The prototype of the organizational maturity model’s digital twin of an educational institution

M G Dorrer
Reshetnev Siberian State University of Science and Technology, 31 Krasnoyarsky Rabochy Ave., Krasnoyarsk, Russia

E-mail: mdorrer@mail.ru

Abstract. The article describes an approach to creating a high-precision model of a system of high-level indicators of an educational organization. The proposed solution is based on building a dynamic model of high-level organizational performance within the digital twin concept. BPMS ELMA was used as a technological platform for the solution. The predictive model is based on a linear model of a discrete-time automatic control system. The digital twin is supplemented by a recommendation module using optimal control methods and recursive filters. The parameters of the predictive digital twin model are refined based on the digital shadow data. As we collect digital shadow data, we should expect an increase in the accuracy of the forecast model, which in the future will allow us to speak of it as a model with high accuracy.

1. Introduction

As part of the Industry 4.0’s implementation, many industries are actively implementing Digital Twins (DT) technology. In this paper, we will use the digital twin model within the framework of the model-oriented systems engineering concept.

Since organizational systems are some of the most complexes, a natural solution to managing them is to use digital twins. Gartner company suggested the Digital Twin of Organization’s concept (DTO) [1] - “a dynamic enterprise programming model based on operational and/or other data to understand how an enterprise implements its business model, reacts to changes and uses resources to obtain the expected value for the client.”

Within the DTO concept, business process modeling is an important section. At the same time, the search for publications revealed only one article on this topic. The article is a corporate publication of the company "Severstal" [2]. The identified publications talk about the digital twins for modeling physical objects’ using and from organizational projects they concern maintenance and repairs and, partly, logistics.

The current state of business process management digitalization is characterized by the following problems:

- The connection between the management systems’ integration by levels is insufficiently represented (“organizational schizophrenia” as defined by Norton and Kaplan). There is no reliable assessment of the management’s integral indicators’ impact of upper levels on the physical indicators of business processes;
- Modelling and simulation are used in strategic and tactical planning activities. For production applications of the models, continuous accounting of events and transactions is required. These
features make the model more complex, more expensive, and more demanding in terms of infrastructure, but they are essential for real-time modelling capabilities.

- Existing business process simulation models only provide the alternative analysis (What-If analysis), without showing areas for improvement analytically.
- Existing methodologies for improving business processes allow you to choose the best of the available proposals for improving business processes by evaluating alternatives. At the same time, model analysis tools such as ProM and ARIS PPM allow you to analyse the actual behavior of the business process [3], but do not provide analytical tools for forming optimal solutions for improving processes by any criteria.

As indicated above, the interaction between the levels of indicators in the management of organizations, as well as the forecasting of integrated indicators is an urgent task. For example, Masaev in work [4] proposes to use control based on the indicator of adaptive stress. In the article [5] Proenca proposes to manage the organizational maturity of an educational organization [6]. As a solution to this problem, it is proposed to develop a digital twin of integrated business process indicators that can provide increased integration and coordination of business process management.

2. Methods

2.1. Object of study

The Institute of Informatics and Telecommunications [7] provides world-class education in the field of information technology and telecommunications. Already from the first-year students are involved in exciting developments, building a high-tech future in our country.

Practical and theoretical training, joint projects allow students to develop on-board computers for communication satellites, optimize transport networks and assess economic risks, protect computer networks from intrusions from the Internet and design mobile communication systems.

Students automate projects of space planetary stations and teach robots to move in an unknown environment, develop systems for recognizing faces on video images and traces of fires on satellite images.

This is a promising profession in the future. A specialist in integrated information security and information systems (this is the basic specialty of the Institute) is in great demand. IITK graduates work in special services, government bodies, large corporations, and computer firms.

IITC students can study and undergo an internship at the University of Michigan and the University of Utah (USA), the University of Ulm and the Technical University of Rhine-Westphalia (Germany), the Czech Technical University (Czech Republic) and others.

The Directorate of the Institute is an educational, scientific and administrative division of the institute, carrying out work on the organization of educational, research activities of the departments in training specialists (bachelors, masters), conducting educational work with students, as well as participating in the organization of training of highly qualified personnel. The director of the Institute is in charge of the activities of the Institute of Informatics and Telecommunications. To help the director of the institute, the directorate establishes a full-time position of deputy director for educational work. To carry out the activities of the Directorate, positions are introduced into its organizational structure:

- specialists and dispatchers from among the training, auxiliary and service personnel;
- secretaries from among the service personnel.

2.2. The context of the proposed solution

The solution presented in this article is a part of a Digital Twin of a Business Process’ concept (DTBP) as part of a digital twin of an organization (DTO, Digital Twin of an Organization, a concept proposed by Gartner in 2019) [1]).

The following set of functions is proposed for the DTBP (see figure 1).
To implement these functions, the concept of the DTBP structure, presented in figure 2, is proposed. The main functional blocks of DTBP are responsible for the implementation of enlarged functions (see figure 1).

Figure 1. Functional Requirements Model for DTBP (SysML Use-Case).

Figure 2. The structure of subsystems and connections DTBP (SysML Block Diagram).
The internal architecture of the "Modeling Subsystem" functional block is shown in figure 3.

![Digital Shadows Database](image1)

![Process Twin Instance Management Module](image2)

![Digital Twin Model Parameter Database](image3)

**Figure 3.** The structure of subsystems and links of the modeling subsystem (SysML Block Diagram).

The conceptual class model of the Process Twin Instance Management Module is shown in figure 4.

