicitly specifying complex temporal dependencies, temporal logic will be used to build the case representation. Since the method is used in real-time systems, one should apply logics for which there are inference algorithms with polynomial complexity estimates. To implement the inference mechanism based on temporal cases, high-quality point temporal logic and metric temporal logic can be applied.

Temporal case is defined as situation S – supplemented by script and expert advice:

$$U = \langle S, R \rangle = \langle V, D, C, P, \alpha, Q \rangle, \quad (1)$$

where $S = \langle V, D, C, P, \alpha \rangle$ – temporal model of the situation, $V = \{V_i\}$, $i = 0, \dots, n$, – set of variables (points in time), $V_i \in \mathbb{R}$, D – range of temporary variables ($D \in \mathbb{Z}$ or $D \in \mathbb{R}$); C – finite number of binary temporal constraints of the form $C_{ij} = \{[a_1, b_1], \dots, [a_k, b_k]\}$, where the intervals are pairwise disjoint, $P = P^1, \dots, P^k$, range of acceptable parameter values, $P^i = \{p_1, \dots, p_m\}$ – a set of parameters that characterized the state of the controlled object or process at points in time $\{V_1 \dots V_m\}$ accordingly, m – the number of case parameters, $\alpha: V \to P$ – a function that associates each temporary variable (event) with a set of parameters that characterize the state of an object or process at a given time, Q – script and expert advice.

Every binary constraint C_{ij} defines for temporary variables V_i и V_j the allowed distance between the corresponding times and are interpreted as a disjunctive constraint:

$$a_1 \le V_j - V_i \le b_1 \lor \dots \lor a_k \le V_j - V_i \le b_k.$$

Additionally, there may be a description of the result of applying the found solution and comments, information on the result found. The expert can refuse the analysed script and form new alternatives. For example, water scarcity in affected areas can be characterized by the following types of parameters: script execution/preparation time; the term for the completion of repair work, the term for the delivery of critically needed resources; script success probability, etc. The expert assigns a weight to each parameter $W = \{w_{1,}, \dots, w_m\}$, which determines its importance.

The CBR process includes four main stages that form the CBR cycle [19]:

- retrieve the most appropriate case (cases) for the current situation from the case base;
- reuse of the retrieved case to attempt to solve the current problem;
- revise in the necessity for the resulting solution following the current problem;
- retain the newly made decision as part of the new case.

The expanded structure of the temporal CBR cycle is shown in Fig. 1.

