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DEVELOPMENT OF SOFTWARE USING DEEP LEARNING ALGORITHMS IN NEURAL NETWORKS FOR AUTOMATION OF DESIGN IN THE FIELDS OF ARCHITECTURE AND CONSTRUCTION

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Abstract

The article discusses the possibilities of using artificial intelligence to train young specialists in the field of architecture and construction. The use of neural networks in training can be applied at the design level, at the construction level, at the level of safety monitoring, at the level of visualization of three-dimensional models, in the design and construction of buildings and a number of other design solutions. Neural networks can be used to optimize the building design process. They can analyze various parameters and factors, such as climatic conditions, site geometry, customer requirements and budget, and offer optimal project options. This allows architects and builders to make more informed decisions and create more efficient and functional buildings and structures.

Keywords

architecture and construction, artificial intelligence, neural networks, deep learning digital technologies, computerization, reverse search algorithms.

Introduction

In the modern world, architecture and construction are among the key industries in the world. Many advanced digital technologies for automation, digitalization and computerization are aimed at solving problems related to these areas.

Among the many different solutions in the field of digital technologies that simplify design in construction and architecture, the most promising is the use of AI using neural networks.

Since in order to make a management decision on the implementation of a specific solution using artificial intelligence (AI) in an enterprise, it is necessary to be able to analyze the offers available on the market and estimate the expected cost, then training young specialists in design using AI is becoming an important direction in the use of digital technologies in education [1].

Artificial intelligence and neural networks have become key technologies that are actively used in various fields, and architecture and construction are no exception. Modern architects use neural networks to optimize design processes, create new forms and structures, and improve the energy efficiency of buildings. In this article, we will consider how AI and neural networks are used in architecture and how this affects the future of design and construction [2].

Methods. The principle of operation of AI in terms of project activities is as follows: first, at the construction site, using specialized equipment, for example, 360° cameras, a photo recording of the current state of work is carried out, after which the AI is connected and compares the actual state of affairs with the BIM model. If any errors, shortcomings, deviations from the planned deadlines or quality are detected, all this is recorded, formalized, the code is transferred to the project and construction manager for analysis and making the right management decisions. For example, you can change the project in some part or speed up the implementation of construction and assembly work. Autodesk Construction IQ is positioned as an intelligent assistant for construction projects based on Autodesk BIM 360. Using machine learning methods, Construction IQ extracts information from audits, technical supervision logs, technical specifications, reports and other design documents, analyzes data on the quality and safety of construction projects, possible project risks and presents the data to stakeholders [3].

There are many modern AI technologies in construction, but many experts highlight only five of the most effective, promising and fast-growing areas that will significantly change the business processes taking place in construction companies in the future:

• Automation of heavy equipment. In this range of tasks, AI relies on satellite measurements and a set of inertial sensors, as well as GNSS (global navigation satellite systems), which together today almost completely automate the processes of managing engineering and construction equipment.

• Augmented reality in construction using smart glasses. Today, AI development is proceeding in a new way, because artificial intelligence has not stood still, but has developed, so the solutions have also become different. This device has built-in sensors that recognize the technical parameters of structures and highlight both errors made during design and construction, and acquired damage

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to the structure. In addition, when using smart glasses, an experienced architect, foreman or engineer can visualize a simple 3D model of the requested object in front of them, be it the facade of a building, a separate room or a proposed foundation.

• Reducing risk during construction work using predictive analytics, safety surveillance and safety monitoring created using powerful AI, in particular machine vision technologies. It is believed that a computer that has viewed more than 17 million images of construction processes can identify risk indicators, rank projects by risk and predict which 20% of projects will cause 80% of incidents in the near future.

• Noise reduction in photorealistic renderings, used to speed up visualization when designing interiors and exteriors of buildings. In other words, this direction serves to facilitate the presentation of the facade of a future project in a computer program. Today, this process requires enormous computing power and even with small changes, an enormous amount of time and resources is spent on their visualization. According to experts, AI will be able to perform these operations in the future with less energy and time consumption.

