Improvement of electronic design and technological documentation approval procedure quality by using the apparatus of artificial neural networks

M V Ivanov¹, S A Afanasenkova¹ and E A Skorniakova²,³

¹ AO “NPP “Signal”, Saint-Petersburg, 4 Knipovich str, 192019, Russia
² Saint Petersburg State University of Aerospace Instrumentation, Saint-Petersburg, 67 Bolshaya Morskaya str, 190000, Russia
³ E-mail: elizavetasesina@mail.ru

Abstract. The necessity of the product life cycle processes reengineering such as design and production stages in order to reduce feedback between design and technological departments and production departments within the framework of the tasks of the organization's quality management service has been substantiated. Design and technological documentation approval processes are overviewed within the usage of single integrated automated system environment. The apparatus of artificial neural networks is applied to simulate processes and identify redundant elements. An optimized neural network model of approval processes for design and technological documentation is obtained.

1. Introduction
Timely release of products that fully meet the specified requirements is the main task of production. The implementation of information technology (IT) requires a revision of the design, construction and direct creation of products.

To organize product manufacturing, it is necessary to have up-to-date information that is promptly and stage-by-stage provided during the product design process. The relevance of information is maintained through feedback between development and production departments.

Inconsistencies may appear at any stage of product manufacturing. Untimely transfer of the identified inconsistencies information complicates the process of creating a product, increasing the time of its production, which can lead to defects and significant material costs for the organization. Therefore, information on emerging inconsistencies must be promptly shared with all participants in the product creation process, which can be done using a single integrated electronic environment automated systems (AS) of the PDM / PLM class.

The quality management service (QMS) of the organization is responsible for eliminating the inconsistencies that arise. IT introduced into production processes allow managing the product life cycle (PLC) in real time. In this regard, QMS has the opportunity to directly participate in the process of controlling the creation of a product.

In addition, the task of prompt transfer of information about inconsistencies between design-engineering and production departments becomes realizable.
2. Optimization of design and technological documentation approval route

Making structural improvements to the product also generates the need to adjust the technological process for its creation, which requires prompt coordination of changes between the participants in the product manufacturing process.

In implemented production processes of the organization AS, the coordination of documentation between the participants is carried out along a specific route in accordance with the regulatory documentation of the organization (developed during the implementation and adaptation of the AS that controls PLC) [1], using the electronic approval protocol (EAP).

The EAP route is a series of combined one by one document statuses. The connections between statuses is the transitions from one status to another. The advancement of a document along the EAP route is a change in its status, according to the route. The transition between statuses is possible if there is an electronic digital signature of the persons who approve the document at each specific transition.

The traditional EAP route is shown in figure 1.

![Figure 1. The traditional EAP route.](image)

Any document created in the AS environment receives the "Design" status. At the end of the design, the designer leaves his own signature on the document and submits it to the verifier for verification (most often the role of the verifier is played by a senior employee of the design department). After the document has been signed by the verifier, the information contained in the document is subject to primary standard control at the “Reconciliation” status. Upon receipt of the signature of the standard inspector, the document is subject to approval by the chief designer of the product, after which the information contained in the document is subject to repeated or final standard control. The standard inspector, having signed the document with his own signature, transfers it to the archive, where the document is subject to registration. When a new version of the document is released, the old one is canceled, and the new one gets the “Design” status, after which the cycle of moving along the PES route is repeated.

With the help of the developed software module [2] based on the apparatus of artificial neural networks (ANN) [3] and its introduction into the AS, it becomes possible to reengineer [4] the existing route for the approval of design and technological documentation (DTD).

ANN-model of the traditional EAP route is created is presenting the transitions between statuses in the form of artificial neurons [5] and combining them layer by layer according to the status of the document.

A feature of ANN functioning is the layer-by-layer processing of incoming information. At the same time, the generalization of its unique features occurs on each subsequent layer [6] in separate artificial neurons. In addition, the error backpropagation algorithm is the main learning algorithm of the ANN [7], it allows us to represent the complete information processing process as a cyclical one without
explicit indication of feedback. Thus, it is possible to construct an adaptive simulation model [8] and highlight redundant features of the system under consideration in it.