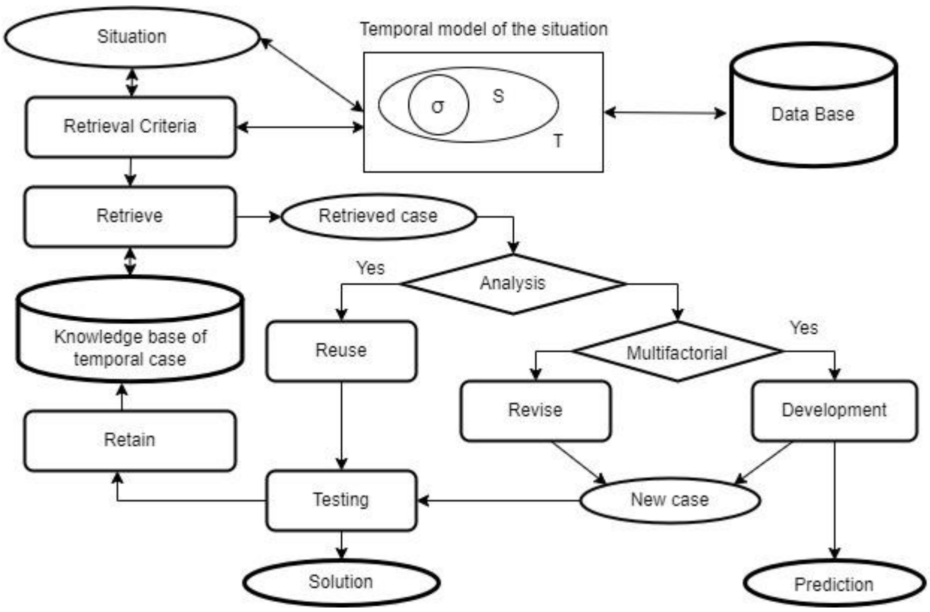

Figure 1: Extended CBR cycle

For the successful implementation of CBR, it is necessary to ensure the correct extraction of cases from the set of temporal cases into the set of "retrieved case" (RC). To do this, the distance is calculated d_{UT} [19] between case U and the current situation S^T, using the appropriate metric $f\left(p^T, p^{U_j}\right)$, taking into account the weight coefficients W for each parameter as a Euclidean metric

$$d_{U_jT} = \sqrt{\sum_{i=1}^{n}\left(w_i \cdot \left(p_i^{U_j} - p_i^T\right)\right)^2}, \qquad (2)$$

where $p_i^{U_j}$ – value of i-th case parameter U_j, p_i^S – value of i-th parameter of the current situation S^T $(i = 1, \dots, m)$; $p^{U_j} = \left(p_1^{U_j}, \dots, p_m^{U_j}\right)$ and $p^T = (p_1^T, \dots, p_m^T)$ – vectors of parameters, respectively, case and the current situation $(j = 1, \dots, n)$; $W = w_{1,}, \dots, w_m$ – vector of weighting coefficients; m – number of parameters in case. Importance coefficient (weight) of i-th parameter $w_{i,}\epsilon[0,1]$ and by default, the weight of the parameter is considered equal to 1, until it is changed by the expert to the required values.

In case is the parameter value is missing $p_i^{U_j}$ in case the calculation continues, taking into account that $p_i^{U_j} = p_i^T$. If there is no value of the parameter p_i^T in the current situation, then the calculations are carried out, taking into account that

$$p_i^T = \max\left\{\left(p_i^{\max} - p_i^{U_j}\right), \left(p_i^{U_j} - p_i^{\min}\right)\right\},$$

where $p_i^{\max}$ и $p_i^{\min}$ – the bounds of the case parameter.

A measure of similarity between the current situation S^T and case U_j is calculated by:

$$\mu\left(U_j, T\right) = 1 - \frac{d_{U_jT}}{d_{\max}}, \qquad (3)$$

Maximum possible distance for all cases $d_{\max}$ determined using the corresponding metric $f\left(p^{\max}, p^{\min}\right)$, where $p^{\max} = (p_1^{\max}, p_m^{\max})$ and $x^{\min} = \left(p_1^{\min}, p_m^{\min}\right)$ – vectors of boundary values for parameters; m – number of parameters in case. On condition that $\mu\left(U_j, T\right) \geq K$ (where K – threshold value), case U is added to the list RC.

As a result of this stage, the expert receives a set of analogues, ordered in accordance with the degree of similarity of descriptions. The kit allows you to get acquainted with the list of recommendations for choosing alternative options for providing water to the population and, based on this information and personal experience, make a decision on choosing a scenario. If there is no such situation in the case base, the expert can re-search the case taking into account the changes made, or save it in the case base as a new case, which can be useful in the future when solving similar problems.

In most systems that use CBR mechanisms, it is assumed that the cases most similar to the current problem situation are also the most applicable in this situation. However, this is not always the case. At the heart of case applicability-based extraction methods is the fact that case extraction is based not only on their similarity to the current problem situation, but also on how good a model they are for the desired outcome. The choice of retrieved cases is influenced by the possibility of their successful application in a particular situation. On some systems, this problem is solved by storing cases along with comments on their use. Using this method makes it possible to make the search for a solution more efficient by discarding in advance some of the obviously unpromising cases.

Most physical processes develop in accordance with some temporary law. Given the history of changes in the states of the observed object or process, it is possible to find better solutions and recommendations than based on the analysis of only the current state. It is necessary to apply such a way of presenting a case (1) that will allow taking into account the history of parameter changes – temporal CBR.

