DOI: 10.46299/ISG.2023.MONO.TECH.3.1.3

1.3 Using of neural network to estimate leakage rate in water distribution networks

An artificial intelligence technique known as a neural network teaches computers to interpret data similarly to how the human brain does. Deep learning is a sort of machine learning that employs interconnected neurons or nodes in a layered structure that is similar to the human brain. It develops an adaptive framework that enables computers to continuously learn from their errors. Artificial neural networks strive to more accurately complete challenging tasks like document summarizing or facial recognition.

An artificial intelligence technique known as a neural network teaches computers to interpret data similarly to how the human brain does. Deep learning is a sort of machine learning that employs interconnected neurons or nodes in a layered structure that is similar to the human brain. It develops an adaptive framework that enables computers to continuously learn from their errors. As a result, artificial neural networks strive to more accurately complete challenging tasks like summarizing papers or identifying individuals. Neural network is a mathematical model that is based on the structure and operation of biological neural networks, which are networks of nerve cells in a living creature. This idea came about as a result of research into and attempts to simulate various brain operations. The neural networks of U. McCulloch and U. Pitts were the source of the first such demand. Following the creation of training algorithms, the resulting models were put to use in real-world applications, such as forecasting, pattern recognition, control, etc.

An artificial neural network (ANN) is a network of interconnected and communicating basic computers. Particularly when compared to processors found in home computers, these processors are typically fairly straightforward. In a network like this, each CPU solely deals with signals that it periodically receives and periodically sends to other processors. Nevertheless, even individually simple processors are still

capable of doing complex tasks when joined in a sufficiently large network with controlled interaction. Computers can make intelligent decisions with minimal human input thanks to neural networks. They are able to research and model the connections between complicated and non-linear input and output data. The following are some examples of tasks that neural networks can carry out.

Write a summary and make judgments.

Without additional training, neural networks are able to comprehend unstructured data and draw broad conclusions. For instance, they can distinguish between two inputs that have the same meaning:

- Could you please explain the payment process?
- Where can I send money?

Both sentences' meanings will be understood by the neural network. Additionally, it can establish that Baxter Road is a location and Baxter Smith is a name. Neural networks have various applications across industries. They can be used for:

- medical image classification,
- social network filtering for target marketing,
- financial forecasting using historical data,
- predicting electrical load and energy demand.

Neural networks also aid in ensuring compliance with requirements and quality control, as well as determining chemical compounds. These are some of the most important tasks that neural networks help to solve.

Machine vision.

Machine vision is the ability of computers to extract information and meaning from images and videos. With the help of neural networks, computers can distinguish between pictures in the same way as humans. The ghost is used in many areas, for example:

- Interviewed with auto cars to respond to traffic signals and other traffic
- Satisfaction for the deletion of a dangerous or unnecessary images and video places

- Helbrance to identify people and find out the events as soon, the glasses and the File
- Image for the identification of the icon, clothes, tools and other info

Voice recognition.

Voice recognition can analyze human speech regardless of its pronunciation, intonation, tone, language, and tone. Virtual assistants like Amazon Alexa and automatic translation software use speech recognition to perform the following tasks:

- User assistance and automatic call notification
- Real-time translation of clinical advice into documents
- Accurate captions for videos and meeting recordings for broad content coverage

Natural language processing.

Natural Language Processing (NLP) is the ability to process natural text from humans. Neural networks help computers extract information and meaning from data and text documents. NLP has many application areas, including:

- Virtual agents and automated chats
- Automatic processing and processing of recorded data
- Business analysis of long documents: such as emails and forms
- The list of key phrases shows the situation: as good and bad words in social networks
- A summary of the literature and the generation of the given subject and subject

Recomendations Services.

Neural networks can track user behavior to generate personalized recommendations. They can also analyze all user behavior and identify new products or services that interest a particular user. For example, Philadelphia-based startup Curalate helps clients turn social media into sales. Brands use Curalate's Intelligent Product Marking (IPT) service to automate the collection and classification of content from social media users. IPT uses neural networks for automatic search and product

recommendation that match the user's activity in social networks. Consumers don't need to dig through online catalogs to find a particular product based on social media images. Instead, they can easily buy the product with Curalate's auto sign.

How do neural networks work? The structure of the neural network replicates the structure of the human brain. Human brain cells, called neurons, form complex networks that are highly interconnected and send electrical signals to each other, helping people process information. Similarly, a functional neural network consists of neurons that interact to solve a problem. Artificial neurons are programmable modules called nodes, and artificial neural networks are programs or algorithms that use computer systems to perform mathematical calculations.

Architecture of Neural Networks

A basic neural network consists of three layers of interconnected artificial neurons:

- Insertion layer

Information from the outside world enters the neural network through the input layer. The input node processes the data, analyzes or categorizes it and passes it on to the next layer.

- Hidden layer

Hidden layers receive input from the input layer or other hidden layers. A neural network can contain a large number of hidden layers. Each hidden layer analyzes the output data of the previous layer, processes it and passes it on to the next layer.