The neural network model of the traditional EAP route is shown in figure 2.

Figure 2. The neural network model of the traditional EAP route.

As a result of the analysis of the traditional model of the DTD approval processes using the ANN apparatus, redundant connections between the elements of the system were revealed (figure 3), namely:
- being at any of the stages of EAP, except for "Archived", the document is sent for revision in the event of inconsistencies in the design. Since the processes of design and revision of the document are identical, it is advisable to combine them into a single design process. Moreover, it is the initial process of documentation approval;
- since the verification of the completed documentation is performed by an employee of the same department as designer, and verifier can also be a designer, the verification process, like the design process, is an initial process;
- primary and final standard control, as a rule, is carried out by the same employee of the standardization department. Therefore, it is advisable to combine these processes into one common;
- procedures for standard control, approval and sending for processing to the archive in a single integrated AS environment can be carried out in parallel with the exchange of information between coordinating persons;
- at the end of the approval procedures, the final state for the document is either registration in the form of an original, or the cancellation of an obsolete or outdated version of it.

Figure 3. Redundant elements of the ANN model.

The result of optimization of the traditional EAP route is shown in figure 4.

Figure 4. Optimized ANN model of the EAP route.
The layers of the obtained ANN model can be represented as statuses of the EAP route. On the basis of the structure of the optimized ANN model of the approval DTD, a new EAP route was created (figure 5).

![Optimized EAP route](image)

**Figure 5.** Optimized EAP route.

The effectiveness of the approval DTD along the new route of the EAP was assessed using the subsystem for collecting information on the duration of the coordination of documentation introduced into the AS (table 1).

| Period (year) | Duration (days) | Period (year) | Duration (days) |
|--------------|----------------|--------------|----------------|
| 2014         | 51             | 2018         | 41             |
| 2015         | 71             | 2019         | 55             |
| 2016         | 58             | 2020         | 46             |
| 2017         | 60             |              |                |

**Table 1.** Average duration of the approval DTD for the periods before and after the implementation of the optimized EAP route.

According to the traditional route of EAP, the average time of DTD approval was 60 days (approximately 2 months). After the introduction of a new route for EAP, the time for approval of DTD began to take on average 47 days (approximately 1.5 months), the time for approval of the documentation was reduced by more than 20%.

3. Conclusions

The problem of operational information exchange between the structural divisions of the organization during the digitalization of the life cycle processes in terms of creating and approving on the product DTD is highlighted.

The use of the ANN apparatus for the analysis of the traditional approval route structure of the product DTD is proposed.

With the help of the ANN apparatus, redundant elements of the traditional DTD approving system were identified, and its optimization was carried out.

On the basis of the optimized ANN-model, a new route for approving the product DTD was created and introduced into the work processes.

The statistical data on the duration of the DTD approving before the development and implementation of the optimized EAP route and after using of proposed solutions are presented.
Based on the results of implementation in work processes, the main requirements for digital production are determined, which are reflected in the organization's regulatory documents and related standards are updated.

References
[1] Afanasenkov S 2017 *Standard of organization RU 090.145-2017 Electronic document management of design, development and product production* (Saint-Petersburg: AO NPP Signal)
[2] Ivanov M 2019 *B. Samara Sci. C. RAS* 21 41
[3] Ivanov M 2020 *Proc. Int. Rus. Automation Conf.* (Sochi: RusAutoCon 2020) p 352
[4] Hammer M and Champy J 1993 *Reengineering the Corporation: A Manifesto for Business Revolution* (New York: Harper Business)
[5] McCulloch W and Pitts W 1990 *Bull. Math. Bio.* 52 99
[6] Wasserman P 1989 *Neural computing: theory and practice* (New York: Van Nostrand Reinhold Co)
[7] Rumelhart D, Hinton G and Williams R 1986 *Parallel Distributed Processing* 1 318
[8] Ivanov M 2019 *Sci. Business Dev. Ways* 8 57