Thus, it is necessary to expand the use of CBR-methods, allowing to take into account the behaviour of the controlled process or object in time. When taking into account the time factor, it becomes possible to consider the problem situation in dynamics, that is, the current situation is compared not with any fixed case values, but the process of changing values is monitored, which allows making assumptions using not only the similarity criterion, but also taking into account changes in the object/parameter in time dependencies.

To represent a case using expressions of metric point temporal logic, a method with "hard" temporal constraints is chosen, which assumes an exact correspondence between the observed events and the events present in the case, as well as for each metric constraint C_{ij} в case and restrictions C^*_{ij} in the observed situation, the conditions must be satisfied $C_{ij} \cap C^*_{ij} = C_{ij}$. To match the events in the case and in the analysed situation, it is supposed to use for their numbering the numbers obtained as a result of sorting by parameter name and time. Among the advantages of this method are high output speed and high accuracy of the result. The method was also chosen because of the importance of a quick response of real-time systems in a critical period.

Determining a case based on a sample of similar situations (training) in this case can be done based on mitigation of constraint C_{ij} in one of the variants so that the conditions of its similarity to other situations are fulfilled.

Formally, the situation is defined as

$$S = \langle V, C, P, \alpha \rangle,$$

where S – current situation; $V = \{V_1 \dots V_m\}$ – a finite set of temporary variables corresponding to moments in time; $C = \{C_{ij}\}$ – a finite set of metric time constraints, where C_{ij} – is the constraint for time variables V_i и V_j; $P = P^1, \dots, P^k$ – a set of parameters of the controlled object; $\alpha: V \to P$ – a function that associates with each temporary variable (event) a set of parameters that characterize the state of an object or process at a given time.

Let's consider building a temporal case according to the history of parameter changes. It contains several steps. At the first stage, we will use the squeeze history of changes in the parameters of the observed object into a series of events $\sigma = \sigma_1 \dots \sigma_r$, where $\sigma_i = (t_i, P_i)$, $t_i \in \mathbb{R}$ – event observation time, $P_i = (p_1, \dots, p_k)$ – parametric description of an object at a point in time t_i, $P_{\tau_i} = \left(p_1^{\tau_i}, \dots, p_k^{\tau_i}\right)$ – parametric description of the object on τ_i-м tact $i = 1, \dots, \varrho$, ϱ – the number of tacts recorded..

Concise description of the situation $S = \{\sigma_i\}$ will take the form:

$$S = \sigma \cup \left\{\left(i, P_{\tau_i}\right)\right\},\ i = 1, \dots \varrho - 1,$$

where $\sigma_i = (t_i, P_i)$ – event, $t_i \in \mathbb{R}$ – event observation time, $P_i = (p_1, \dots, p_k)$ – parametric description of an object at a point in time t_i.

When forming the primary temporal case according to the description of the situation, we assume for $\sigma_i = (t_i, P_i) \in \sigma: \forall j \neq i, t_j > t_i$ и $\sigma_j = \left(t_j, P_j\right), \forall \sigma_k \in S, k = 0.1 \dots, n$:

$$\sigma^*_k = (t_k - t_i, P_k),$$
$$V^* = V \cup \{V_k\},$$
$$P^{*\prime} = P' \cup \{P_k\}.$$

For $\forall\ i, j = 0, 1, \dots, n$

$$C_{ij} = \begin{cases} \{[t_j - t_i, t_j - t_i]\}, & i \neq j, \\ \emptyset, & i = j, \end{cases}$$

where t_i и t_j are defined from $\sigma_i = (t_i, P_i)$ и $\sigma_j = \left(t_j, P_j\right)$.