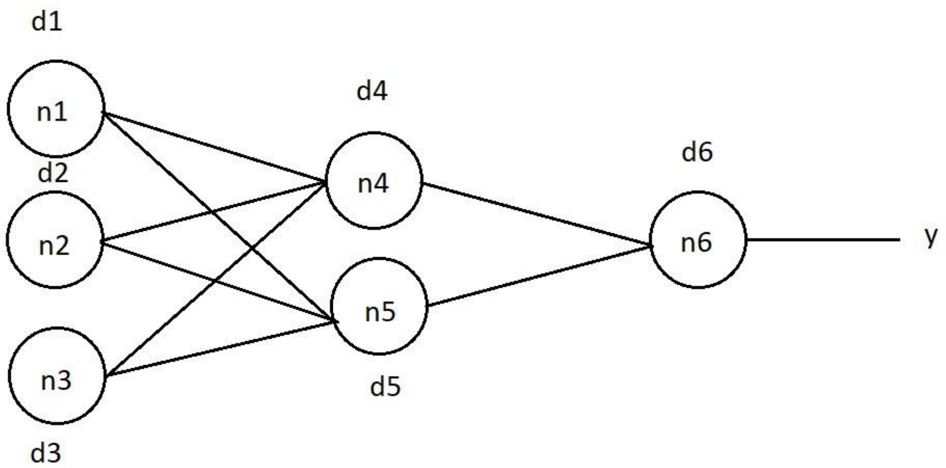

Figure 1. Structure of a deep learning neural network

So, to train a deep learning network, we need to change the values of the weight coefficients. Changing the weight of a connection is directly proportional to the error that the corresponding neuron gives. In that paper, the error is defined as:

$dj = f(netj)(1 - f(netj))k \sum dk\, wkj$ where j is the number of the element for which we calculate the error, k is the number of the layer from which the error came, i.e. the layer to the right of our network.

Let's start calculating the error of each neuron, starting from the end. Let's assume that we expect the value "O" at the network output. Then for neuron n6 the error is d6 = (O - y)*(f(in))*(1 -(in)) (2), where in is the input value to element n6, f(in) is the value of the activation function from this input value.

Now, based on formula (1), we calculate the errors for the neurons of the layer on the left. For n4, the error looks like this: *d4 = d6 * w46 *(f(in4)) * (1 – f(in4))*, where w46 is the weight of the connection between n4 and n6, in4 is the input value of neuron n4. d5 = d6 * w56 *(f(in5)) * (1 - f(in5)), for n5.

*d1 = (d4 * w14 + d5 * w15) *(f(in1)) * (1 – f(in1))*, and this is what the error of neuron n1 looks like, it has not one connection, but two - so we add the error of the second connection to the formula. Then for n2 and n3 the errors look like this: *d2 = (d4 * w24 + d5 * w25) *(f(in2)) * (1 – f(in2)) d3 = (d4 * w34 + d5 * w35) *(f(in3)) * (1 – f(in3))* And now, finally, let's calculate the weight adjustment:

*Δw46 = d6 * A * f(in4)*, w46 — the weight of the connection between the n4 and n6 neurons, and f(in4) is the value of the activation function from the input value of the n4 neuron, A is the deep learning speed coefficient, the closer it is to zero, the slower but more accurately the network learns.

*Δw56 = d6 * A * f(in5)*, accordingly, the adjustment of the connection of elements n5 and n6.

Let's make adjustments for the remaining connections:

*Δw14 = d4 * A * f(in1)*
*Δw24 = d4 * A * f(in2)*
*Δw34 = d4 * A * f(in3)*
*Δw15 = d4 * A * f(in1)*
*Δw25 = d4 * A * f(in2)*
*Δw35 = d4 * A * f(in3)*

Let's write the text of the corresponding program in C++:

```
void NeuralNet::learnBackpropagation(double* data, double* ans, double acs, double k)
{ //k - number of training epochs acs- learning rate
for (uint32_t e = 0; e < k; e++) {
double* errors = new double[neuronsInLayers[numLayers - 1]];
  Forward(neuronsInLayers[0], data);
  getResult(neuronsInLayers[numLayers - 1], errors);             for (uint16_t n = 0; n < neuronsInLayers[numLayers - 1]; n++) {
neurons[n][2][numLayers - 1] = (ans[n] - neurons[n][1][numLayers -
1]) * (neurons[n][1][numLayers - 1]) * (1 - neurons[n][1][numLayers - 1]);
}
```

