Numerical modelling of the process of implementing media educational projects using GERT networks

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Abstract. The purpose of this work was to test the applicability of the methods for work networks based on the stochastic GERT networks analysing to the analysis and forecasting of the executing similar projects processes. The experimental object was the data on the implementation of media education projects by students of the general education lyceum. The processes were modelled using the graphical BPMN methodology. For numerical prediction, we used formulas and algorithms for constructing and analysing stochastic GERT networks. The GERT network, built on the basis of data analysis of the implemented media educational projects, made it possible to calculate the probability distribution density of the time of the media project execution, as well as to calculate the first central moments of the distribution law - significant in practice indicators of the average execution time of a media project, taking into account loops and cycles, as well as an indicator of the variance of the project execution time, which makes it possible to estimate the spread of the execution time of the same type of media projects. The result obtained allows us to speak about the applicability of the GERT-model for predicting the numerical indicators of models of business processes for executing projects of the same type as an alternative to statistical simulation.

1. Introduction
Management and improvement of educational business processes is a very relevant topic in the modern educational system. The methods of project-based teaching that are being introduced in many areas of education are very popular.

Thus, in work [1], the authors describe the experience of reforming innovative education, which consists in improving the 2D Animation Design curriculum with an emphasis on strengthening the management of the educational process.

The work [2] proposes a conceptual solution in the form of a learning system that allows to manage the process of developing language and work skills in adults and combines advanced pedagogical methodological principles, visual process models and an IT solution to support the process.

Decisions on the organization of the educational process are also proposed in [3]. The authors propose a set of educational management systems that combine monitoring and feedback functions. A system of educational process management is proposed, aimed at helping students manage the growth of their knowledge and skills.

In all the above cases, the task of predicting the educational process is relevant. The classic solution to this problem is the use of simulation. Computer simulation models make it possible to assess in...
measurable terms the consequences of improving business processes, to predict, using a numerical experiment, changes in business process indicators during the transition from the “As-Is” model to the “To-Be” model. The simulation experiment reveals potential problems in implementing the proposed changes to the business process.

In recent years, for modeling and optimization of technical and organizational systems, the use of alternative stochastic networks has become widespread [4], in particular, the mathematical apparatus of GERT networks (GERT - graphical evaluation and review technique).

A detailed description of GERT networks is presented in the works of Phillips [5], Neumann [6], Pritsker [7], Shibanov obtained significant results in the development of the GERT-networks apparatus and their application in the analysis of communication networks [8].

GERT networks are widely used for probabilistic modeling and analysis of discrete event systems of various nature. Thus, the classic application of GERT networks is the analysis of the dynamics of technical, including software systems.

In the article [9], the authors propose a set of mathematical GERT-models for the technology of cloud anti-virus protection of a telecommunications system. The proposed solution made it possible to obtain analytical expressions for synchronizing the transfer of metadata files, generating and issuing commands. transfer of control.

The authors of [10] have developed a unified GERT-model of the obfuscation process of software modules. The proposed solution provides a forecast of the behavior of the software modules protection system in terms of execution time, which allows to reduce the time for deciding on the expediency of using the obfuscation process.

Work [11] is devoted to the assessment of the contribution of system equipment (SoS) in terms of efficiency using the apparatus of GERT networks. The equivalent algorithm of the transfer function for the SoS-GERT network is proposed, the formula for the algorithm for evaluating indicators such as the operational efficiency of the SoS and the level of its stability is given.

A number of papers consider the application of GERT networks to management tasks, including modeling and forecasting educational processes.

Thus, in [12], a new method for analyzing and predicting the progress of work on a project is proposed, based on models of Bayesian networks and on GERT networks.

Article [13] is devoted to an overview of the application of GERT networks to management problems. The authors demonstrate the results of using the GERT network to analyze a hypothetical R&D project. The paper provides an assessment of improving the efficiency of project planning, workload, resources and equipment of the project.

A similar solution is presented in [14], which proposes a timing model using graphical evaluation and analysis (GERT) to analyze concurrent new product development (NPD) processes.

The article [15] presents a model for optimizing technologies for managing hazardous production processes based on the formulas of the GERT network. It is shown that the proposed solution makes it possible to consider in the model random deviations and uncertainties that arise directly during the implementation of each separate task of the management technology of hazardous industries.