At the output, we get the primary temporal case

$$U = \langle V^*, D, C, P^{*\prime}, \alpha, Q \rangle,$$

where $V^* = \{V_i\}$, $i = 0, \dots, n$, – set of variables (points of time), $V_i \in \mathbb{R}$, $P^{*\prime} = \{P'_i\}$, – parametric description of an object at a point in time V^*_i, $P'_i = p_1, \dots, p_k$, D – range of temporary variables ($D \in \mathbb{R}$); C – a finite number of binary time constraints of the form $C_{ij} = \{[a_1, b_1], \dots, [a_k, b_k]\}$, where the intervals are pairwise disjoint, $\alpha: V \to P$ – function that associates each time variable (event) with a set of parameters that characterize the state of an object or process at a given time, Q – scenario and expert recommendations.

If an existing case is specified, then after that it is necessary to merge cases U_1, U_2, where $U_l = = \langle V^l, D^l, C^l, P^l, \alpha, Q^l \rangle$, $V^l = \{V_i\}$ $(i = 0, \dots, n)$ – set of variables (points of time), $V_i \in R$, $P = \{P_i\}$ – parametric description of an object at a point in time V_i, $P'_i = (p_1, \dots, p_k)$, D – range of temporary variables ($D \in \mathbb{R}$ set of real numbers); C^l – a finite number of binary time constraints of the form $C^l = \{[a_1, b_1], \dots, [a_k, b_k]\}$, where the intervals are pairwise disjoint. It is assumed that $|V^1| \neq |V^2|$.

For $i, j = 0, 1, \dots, n$+1

$$C^*_{ij} = C^1_{ij} \cup C^2_{ij},\ i \neq j. \tag{4}$$

Thus, the combined temporal case is obtained

$$U = \{V, D,\ C^*, P', \alpha, Q\}.$$

Note that both when merging cases and when refining case, it is assumed that the state of the controlled object in the merged cases is identical at the corresponding points in time. However, in practice, this condition may not always be met.

Therefore, it makes sense to implement an algorithm that averages the values of the parameters when combining events or makes the transition from the exact value of the parameter to the allowable range of its value. It should be noted that averaging is not the only way out in this situation. For example, you can implement the accounting of qualitative characteristics for each parameter, such as growth, persistence, decrease, overcoming a critical level, and so on.

Merging temporal cases (having sufficient differences). U_1, U_2 – cases to merge, where

$$U_l = \langle V^l, D^l, C^l, P^l, Q^l \rangle$$

where $V^l = \{V_i\},\ i = 0, \dots, n,$ – set of variables (points of time), $V_i \in \mathbb{R}$, $P = \{P_i\}$ – parametric description of an object at a point in time V_i, $P_i' = (p_1, \dots, p_k)$, D – range of temporary variables (set of real numbers); C^l – a finite number of binary time constraints of the form $C^l = \{[a_1, b_1], \dots, [a_k, b_k]\}$, where the intervals are pairwise disjoint. It is assumed that $|V^1| \neq |V^2|$.

The averaging of parameter values can be found by the formula

$$P_i{}' = \frac{(P_i^1 + P_i^2)}{2},\ i = 0, 1, \dots, n. \quad (5)$$

In this case, the combination of restrictions is carried out according to the formula (4) to obtain a combined case $U = \{V, P', D, C^*, Q\}$.

It remains to describe the extraction of case. S – observed situation where S = $\{\sigma_{\mathrm{i}}\}$, $i = 0, \dots, n$, where $\sigma_i = (t_i, P_i)$ – event, $t_i \in \mathbb{R}$ – event observation time, $P_i = (p_1, \dots, p_k)$ – parametric description of an object at a point in time t_i, Q – scenario, expert recommendations and a possible forecast, $U = \langle U_i \rangle$ – case base, where $U_k = \langle V^k, D^k, C^k, P^k, \alpha, Q \rangle$ – temporal case, $V^k = \{V_i\}$, $i = 0, \dots, n,$ – set of variables (points of time), $V_i \in \mathbb{R}$, $P^k = \{P_i\}$ – parametric description of an object at a point in time V_i, $P_i = (p_1, \dots, p_k)$, D^k – range of temporary variables ($D^k \in \mathbb{R}$); C^k – a finite number of binary time constraints of the form $C_{ij} = \{[a_1, b_1], \dots, [a_k, b_k]\}$, where the intervals are pairwise disjoint.

