MULTI-CRITERIA EVALUATION OF THE EMERGENCY AND PRE-EMERGENCY MODES OF TECHNOLOGICAL OBJECT

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MULTI-CRITERIA CLASSIFICATION OF MODES

$X = \{X_1 ... X_N\}$ - Technological object as set of technological modules (rooms, devices, etc.)

$s_i(X_k, t)$ - signals from sensor (for example, temperature, smoke, CO, CO2 in case of fire alarm system)

$f_i = f(s_i, t)$ - criteria based on one signal ("static" and "dynamic" criteria)

$f_{j,k} = f(s_j, s_k)$ - criteria based on two signals (cross-correlation, selective cross-correlation)

Multi-criteria vector function of the state of the object:

$$X_k \rightarrow F(X_k, t) = (f_1(t).....f_n(t))_k{}^T$$

DECISION MAKING GOALS

1) Simple binary classification

$F(X_k, t) \to E(X_k) \in \{0,1\}$, where 0 is "regular mode" and 1 is "emergency mode"

2) Multi-modal classification

$F(X_k, t) \to E(X_k) \in \{0, a_1, ..., a_p, 1\}$, where $0 < a_1 < ... < a_p < 1$ corresponds to different pre-emergency modes. The simplest case is 0="regular", 0.5="pre-emergency" and 1="emergency"

3) Ranking by response priority

The goal is to set a binary preference relation R on the set X, where $X_i R X_j$ means that X_i is higher priority for emergency response than X_j

CRITERIA

1) Static.

The term "static" here indicates that these criteria evaluate only the values at the current time, and not the dynamic characteristics. The simplest case is limit criterion:

$$f_i(X) = \begin{cases} 0, & s_i(X) \le s_{i\,\mathrm{lim}} \\ 1, & s_i(X) > s_{i\,\mathrm{lim}} \end{cases}$$

Limit criterion with two limit values:

$$f_i(X) = \begin{cases} 0, & s_i(X) \le s_{i\ pre-emergency} \\ 0.5, & s_{i\ pre-emergency} < s_i(X) \le s_{i\ emergency} \\ 1, & s_i(X) > s_{i\ emergency} \end{cases}$$

CRITERIA

2) Dynamic

These are criteria based on dynamic characteristics of signals: increase rate (gradient), the duration of exceeding the threshold etc. They can be calculated by simple well-known algorithms.

3) Correlation.

We propose correlation function calculated on selective set, where signals are rising:

$$y_i(t) = \begin{cases} s_i(t), & s_i(t+1) \geq s_i(t) \\ 0, & s_i(t+1) < s_i(t) \end{cases},$$

$$\overline{y}_i(t) = \frac{1}{T}\sum_{k=0}^{T-1} y_i(t-k), \quad Y_i(k) = y_i(t) - \overline{y}_i(t), \quad K_{ij}(\tau) = \sum_{k=0}^{T-1} Y_i(k) Y_j(k-\tau), \quad R_{ij}(\tau) = \frac{K_{ij}(\tau)}{\sqrt{K_{ii}(0) K_{jj}(0)}}$$

Criterion:

$$f_{corr}(t) = \begin{cases} 1, \exists(\tau, i, j) : R_{ij}(\tau) \geq 1 - \delta_{ij}, \\ 0, \forall(\tau, i, j) : R_{ij}(\tau) < 1 - \delta_{ij} \end{cases}$$

DECISION MAKING

Data in table form for decision making problem:

	static criteria			*dynamic criteria*			*correlation criteria*		
	f_1	$\dots$	f_m	$f_{1,(1)}$	$\dots$	$f_{m,(p)}$	$f_{1,2}$	$\dots$	$f_{m-1,m}$
X_1	$f_1(X_1)$	$\dots$	$f_m(X_1)$	$f_{1,(1)}(X_1)$	$\dots$	$f_{m,(p)}(X_1)$	$f_{1,2}(X_1)$	$\dots$	$f_{m-1,m}(X_1)$
X_2	$f_1(X_2)$	$\dots$	$f_m(X_2)$	$f_{1,(1)}(X_2)$	$\dots$	$f_{m,(p)}(X_2)$	$f_{1,2}(X_2)$	$\dots$	$f_{m-1,m}(X_2)$
$\dots$	$\dots$	$\dots$	$\dots$	$\dots$	$\dots$	$\dots$	$\dots$	$\dots$	$\dots$
X_n	$f_1(X_n)$	$\dots$	$f_m(X_n)$	$f_{1,(1)}(X_n)$	$\dots$	$f_{m,(p)}(X_n)$	$f_{1,2}(X_n)$	$\dots$	$f_{m-1,m}(X_n)$

Linear scalarization: $E(X) = \sum_{i=1}^{N} \alpha_i f_i(X)$

Ideal point method: $E(X) = \sqrt{\sum_{i=1}^{N} \alpha_i (f_i(X) - f_i(X^*))^2}$ where X^* is “absolute emergency state”

DECISION MAKING

Classification:

$E(x) < E_1$ - regular mode,

$E_1 \le E(x) < E_2$ - pre-emergency mode,

$E(x) \ge E_2$ - emergency mode.

Ranking:

$E(X_i) > E(X_j)$ thus $X_i R X_j$, where R is binary preference relation

Problems: incomparable or equivalent alternatives.

Goal: narrow the Pareto-set step by step

Methods: ELECTRE, main criterion method, analytic hierarchy process etc.

MODEL QUALITY

Type I error: false positive (emergency signal where there is no emergency state)

Type II error: false negative (non detection of emergency or pre-emergency mode)

Goal: to reduce number of Type II errors (main) and type I errors.

Adjustible of model parameters: weight factors α_i , ELECTRE indices, criteria limits and thresholds.

Methods:

- manual,
- expert evaluation,
- machine learning