Work [16] proposes a solution that includes the following methods and technologies: collection of primary data on the business processes of the research object using LMS Moodle; identification of a business process model based on information system data using Process Mining methods and ProM 6 software and forecasting system operation parameters - total execution time and process complexity using GERT network devices and agent simulation models. The authors show that the proposed approach is not inferior in prediction accuracy to traditional approaches to simulation modeling.

From the above, it can be seen that the task of modeling and analyzing business processes in the educational industry is relevant, and the apparatus of GERT networks is a promising tool for solving this problem. In accordance with this, the authors propose to apply the apparatus of GERT-networks to the study of the activities of an educational TV channel that implements the direction of additional education in a general education lyceum. The objective of the study was to assess whether the approach to predicting the dynamics of event models using GERT networks for an organizational system operating
in the mode of implementing a series of typical projects will work. The authors of [13] consider the application of GERT networks to a hypothetical project.

The object of the research in this article is the process of implementation of media educational projects by students of the general education lyceum in Krasnoyarsk.

Improving the system of school media in modern conditions is an urgent task. Preparation of media content and work in social networks have become an integral part of the educational process for schoolchildren, even in elementary grades. A multimedia computer in the house is a common occurrence today, teenagers cannot imagine a cell phone without an MP3 player, internet, and a camera, and university students study using tablets and smartphones.

At the same time, the availability of technology and installed application packages does not solve all problems. The use of media technologies allows us to modify the main types of school activities - educational, educational and vocational guidance.

Based on the use of media technologies, the school has the opportunity to involve students in the creation of a variety of media content in real projects for school media, taking into account the professional orientation of such activities. After all, the main task of the school media is to develop the creative thinking of the younger generation, the ability to apply the knowledge gained in solving complex life problems, make important decisions and act collectively.

Thus, in this work it is supposed to consider a model built on the experience of implementing a series of completed school media education projects. Confirmation of the hypothesis about the applicability of the GERT model to a series of small projects of the same type will allow us to speak about the efficiency of this approach and will allow working with the approach to more serious and large-scale projects.

2. Methods

2.1. Object of study

In order to study various aspects of creative activity in the creation of media content, as well as to study organizational and managerial aspects, in the general education lyceum "Perspektiva" in Krasnoyarsk, the authors organized a lyceum TV channel that unites the activities of schoolchildren and teachers.

Within the framework of the school-wide project "Lyceum TV Channel", a two-stage training was implemented. The first stage of training is the direction of video editing. The second stage is media planning and project activities.

In the first year of study, schoolchildren get acquainted with the basic concepts of the media, mastered the technology of video filming, received basic skills in editing the simplest videos. As the media products were produced, they were broadcast on the Lyceum TV channel.

Publication on the school media channel was provided by lyceum students of the second stage of study in the framework of the direction "Media planning". The main goal is to demonstrate videos at breaks, meetings and parenting meetings, and various events. The tasks of media planning are searching for media content for broadcasts in accordance with the topic according to the plan, drawing up a broadcast program, alerting the management and creating video greetings.

The organization of media project activities at the second stage provided the lyceum with the opportunity to conduct real work of TV crews in a reduced, "children's" format. The created media content was of general school significance, and a number of adolescents of different classes directly or indirectly participated in its formation. Pupils of the second stage of education involved the entire lyceum, including teachers, in the activities of the TV channel, thereby ensuring the interactivity of the TV channel.

2.2. Modelling operations of a typical educational media project in BPMN notation

The description of the operations of a typical media education project was made in BPMN notation. A description of the BPMN standard is given at the link [17].

A process model in BPMN notation is an algorithm for executing a process. The diagram can define events, executors, material and documentary flows that accompany the execution of the process. The
diagram given in this paper uses the symbols shown in figure 1. Their detailed description can be found in the description of the standard.

Figure 1. BPMN symbols used in this article.

2.3. Stochastic GERT networks
The GERT-network is a probabilistic model of a discrete-event system that allows to take into account random deviations in the parameters of the system that occur when performing each of the operations [7]. The work (operation) of the business process is compared with the branches (arcs) of the GERT network, which are characterized by additive random variables. The calculation of the output characteristics of GERT networks is based on the moment generating functions of random variables, and the activation of each branch outgoing from the node is set by the probability of this branch triggering.

A GERT network is described by a directed weighted graph 

\[ G = (V, E), \]

where \( V \) is a set of vertices (nodes); \( E \) is a set of branches (arcs).

The nodes of the GERT network are interpreted as states of the system, and branches (arcs) as transitions from one state to another. When describing a model of a discrete-event system, such transitions are compared with the execution of generalized operations characterized by the density of the distribution of the measured quantity (time, money or other resources) and the probability of execution.