It is necessary to compare the similarity of parameters

$$\left(\alpha(V^i), \alpha(V^k)\right),\ (i = 0, 1, \dots, |V^s|)$$

using formulas (2), (3). To find a similarity of the current situation, we compare with each $U_k \in U$, provided that $C_{ij}^s \cap C_{ij}^k = \emptyset$, where $C_{ij}^k \in C^k, C_{ij}^s \in C^s$ from the generated temporal case U_s. If (2) is met and $\mu(U_j, T) < K$, K – threshold value, we get $U_k = \langle V^k, D^k, C^k, P^k, \alpha, Q \rangle$ – case corresponding to the situation S, otherwise – $\emptyset$, $U_k \subset RC$.

4. Experiments

Let's consider the use of the developed method on the example of a humanitarian response to the population's water needs. The "Humanitarian Response Plan of Ukraine 2023" [20] and the relevant legislative framework were used for the initial filling of the case base. Table 1 shows the change over time of some criteria on the basis of which the need for humanitarian response is determined. Based on the analysis of the presented data, it is possible to trace not only spatial factors, but also time segments, how this or that parameter was changed after the execution of the selected scenario. The tabular presentation for the expert is convenient and visual, if necessary, it is visualized with the help of graphs and automatically transformed into a temporal model of the situation.

All parameters can be divided into two groups: those that are measured and/or calculated based on external factors (P_1 – P_7), and those that can be directly influenced in the process of implementing scenarios (Q_1 – Q_4).

Figure 2 shows an example of a time diagram that allows evaluating the effectiveness of using scenarios. Four parameters were selected for analysis, four scenarios were used as a result of observations.

Table 1
Some parameters of the experiment

Parameter	τ_1	τ_2	τ_3	τ_4	τ_5	τ_6	τ_7	τ_8	τ_9
P_1. Territory area, km^2	62	62	62	62	62	62	62	62	62
P_2. Population, thousand people	180	177	50	40	45	30	30	60	70
P_3. Technical water availability coefficient	1	1	0,3	0,2	0,2	0,4	0,55	0,8	1
P_4. Drinking water availability coefficient	1	0,9	0,3	0,3	0,5	0,4	0,3	0,7	0,4
P_5. Number of open water sources	3	3	3	2	2	2	2	2	2
P_6. Coefficient of water quality	0,8	0,5	0,6	0,65	0,5	0,5	0,6	0,6	0,7
P_7. Provision of centralized water supply, %	100	100	0	0	0	30	40	40	100
Q_1. Delivery of chemical reagents to treatment stations	-	20	-	-	-	-	-	10	-
Q_2. Delivery of individual cleaning products	-	-	-	-	-	1000	1500	-	-
Q_3. Water delivery (number of cars)	-	-	20	25	20	15	25	15	-
Q_4. Creation of additional water sources	-	-	-	2	-	-	-	-	-