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```
for (uint8_t L = numLayers - 2; L > 0; L--) {      for (uint16_t neu = 0; neu < neuronsInLayers[L]; neu++) {      for (uint16_t lastN = 0; lastN < neuronsInLayers[L + 1]; lastN++) {
    neurons[neu][2][L] += neurons[lastN][2][L + 1] *
    weights[neu][lastN][L] * neurons[neu][1][L] * (1 - neurons[neu][1][L]);
    weights[neu][lastN][L] += neurons[neu][1][L] * neurons[lastN][2][L + 1] * acs;
    }
    }
    }
    }
    }
```

Results. Training young professionals in the use of AI in design in the field of architecture and construction will provide a solid foundation for future investments.

In the modern world, the construction industry needs revolutionary changes. The use of AI can radically change the course of construction history - fundamentally transform the methods of designing buildings and the approach to design itself. The use of AI has already achieved certain results in this area, it is obvious that teaching students to use AI in design will continuously improve these results 4]. AI used in training young professionals:

1. Generative artificial intelligence is a type of artificial intelligence that can create new content based on the data it has studied before. A striking example of generative artificial intelligence are the ChatGPT and Midjourney neural networks.

2. Labeled data (in the context of machine learning) is data that has been assigned specific labels or tags that define the content or characteristics of the data.

3. Black box model - a system or process whose internal workings are not visible or accessible to the user or observer. In other words, it is a model that operates on input data provided to it and produces output data, but the user does not know how the model arrived at the output data. The model is often used with complex algorithms or machine learning models, where the relationship between the input and output data is difficult to explain or understand.

4. Deloitte is the largest network of companies providing audit, consulting, financial advisory services, dealing with risk management, taxation and related services. Deloitte operates in more than 150 countries and has more than 330,000 professionals.

Discussions. In the modern world, using AI to solve routine tasks has become commonplace. In the construction industry, companies use AI for planning and document analysis. In practice, it looks like this: the user forms a request, and the neural network develops a response using large volumes of labeled data.

Revolutionizing building design. A new method for rule-based AI systems provides reliable data in the form of generated designs that can be used to train a machine learning model. This approach can speed up end-to-end design from months to days, simplifying the work of architects, developers, and engineers, while addressing cost, schedule, and efficiency issues.

Advantages of automated design in construction:

1. Fewer risks, missed deadlines, and error corrections

Automation of design processes increases the speed at which residential and commercial buildings are designed and built. The amount of money spent over budget on rework can reach 6% of the total project cost. Automated design in construction should solve this problem by reducing the influence of the human factor on the design processes.

2. Striving for sustainable design. The construction industry is a large consumer of energy and resources. Automated design minimizes the number of errors at the design stage.

3. Variability. Automated design also allows for the creation of several design alternatives in parallel, helping to find ways to develop buildings with better performance characteristics using fewer materials. Modern design methods also help improve the energy efficiency of a building - a critical indicator, given that according to the UN, buildings consume about 40% of global energy and resources. Now design firms can understand what to do: optimize only cost and time, or also design for more rational use of materials and operation. Automatically creating designs with a high level of detail ensures that they only order what they need, reducing material waste.

4. Increased productivity and profitability.

Using generative AI, buildings can be designed and optimized for maximum efficiency and productivity. Not only does this benefit the environment, but it also makes the construction industry more productive and profitable. In the past, architects, engineers, and construction professionals spent a significant amount of time resolving design and approval errors, which accounted for up to 20% of their work time.

With generative AI, the design and construction processes are becoming increasingly automated, resulting in faster, better designs and fewer construction errors. The reliability of generative AI design allows professionals to improve workflow efficiency and spend less time correcting errors.

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By automating the design process, young professionals are given a mentor, allowing even inexperienced designers and engineers to create designs that comply with building codes and design features. This approach to training frees up newcomers from the usual and tedious way of designing. Instead, they can better understand the needs of clients, free up time to explore different design options, and at the same time increase the efficiency of the project to the maximum level.

Conclusions. Artificial intelligence in architecture and construction can be applied at the design level, at the construction level, at the security monitoring level and at the project visualization level. Today, it is possible to conduct almost the entire cycle of construction work with much greater efficiency, using appropriate AI solutions without resorting to excessive spending.

Design Optimization. Neural networks are used to optimize the building design process in architecture and construction, so teaching students to use AI in design is one of the most important tasks in the use of digital technologies in education. They can analyze various parameters and factors, such as climatic conditions, site geometry, customer requirements and budget, and offer optimal design options. This allows architects to make more informed decisions and create more efficient and functional buildings.

Generation of new shapes and designs. The use of AI in education, in particular, neural networks can be used to generate new shapes and designs of buildings. Deep learning algorithms can analyze hundreds and thousands of architectural samples and create new, unique shapes that meet the specified parameters and requirements. This helps young professionals in creating modern and innovative architectural solutions.

Energy efficiency and sustainability of buildings. Neural networks are used to optimize the energy efficiency and sustainability of buildings. They can analyze data on energy consumption, climate conditions and materials to offer solutions that reduce the burden on the environment and increase resource efficiency.

Construction automation. Neural networks can be used to automate some tasks in construction. For example, they can control robotic systems to lay bricks or create structural elements accurately and efficiently. This speeds up the construction process and reduces the likelihood of errors.

Training young professionals in AI design is fundamental to modern digital technologies. They allow architects and builders to create more efficient, sustainable and innovative buildings.

However, it is important to remember that neural networks will not replace human creativity and experience, but will serve as collaborators and assistants for architects, complementing their knowledge and capabilities.

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