Thus, a GERT network is a network with sources \( R \) and sinks \( S \) of the form "work on an arc", in which each node belongs to one of six types of nodes [7], for each arc \( <i,j> \) a weight of the form \([p_{ij}, F_{ij}]\), where \( p_{ij} \) is the conditional probability of the arc \( <i,j> \) under the condition of node \( i \) activation, \( F_{ij} \) is the conditional distribution function of some random variable.

When solving the problem of calculating the parameters of a GERT network, the problem of finding the first central moments of the distribution of the measured random variable of the network is most often posed. Usually, for practical needs, it is sufficient to find the first and second central moments of a random variable - mathematical expectation and variance. A more detailed study of the system can be performed by constructing the distribution function of a random variable of the entire network.

Formulas and algorithms for calculating the parameters of GERT networks are given in the work of Phillips, Garcia-Diaz [5].

2.4. Experimental data collection procedure
The practical part of the research work on the organization of the lyceum TV channel in the general education lyceum began in 2008 and officially ended in October 2010. In total, lasting 2 academic years. However, despite the completion of experimental research in Lyceum No. 6, data collection took place at the Siberian State Technical University on the basis of the Faculty of Automation and Information Technologies, and later, at the SibSU named after M.F. Reshetnev on the basis of the disciplines "Multimedia Technologies", "Hypermedia Technologies", "Information Technologies", "Fundamentals of Artistic Design", "Graphic Design" of the Institute of Informatics and Telecommunications.

The experiment on organizing a lyceum TV channel was initiated in order to determine effective methods of managing the creation of media resources by schoolchildren in an educational institution and the feasibility of introducing mass media in schools. The creation of conditions for the implementation of the experiment was fixed by the schedule of the elective course "Video editing". It is
assumed that the results of the experiment will serve as the basis for the introduction of the media, and
television, in particular, in educational institutions of a higher level - open source vocational education
and universities.

The official start of the experiment can be considered the autumn holidays of 2008, during which
the "Autumn Media School" was held on the basis of Lyceum No. 6 "Perspektiva" together with the Center
for Continuing Education of the Central District of Krasnoyarsk "Radiotechnik".

3. Results

3.1. Description of the business process
As part of the training direction "Video editing", students individually or within the framework of project
teams created various media products. Topics were chosen independently or were appointed by the
teacher in accordance with the plan agreed with the administration.

The schoolchildren, together with the head of the educational TV channel, carried out the following
work on the production of the video film: the head of the lyceum television, in accordance with the work
plan and the regulation on the TV channel, gave students topics for the development of a video film.
Further, the student, together with the supervisor, developed a script for the film, made an approximate
calendar plan for collecting information - filming (photographing) or searching for information on the
Internet. Further work was carried out on the basis of the compiled schedule and script: video filming
or photographing of objects was carried out, photographs were selected on the Internet, an audio
sequence was formed - the children were looking for music, or recorded a voice on a camera. At this
stage, the verbal line of the film was also formed.

The next stage in production is the editing of the media resource in a non-linear video editing
program; for this purpose, the Adobe Premiere Pro 2.0 software package was used. The students brought
together the footage, sound and text. The result of this stage was a ready-made media product for
delivery to the customer (the head of the TV channel, the teacher).

The sequence of work execution in the production process is built in the form of a BPMN diagram
using the Business Studio software. The execution of the business process begins with the event “The
student decided to complete the project”. The completion of the project corresponds to the event "Project
completed". During the production of a media product, the following operations are performed:

- Select project theme;
- Write a script;
- Collect materials for a media project;
- Perform video editing;
- Transfer the media product to the customer.

In addition, some of the control flow links correspond to events in the process:

- The script needs some work;
- Materials are not enough;
- Video editing not completed.

The BPMN diagram of the Implementation of an educational media project is shown in figure 2.

The beginning of this process is the receipt of an order to produce a video film (event "Students
decided to complete the project"). The first step is to choose a theme for development (operation "Select
project theme") - it is given by the manager according to the work plan for the period, in accordance
with the conditions of various competitions, or the student himself chooses the theme of the film. Next,
the student develops a script in accordance with the chosen topic (operation "Write a script").
Select project theme
Students decided to complete the project

G1
Write a script

G2
The script needs some work

G4
Collect materials for a media project

G5
Materials are not enough

G6
Perform video editing

G7
Video editing not completed

G8
Transfer the media product to the customer

Project completed

Figure 2. Decomposition of the process "Implementation of an educational media project".