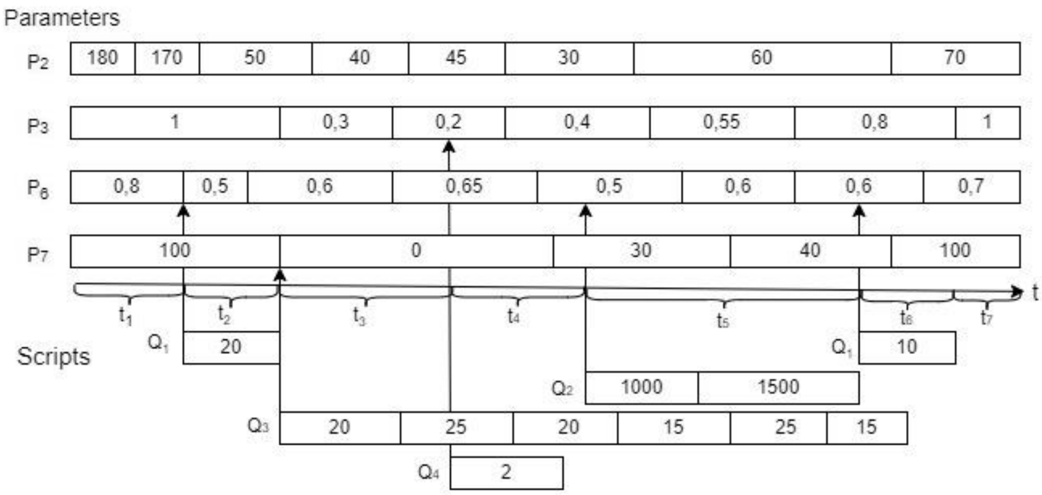

Figure 2: Time diagram of the application of temporal cases: P_2 – population, thousand people; P_3 – technical water availability coefficient; P_6 – coefficient of water quality; P_7 – provision of centralized water supply, %; Q_1 – delivery of chemical reagents to treatment stations; Q_2 – delivery of individual cleaning products; Q_3 – water delivery (number of cars); Q_4 – creation of additional water sources.

At the beginning of the countdown (tact t_1) the water supply situation was under control, so humanitarian response scenarios were not involved. On tact t_2 the water quality coefficient decreased to a critical level (less than 0.65), a scenario involving the delivery of chemical reagents to water treatment plants was used. This made it possible to improve the quality of water, but at the end of the tact t_2 an accident occurred at the central water supply facilities, which completely stopped the supply of water to the population. Therefore, a scenario was used, which involves the delivery of technical water.

During tact t_3, despite the decrease in the population of the district, the coefficient of provision of water needs is decreasing, therefore, within the framework of the water transportation scenario, the number of vehicles involved and the places of water pickup were operationally regulated. But it was not possible to stabilize the availability ratio, therefore, at the time t_4 no matching case was found. A new case was built during the training process. It provides for the creation of additional sources of water (drilling of wells) in parallel with the transportation of water. Combining the two cases made it possible to increase the water supply ratio. Also on t_4 centralized water supply was partially restored, which in turn led to a drop in the water quality factor. So on the tact t_5 case was spread due to the distribution among the population of individual means of water purification. But the quality factor remains critical, so the scenario of delivering reagents to the purification station was again used.

As a result of the involved scenarios, a gradual stabilization of the parameters of water supply and water quality, as well as a partial restoration of centralized water supply, is observed at t_5.

At the beginning of the tact t_6 we see that the scenario of individual distribution of reagents does not lead to an increase in water quality. Therefore, scenario Q_1 is chosen to replace it, which, in combination with scenario Q_3 allows to improve water quality to an acceptable level. On the tact t_7 we see that after the complete restoration of centralized water supply, all parameters are stabilized, there is no need for humanitarian response.

Thus, thanks to the use of temporal cases on a real time scale, it is possible to find effective solutions that take into account both the current situation and the history of changes in the state of the object and pre-made decisions with strict time limits.

5. Discussions

The proposed temporal CBR is implemented by the structure of the corresponding module of the intelligent decision-making system (fig. 3).

