Analytical Estimation of the Component Viability of Distributed Automated Information Data Systems

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Abstract: There is provided the analytical estimation of viability of distributed automated information data systems based on chance-risk estimation of their components. Viability estimation is provided for the log-logistical distributive law. There is solved an urgent task of the procedure creation, which would meet the following requirements: sufficient formality, to be used as a part of tools; simplicity of risk assessment, determined by the necessity of practical use of the procedure; adequacy and universality of risk control, i.e. use of the procedure for the majority of information systems; complexity, covering all significant aspects of the system functioning. The suggested procedure of durability estimation meets these requirements and, certainly, can be efficiently put into practice. In particular, the analytical expressions of the chance and the risk, obtained during the work, can get the wider practical use. The suggested viability estimation stands out with its maximum novelty; it can be used for absolutely different systems, the components of which can lose their working capacity irrevocably. In the work, as applied to the log-logistical distribution, the appropriate estimation of viability is obtained, as well as the required illustrative material is provided in the form of diagrams, which qualitatively reflect the functions of utility, chance and risk.

Key words: System chance • Risk • Distributed automated information data system • Viability

INTRODUCTION

Nowadays the distributed automated information data systems (DAIDS) play a key part in provision of efficient process execution of both commercial and state enterprises. Alongside with that, common usage of DAIDS for data storage, processing and transfer results in increase of the problem urgency, connected with risk estimation [1] and their protection. It is proved by the fact that for the last several years, both in Russia and in the leading foreign countries, there is a tendency of increase of the information attack quantity, resulting in the significant financial and material losses. It is put into the foreground the item of the viability of such kind of systems [2-4], as a result of destructive actions of the intruder, making the works in this direction undoubtedly relevant.

Main Part: Practically, the viability is understood as the ability of the system to confront the safety hazards, excluding the fatal fault of its components for the specified lifetime period of this system.

In this period the component continues to function normally and to produce the useful product (utility) and upon expiration there is the fatal damage, mainly measured by the short-received utility (up to the average life expectancy of the component).

Certainly, a fault process has a random character and it can be described by the law (time-dependent) of frequency distribution \( f(t) \) of fatal fault emergence in the specified time moment of life \( t_0 \).

Based on the abovementioned, to measure the viability, it is appropriate to use such notions as the risk and the chance, i.e. the functions, determining the possibility (probability) of damage \( u(t) \) and utility \( v(t) \) emergence of the definite value [1].
Their measures are given below:

\[ \text{Risk}(t_0) = u(t_0)P[u(t_0)], \]
\[ \text{Chance}(t_0) = v(t_0)P[v(t_0)], \]  

where:

\[ P[u(t_0)] = (\Delta t)f(t_0); \]
\[ P[v(t_0)] = 1 - F(t_0); \]
\[ F(t_0) = \int_{0}^{t_0} f(t)dt; \]

\[ \Delta t \] – discretization interval of time axis \( t \).

Taking into consideration that the average life duration of the component equals to

\[ T_{cp} = \int_{0}^{\infty} f(t)dt, \]

it is possible to implement the standardization as per \( T_{cp} \).

In this case we have the following:

\[ \bar{t} = \frac{t}{T_{cp}} \frac{\Delta t}{T_{cp}} = \frac{\Delta t}{T_{cp}}; \]
\[ \text{Risk}(\bar{t}) = u(\bar{t})P[\bar{t}]; \]
\[ \text{Chance}(\bar{t}) = v(\bar{t})[1 - F(\bar{t})]. \]  

Hence, it is possible to build the corresponding timing diagrams for the probability of full fault (death) of the component (Fig. 1, a), probability of its successful functioning (Fig. 2, b) and utility function (Fig. 1, c), determining the quantity of utility, created per unit time (here the curve I is the first approximation and the curve II is a nonlinear approximation of the component life process).

Fig. 2 shows the timing diagrams of the standardized utility (Fig. 2, a), resulting from the Fig. 1 where \( \tau_P \) are the inputs to the component creation; standardized damage (Fig. 2, b), where \( \tau_D \) are the expenditures for its utilization; and also (Fig. 2, c) are the chance (to the left of \( \bar{l}_0 \)) and the risk (to the right of \( \bar{l}_0 \)).

Considering these diagrams, it is possible to suggest some standard of the component vitality, as a relation of chance of the successful operation and risk of the full loss of operability

\[ L(\bar{l}_0) = \frac{\text{Chance}(\bar{l}_0)}{\text{Risk}(\bar{l}_0)}. \]  

The expression (4) taking into account the mathematical manipulations (1) - (3) can be written in the following way

\[ L(\bar{l}_0) = \frac{v(\bar{l}_0)[1 - F(\bar{l}_0)]}{u(\bar{l}_0)(\Delta t)f(\bar{l}_0)}. \]  

Fig. 1: Timing diagram of probability and utility function
where \( \alpha_s > 1 \) and \( \alpha_d \) are the nonlinear coefficients, setting the steepness of "rise" and "decline" of the utility function, \( T_{av} \) is the average duration of working capacity of the object, \( \bar{\omega} \) is the standardized utility, obtained per unit time.