Based on the results of these stages, further work is carried out: in case of errors (event "The script needs some work") - the script is rewritten, if everything is successful - the student can either start editing (if the information is already available), or collects material - searching for text in the literature or the network, taking photos or videos, or recording sound or selecting music. If the material is assembled correctly, the next step will be editing the film in the program. If there is not enough information for editing (event "Materials are not enough"), you will have to make additional filming of video (photo), record additional volumes of sound, or find additional text information.

Depending on the quality of the collected material, it is possible to return to the previous step when the script needs to be reworked (the "The script needs some work" event).

After completing the work "Collect material for a media project", the next operation is performed - "Perform video editing". As a result of its implementation, the process can develop in three ways:

- return to the editing stage and review the edited film and correct the comments (event “Video editing not completed”, “Video editing not completed”);
- return to the previous step and carry out additional survey of the material (event "Materials are not enough");
- go back one step earlier and revise the script of the film (event "The script needs some work").
- If the editing of the film is successful, the film is handed over to the head of the TV channel (operation "Transfer the media product to the customer").

3.2. The result of collecting experimental data

The experiment involved schoolchildren of grades 7-9. At the same time, some of them received additional education in schools, centers and various circles. Medical products were created by students individually and in teams.

Research work on the organization of media education projects in the Lyceum was carried out in 3 stages: preparatory, practical and analytical.

A methodological substantiation of the experiment was carried out, including an analysis of information regarding the position of television in schools in Russia and the existing experience in the production of media products by the young generation. The development of the experiment regulations, which reflects the main aspects of its implementation.

Further, a software and hardware base were prepared, including a software package for a nonlinear video editing system for the production of media products, and a general educational institution was selected. At the last stage, a concept for conducting research was developed, parameters for recording and output metrics were determined, the activity of a lyceum television channel was organized, and a multistage program for the development of television at school was developed.
Let us denote as $t_i$ the stages of creating an educational media project (table 1).

**Table 1.** Stages of creating a media product.

| Stage №, $t_i$ | Stage name                                      |
|---------------|------------------------------------------------|
| $t_1$         | Select project theme                           |
| $t_2$         | Write a script                                 |
| $t_3$         | Collect material for a media project           |
| $t_4$         | Perform video editing                          |

In the course of the experiment, data were collected, a fragment of which is shown in table 2.

**Table 2.** Results of the experiment.

| № of Media Product | Time of stages of product creation (min) |
|--------------------|------------------------------------------|
|                    | $t_1$          | $t_2$          | $t_3$          | $t_4$          |
| 1                  | 1:00:00        | 0:30:00        | 2:00:00        | 1:05:00        |
| 2                  | 0:01:00        | 0:05:00        | 1:10:00        | 1:20:00        |
| 3                  | 0:01:00        | 0:05:00        | 0:50:00        | 0:40:00        |
| 4                  | 0:01:00        | 1:00:00        | 1:00:00        | 3:00:00        |
| 5                  | 0:01:00        | 0:05:00        | 0:40:00        | 0:30:00        |
| 6                  | 1:00:00        | 0:10:00        | 3:00:00        | 2:00:00        |
| 7                  | 0:03:00        | 0:30:00        | 1:00:00        | 3:00:00        |
| ..                 | ...            | ...            | ...            | ...            |
| 47                 | 0:10:00        | 5:00:00        | 7:00:00        | 4:00:00        |

3.3. Description of the "Implementation of an educational media project" process in terms of the GERT network

Consider a business process model "Implementation of an educational media project" (figure 2) in BPMN notation and a GERT network corresponding to this business process. The task of translating a business process model into a GERT network model is considered in [18].

Table 3 shows a comparison of the elements of the business process model and the GERT network.

**Table 3.** Comparison of model objects.

| BPMN model object                      | BPMN model object type | GERT network node | GERT network node type |
|----------------------------------------|------------------------|-------------------|------------------------|
| Select project theme                   | Activity               | V1                | STEOR                  |
| G1                                     | Gateway                | V2                | STEOR                  |
| Write a script                         | Activity               | V3                | STEOR                  |
| G2                                     | Gateway                | V4                | STEOR                  |
| G4                                     | Gateway                | V5                | STEOR                  |
| Collect material for a media project   | Activity               | V6                | STEOR                  |
| G5                                     | Gateway                | V7                | STEOR                  |
| J6                                     | Gateway                | V8                | STEOR                  |
| Perform video editing                  | Activity               | V9                | STEOR                  |
| J7                                     | Gateway                | V10               | STEOR                  |
| Transfer the media product to the customer | Activity            | V11               | STEOR                  |
An image of the GERT network describing the production process of media products is shown in figure 3.