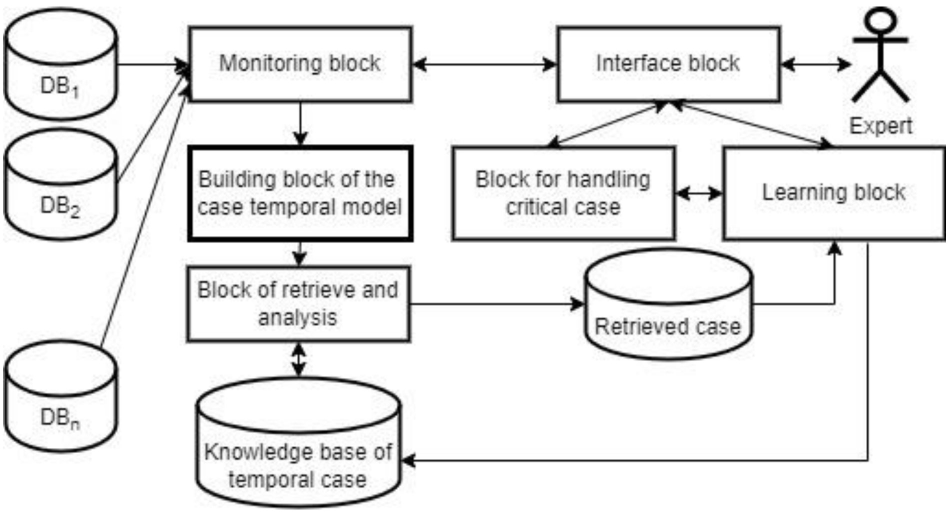

Figure 3: The structure of the temporal cases training module

Knowledge base of temporal case contains a description of situations in the following form: number, name, set of parameter values, structure of events, response scenario and expert recommendations. The monitoring block allows you to monitor process parameters stored in distributed databases. A critical situation means a case when one or more parameters cross a critical limit.

In the event of a critical situation, a corresponding model is created in the building block of the temporal model of the situation. The analysis and extraction block compares the model with those described in the case base and forms a subset of the extracted cases. Next, the case is specified in the training block. Several methods can be used for this: finding the arithmetic average of parameters, the shortest path, merging cases, comparing time limits.

The revised case is issued as a decision for expert approval and recorded in the data case as a new case. If a situation arises for which there is no previous experience and the case is not written, the actions of the system are uncertain. In this case, the expert can develop a case based on his own experience and record it in the case base for further use. Another option for solving the problem is the introduction of "soft" restrictions. Such restrictions, in contrast to "hard" ones, allow you to manoeuvre the restrictions in such a way that conditions similar to the current case situation in the database are fulfilled. The specifics of their application are planned to be considered in the following studies.

Depending on the type of parameters and the criticality of the situation, methods based on a different principle than the average value of parameters can be used to determine similarity. In the future, cases can be presented not only in a parametric form, but also in another specific form, for example, in the form of graphs. The mathematical apparatus of multi-valued logic can allow more effective use of the acquired experience in real time.

6. Conclusion

The considered temporal CBR is based on the idea not only of the current situation, but also takes into account the previous characteristics of the management object. The process of learning on temporal cases allows developing classical CBR by taking into account and analyzing the decisions that were obtained earlier. Time logic with polymial estimation of algorithm complexity is used for logical derivation.

The advantages of the method can be considered the ease of acquiring knowledge, the possibility of explaining solutions, obtaining new solutions through training and modification of existing cases. The integration of spatial and temporal factors makes it possible to create adequate models of knowledge about the processes of humanitarian response, which are able to adapt to a rapid change in the situation with minimal costs. Involvement of an expert in the process of adaptation of models allows assessing the applicability of the scenario in the current situation, make adjustments to the proposed scenarios and save them as experience for further use. The method can be used in conditions when it is impossible to obtain all the characteristics of the current situation due to forecasts based on the previous values of the parameters.

The structure of the case generation module can be used in an intelligent decision-making system. This will make it possible to increase the efficiency of decision-making in conditions of rapid changes in the situation during humanitarian response, taking into account the analysis of the history of changes in the state of the object of management.

The proposed structure can be used by both humanitarian aid organizations and government agencies. In the future, the possibility of building a distributed temporal case knowledge base should be considered, which allows the system to both accumulate its own experience of humanitarian response and invite data from other case databases.

A more detailed study of the process of division into tacts can also be considered as a perspective for further research, because there are reasons to believe that the number and length of time segments can have an impact on the parameter values.

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