- production layer

The production machine provides the final result of the processing of all the data through an artificial neural network. It can have one or more nodes. For example, when solving a binary (yes/no) sorting problem, the output layer will have an output node, which will give the result \"1" or \"0". However, in the case of multi-level processing, the output layer may include multiple nodes.

Architecture of deep neural networks is following. A deep neural network or deep learning network consists of many hidden layers with millions of interconnected neurons. A number called a weight indicates the connection between a node and others.

Weight is a positive number if one node stimulates another, or a negative number if one node inhibits another. A node with a higher weight value has a greater influence on other nodes.

Obviously, a deep neural network can match any type of input to any type of output. However, it should be considered that they require more complex training than other machine learning methods. These algorithms require millions of examples of training data, not hundreds or thousands as in simple networks.

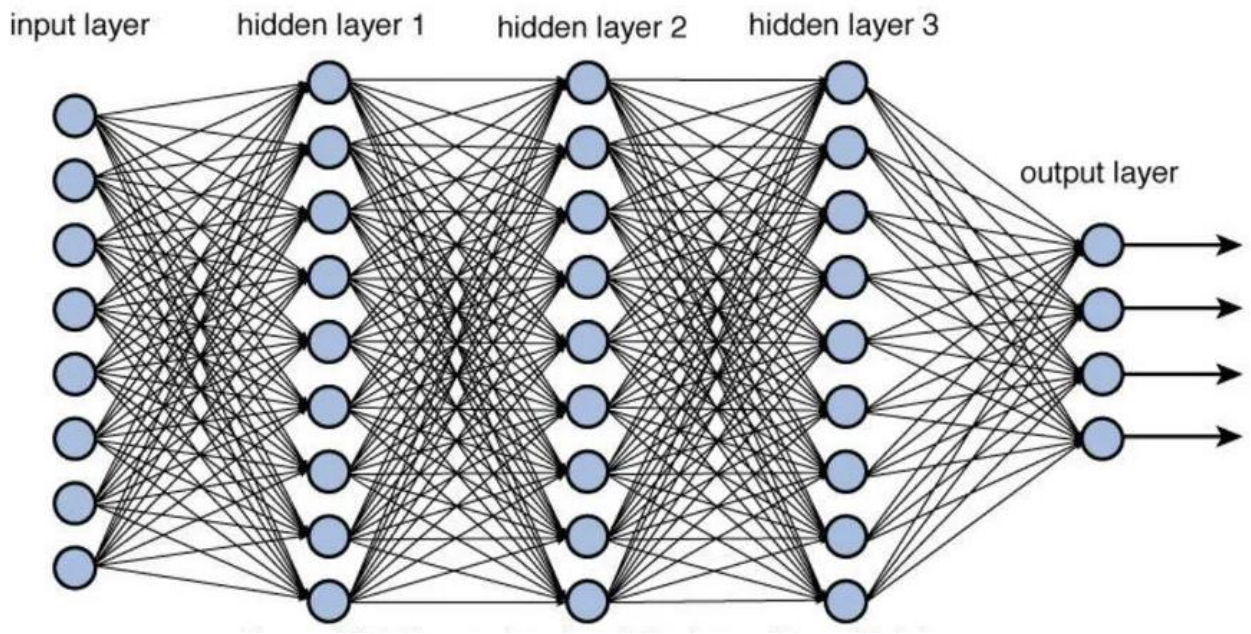

Fig. 1. Deep neural network architecture with multiple layers.

So, everyone may ask: what types of neural networks are there? Artificial neural networks can be classified based on how data is passed from input nodes to output nodes. Here are some examples.

- *Continuous Propagation Neural Networks*

Routing neural networks process data in one direction, from input nodes to output nodes. Every node in one layer is connected to every node in the next layer. Neural networks that feed forward use feedback mechanisms to improve predictions over time. Backpropagation algorithm

Artificial neural networks are regularly trained using self-correcting feedback loops to improve their predictive analytics. Simply put, it is data that travels from an input node to an output node in many ways in a neural network. Only one correct path

that maps the correct entry and exit points. To find this path, the neural network uses a feedback loop that works like this: Each node plans for the next node in the path. It checks if the idea is correct. Thresholds assign higher weight values to nodes that lead to correct inferences, and lower weight values to nodes that lead to incorrect inferences. For the next data point, the node makes a new prediction using the path with higher load, and repeats step 1.

- *Convolutional Neural Networks*

The hidden layers of the convolutional neural network perform some mathematical operations (eg, summation or filtering), which are called convolutions. They are very useful for image processing, as they can generate useful matching features for recognition and processing. The new model is easy to configure without losing the functions that are essential for the right idea. Each hidden layer captures and processes different features of the image: scale, color, and depth.

Also, the next important question is: how are neural networks trained? Neural network training is a method of training neural networks to perform tasks. Neural networks are trained from the initial processing of many large sets of labeled or unlabeled data. Based on these examples, the network can handle unknown input data well.