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Figure 3. GERT network for the "Implementation of an educational media project" process.
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Based on the analysis of the execution time series and the frequency analysis of events at the process gateways, the probabilities of edge execution and distribution laws on the edges of the GERT network were identified. The result is shown in table 4.

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| Arc  | $p_{ij}$ | $M_{ij} (s)$ |
|------|---------|-------------|
| <V1, V2> | 1       | $\frac{1}{1 - 15.86956s}$ |
| <V2, V3> | 1       | 1           |
| <V3, V4> | 1       | $\frac{1}{1 - 31.4893s}$ |
| <V4, V2> | 0.15    | 1           |
| <V4, V5> | 0.8     | 1           |
| <V5, V6> | 1       | 1           |
| <V6, V7> | 1       | $\exp(1477174s + 1572s^2)$ |
| <V7, V5> | 0.15    | 1           |
| <V7, V2> | 0.05    | 1           |
| <V7, V8> | 0.8     | 1           |
| <V4, V8> | 0.05    | 1           |
| <V8, V9> | 1       | 1           |
| <V9, V10> | 1       | $\exp(166.8085s + 4048.63s^2)$ |
| <V10, V11> | 0.5   | 1           |
| <V10, V5> | 0.2     | 1           |
| <V10, V8> | 0.25    | 1           |
| <V10, V2> | 0.05    | 1           |
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Table 4. GERT network of the "Implementation of an educational media project" process.
Table 4 shows the parameters characterizing the arcs of the GERT network - the probability of the arc and the probability density of the distribution by the additive parameter - the time of the operation. The data shown in table 4 allow building a GERT network model that fully reflects the model of the system under study. For each arc of the network, the conditional probability and the generating function of moments are determined.

Based on the data presented in table 4 and the topology of the GERT network, shown in figure 2 using the formulas given in [5], the mathematical expectation and the variance of the execution time of the media production process in minutes were calculated for the drain of the GERT network.

Expected value: $\mu = 334$.

Dispersion: $\sigma^2 = 133225$.

In figure 4 shows the graphs of the probability density, mathematical expectation and distribution function of the calculated random variable (time of the business process execution) of the GERT network.

![Figure 4. Probability density and distribution function of the GERT network.](image)

Here the gray histogram shows the probability density function of the total execution time of the process, the black line is the distribution function of the execution time. The red line shows the mathematical expectation of the process execution time. The Y-axis is counted from 0 to 1.

Based on the data obtained, it is possible to build further optimization models for the “Implementation of an educational media project” business process.

4. Discussion

The results presented in the work show that GERT networks are a convenient tool for the numerical forecasting of business process models. So, after one-time construction of the structure of the GERT-network model, a tool for the numerical assessment of the business process appears in the future without performing time-consuming and computationally complex simulation experiments. In this case, the resulting model allows you to obtain the required number of moments of the distribution law of the probabilistic model of the business process, which will allow solving the problems of analyzing the efficiency of business processes and risks of a business process. The availability of these data will allow
obtaining estimates of the investment attractiveness of investments in improving the business process. Thus, the hypothesis considered in [13] was confirmed by experiment on real data.

The proposed procedure for refining the GERT-model of a business process allows you to continuously maintain its adequacy, which will increase the accuracy of decisions made on the basis of the model.

5. Conclusion

Thus, it is shown that the GERT network makes it possible to predict the probability of the project execution time for the development of a media product based on the accumulated statistics on previous projects. Unlike traditional multi-pass simulation experiments, the proposed method for analyzing the execution of similar projects allows one to obtain analytical expressions, on the basis of which one can directly calculate the required parameters of business processes. Such a solution has a number of advantages over a simulation experiment, among which there is less computational complexity, as well as the independence of the result obtained from the number of experiments performed.

Evaluating the prospects for the development of this work, it can be assumed that the analytical record of the distribution laws of numerical parameters will make it possible to formulate and solve analytically the problem of optimizing the target parameters for the execution of standard projects by varying the parameters of business processes, the probabilities of triggering the process branches, as well as the structure of the process of working on a project in the whole. From an economic point of view, the obtained optimal solution will allow to determine the directions of improving work on the class of projects investigated in each specific case.

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