![Conceptual class model](image4)

**Figure 4.** Conceptual class model of the BPDT modeling system (SysML Block Diagram).

The proposed system models show the architecture of BPDT. Following this architecture, the methods and algorithms implemented in this article will be further considered.
2.3. The boundaries decision described in this article
This article describes the BPDT’s implementation in terms of the organizational maturity digital twin, which is part of the integrated metrics model twin (see figure 4). The implementation of the functions (in terms of organizational maturity) of the BPDT is described (see figure 1).

Based on the collected data and the implemented algorithms, the decision-maker can at any time obtain the following information regarding the values of the levels of organizational maturity:

- Current values of maturity indicators by component;
- Forecast of indicators of maturity for any given period;
- A recommendation for allocating resources to organizational development projects.

2.4. The methodological approach to assessing and forecasting indicators of organizational maturity
The collection of digital shadow data of the integrated indicators model is implemented using the methods and algorithms described in work [8] based on the ELMA system.

The predictive model of the digital twin is implemented based on mathematical models described in papers [9].

ISO 9004 international standard provides a methodology for self-assessment of organizational performance, including separate self-assessment tables for key elements and details [8].

2.5. Implementation of a prototype predictive digital twin system using the Matlab
Figure 5 shows the Matlab code that calculates the optimal controller. The program formulas and variables correspond to the model parameters described in Ref. [9].

```matlab
P=zeros(7,7,5);
Xdif(:,1,:)=X0;
Ksi=diag([0 0 0 0 0 0 0]);
P(:,:,5)=Ksi;
for i=4:-1:1
    P(:,i,:)=P(:,i+1,:)+dT2*(A'*P(:,:,i+1,:)+P(:,:,i+1,:)*A-
    P(:,:,i+1,:)*Bcalc*inv(R)*diag(B')*P(:,:,i+1,:)+Qi);
end
% Trajectory construction
for i=2:5
    Ki=-inv(R)*Bcalc'*P(:,i,:);
    U(i,:)=Ki*Xdif(i-1,:);
    Xdif(i,:)=Xdif(i-1,:)+((A*Xdif(i-1,:))'+(Bcalc*U(i,:))')*dT2;
end
```

**Figure 5.** Matlab code for optimal controller.

If the problem is solved in a non-deterministic version, then to re-estimate the state vector of an a priori known dynamical system, it is necessary to use recursive filters. An example of such a solution is shown in figure 6.

Calculations of the discrete-time control system model for managing organizational maturity indicators, originally implemented in the Matlab system as shown in figure 5, 6, were then imported as C# code using the Matlab Coder module.
% Solution of the Ricatti equation for S(i) at the i-th step
\[ S_{i}(:,:,i) = S_{i}(:,:,i-1) + 2A*S_{i}(:,:,i-1) - S_{i}(:,:,i-1)*H'*\text{inv}(W)*H*S_{i}(:,:,i-1) + V; \]

% Calculation of the recursive filter L(i) at the i-th step
\[ L_{i}(:,:,i) = -S_{i}(:,:,i)*H'*\text{inv}(W); \]
\[ K_{i} = -\text{inv}(R)*B_{calc}'*P(:,:,1); \]
\[ U_{i} = K_{i}*X_{dif}(i-1,:); \]
\[ X_{dif}(i,:) = X_{dif}(i-1,:) + ((A*X_{dif}(i-1,:))' + (B_{calc}*U_{i})')*dT2; \]
\[ X_{dif}(i,:) = X_{dif}(i-1,:) + X_{dif}(i-1,:) * (A-B_{calc}*\text{inv}(R)*B_{calc}'*P(:,:,i)*k^2)*k - (Y_{dif}(i-1,:) - X_{dif}(i-1,:)*H)*L_{i}((:,:,i)*k); \]
\[ Y_{dif}(i,:) = (H*X_{dif}(i,:))' + W_{i}(i,:); \]

**Figure 6.** Matlab code for calculating recursive filter.

3. Results

3.1. Results of collecting data
The constructed control system provided the collection of digital shadow data of the integrated indicators for three years of work of the Directorate. Averaged over three years (2017, 2018, 2019) indicators for the indicators of the upper level of the standard [8] are equal, respectively:

\[ x_{2017} = [2.72, 2.00, 2.50, 2.00, 2.17, 2.00, 1.87], \]
\[ x_{2018} = [2.82, 2.17, 2.58, 2.33, 2.00, 2.67, 2.00] \text{ and} \]
\[ x_{2019} = [2.58, 2.70, 2.60, 2.80, 2.13, 2.53, 2.55] \]

A meaningful analysis of the collected data is given in work [9].

3.2. Solving the problem of constructing optimal trajectories of target indicators
The predictive subsystem of the digital twin calculated the trajectories of target indicators based on the algorithms described in [9] for a time range of 5 years for various priorities of decision-makers.

**Figure 7.** Integrated metric trajectories constructed by the digital twin predictive system.
4. Discussion
Thus, this article describes the implementation of a prototype digital twin of the integrated scorecard model. ELMA objects of the DataObject type are used as the digital shadow of the integrated indicators model. The implemented simulation model makes it possible to generate forecasts of maturity levels and propose optimal solutions for their management. Combining the functions of collecting maturity estimates and determining the parameters of the predictive model in one system allows us to say that a highly accurate model has been created. It is shown that the predictive model implemented in the digital twin has shown its efficiency for managing a set of integrated indicators.

Such a digital twin will not only have forecasting functions but will also be able to offer solutions for the optimal distribution of resource investments in organizational development projects.

5. Conclusion
Further work will be as follows:

- Development of a twin of a dynamic business process model;
- Development of a twin model of the digital twin of the correlation tension of the organizational system.

The development and filling with a digital shadow of a digital twin containing both these models, as well as a model of interaction between them, looks especially interesting.

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