In supervised learning, data scientists come up with artificial neural networks labeled sets of data that give the correct answer in advance. For example, a deep learning network trained to recognize faces processes hundreds of thousands of images of human faces with different terms related to ethnicity, country, or emotion describing each image. A neural network gradually collects knowledge from these data that provides accurate answers in the future. After the training, the network begins to make assumptions about the race or emotion of a new image of a human face that it has never seen before.

What is deep learning in neural networks? Artificial intelligence is the branch of computer science that studies how machines can perform tasks that require human intelligence. Machine learning is an artificial intelligence technique that allows computers to access large amounts of data for further training. Machine learning

software finds patterns in existing data and applies those patterns to new data to make intelligent decisions. Deep learning is a type of machine learning that uses deep learning networks to process data.

Machine learning and deep learning. Traditional machine learning methods require human assistance for the software to function properly. A data scientist manually defines a task that is important for the software to analyze. This limitation makes building and maintaining software a tedious and time-consuming process. In contrast, in deep learning, data scientists provide only raw data and software. A deep learning network automatically generates strategies and learns more on its own. It can analyze unstructured data (for example, text documents), prioritize data features, and solve complex tasks.

For example, when you're training software and machine learning algorithms to correctly recognize the image of a pet, you'll want to take the following steps:

- Find and manually tag thousands of pet images: cats, dogs, horses, hamsters, parrots and more.
- It will tell software with machine learning algorithms which features should be found so that it can identify images by subtraction. For example, it can count the number of feet, then look at the shape of eyes, ears, tail, color of fur, etc.
- Manually review and edit tagged data records to improve software accuracy. For example, if your training set contains many images of black cats, the software will correctly identify black cats, but not white ones. With extensive training, the neural network will process all the images and realize that they need to first analyze the number of legs and the shape of the face and then look only at the tail in order to correctly identify the animal on the screen.

Due to the rapid population growth and industrialization, water resources are under extreme pressure. Water is a finite resource, and as such, its management should be done to ensure that the least amount possible is used. This fact makes the problem very important. Also, more than 40% of treated water is lost as non-revenue water in some countries. One such aspects is leakage. Usually, the water distribution system experiences water loss. An average of 36% of the total water loss for the City of Harare

is lost through leakage. Leakage is influenced by factors such as pipe age, pipe material, pressure, soil type, and pipe laying technique. Four fundamental leakage management strategies were suggested by the International Water Association (IWA)

(i) pressure management;

(ii) active leakage control;

(iii) speed and quality of repair;

(iv) pipeline asset.

Water loss management nowadays is a key priority for all cities in many countries. But at the same time management of the water losses wasn't an easy task in all times for all water management organizations. The main reason for that is the complex nature of the water distribution networks and complex water demand during the day.

Let's consider the concepts and principles of the learning process of a neural network. The process of learning ANNs is the process of setting up the network architecture (structures of connections between neurons) and weights of synaptic connections for effective solution of the task. The training of the neural network is carried out on the basis of the training one data sampling according to a certain algorithm. There are three paradigms of ANN learning:

- Learning with a teacher
- Learning without a teacher
- Blended learning

When learning the network with the teacher, the correct answers are known to of each input data example, and the weights are adjusted to minimize a mistake. Among the majority of algorithms, learning with a teacher is the most successful there is an error backpropagation algorithm. The main idea of the algorithm is in that the change in the weight of synapses takes place taking into account the local gradient of the error function. The difference between real and correct responses of the neural network, which are determined at the output layer of the ANN, propagates in the opposite direction - towards the flow of signals. As a result, each neuron could determine the contribution of each of its weights to total network error. The simplest learning rule

corresponds to the method coordinate descent, that is, the change in synaptic weights in proportion to their contribution to common mistake.

Among the shortcomings of the algorithm, an indefinitely long process can be distinguished training, which may arise in cases of:

- Network paralysis: in the process of learning the neural network, the value of the weights can become very high as a result of correction. Majority neurons will function in the region where the compressive derivative function has very little value.

- Local minima: the network may fall into a local minimum, when a deeper minimum is nearby.

There is also an option to retrain the network. The whole set of images, provided for training will be learned by the network, but any other images, even those that are similar may be misclassified. To train ANN to estimate leakage rate in water distribution networks we need to collect a list of complex data sets and all available information about water supply and network characteristics for specific cities. As one of the most important parameters which is required for modeling process is water demand information. Namely, detailed information about actual consumption in the city in real time mode during some period. Complex analysis of similar research showed that information about the flow should be logged over a 24-hour period in at least 15-minutes interval over 24 hours on each of the days. Thus, the sampling period will consist of at least a 15-day interval with 24-hour data for all distribution networks. Also, one of the most important requirements is amount and distribution over the networks logging points which collect data. Uniform distribution is a key to creating, configuring, and training ANN. Logged data should be spited into next categories: (I) the training group (70%) of the data; (II) the validation group (15%) of the data; (III) the test group (15%) of the data. The next step should be the construction of training inputs and targets. Then the neural network should be constructed and trained. After that, following the testing of the network performance phase. Finally, the comparison of the simulated water flow and the actual flow. The less the error the more the forecast accuracy.