Hence, the function of the standardized damage can be described by the following expression:

\[
\overline{u}(t_i) = S_2 = \int_{t_i}^{T_{av}} v(t) dt = \frac{T_{av}}{2} \int_{t_i}^{T_{av}} \left[ 1 - \left( \frac{t}{T_{av}} \right)^{\alpha_d} \right] dt =
\]

\[
- T_{av} \left[ \frac{1}{\alpha_d + 1} + \frac{1}{\alpha_d + 1} + \frac{1}{\alpha_d + 1} \right]
\]

(8)

where \( t_i \) is the fault moment of the analyzed system.

It is evident that at \( \gamma \rightarrow \infty \) the utility function degenerates at the angle of unit square and the function of standardized damage degenerates into its diagonal (Fig. 1, c). As a result, the expression of damage (8) is the following

\[
\overline{u}(t) = \frac{\gamma}{\gamma + 1} - \bar{t} + \frac{\bar{t}_0}{\gamma + 1}.
\]

(9)

At \( \gamma=9 \). In this case the last member of expression (9) introduces an error of less than 10% even for \( \bar{t}_0 = 0.9 \). Thus, damage expression is possible for practical use

\[
\overline{u}(t) = \frac{\gamma}{\gamma + 1} - \bar{t},
\]

(10)

Log-logistical distribution is the most appropriate distribution to describe the frequency function of the system fault and its components [5]. In this case the analytical expression to find the risk function of the fault emergence in the time moment \( t_i \) with accuracy \( \Delta t \) is the following [1]:

\[
Risk \left( t_i, \frac{\Delta t}{2} \right) = \left( \frac{\gamma}{\gamma + 1} - \bar{t}_0 \right) \frac{(\beta/\alpha)\left(\bar{t}_0/\alpha\right)^{\beta-1}}{\left[1+(\bar{t}_0/\alpha)^{\beta} \right]^2} \Delta t.
\]

(11)
Based on the set utility function, the function of the standardized utility can be described by the following expression:

$$
\theta(\tilde{t}) = S_2 = \frac{t_0}{0} \tilde{v}(\tilde{t}) \, d\tilde{t} = \frac{t_0}{0} \left[ 1 - (\tilde{t}/\gamma)^{\gamma+1} \right] \, d\tilde{t} = \frac{t_0}{\gamma+1} = t_0 - \frac{(t_0)^{\gamma+1}}{\gamma+1},
$$

where at $\gamma \to \infty$ the last member introduces an error of less than 10% even for $t_0 = 0.9$. Thus, the utility expression is possible for practical use

$$
\theta(\tilde{t}) = \tilde{t}_0. \quad (12)
$$

Hence, the chance can be found as per the following formula

$$
\text{Chance} \left( \tilde{t}_0 \pm \frac{\Delta \tilde{t}}{2} \right) = \theta(\tilde{t}_0) \left( 1 - f(\tilde{t}_0) \right) (\Delta \tilde{t}). \quad (13)
$$

where $(1 - f(\tilde{t}_0))$ is the system survival probability,

As a result, the analytical expression for the chance function is the following:

$$
\text{Chance} \left( \tilde{t}_0 \pm \frac{\Delta \tilde{t}}{2} \right) = \tilde{t}_0 \cdot \left[ 1 - \frac{(\beta/\alpha)(t_0/\alpha)^{\beta-1}}{1 + (\tilde{t}_0/\alpha)^{\beta}} \right] (\Delta \tilde{t}). \quad (14)
$$

Respectively, the suggested survival estimation for log-logistical distribution is the following

$$
L(t_0) = \frac{\text{Chance}(t_0)}{\text{Risk}(t_0)} = \frac{\tilde{t}_0}{\gamma+1} \left[ 1 + \left( \frac{t_0}{\alpha} \right)^{\beta-1} \right]. \quad (15)
$$

**CONCLUSION**

The expression (15), obtained above, meets the need to solve the analysis problem of DAIDS under attack (in particular the estimation of component "survivability"), as there is a growth tendency of attack frequency on the DAIDS components. The suggested analytical estimation of viability of DAIDS components can be rather efficient instrument in solution of such problems.

**Summary:** The suggested survivability function opens a prospect of model risk construction of the distributed automated systems, exposed to different types of attacks (dos-attacks [8], attacks as per protocol ICMP [9], attacks using the programs of SMB Relay type [10] etc.), as the alternative to the well-known approach to the survivability analysis without taking into account damage extent [6-10].

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