

INTELLIGENT EDGE IN COMPUTER ENGINEERING

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Abstract: *Until recently, artificial intelligence tools required significant energy consumption and expensive complex equipment such as remote servers or clouds. Now, with the appearance of Intelligent Edge microcontrollers, such as the MAX7800x family and etc., which contain a special convolution neural network accelerators, computer devices and means for various purposes can solve artificial intelligence tasks, while working for a long time from an autonomous power supply. All this makes artificial intelligence tools available and expands the possibilities for creating new efficient applications that were previously built on powerful computers and were limited in widespread use. The advantages of such devices and means are considered in this article.*

Keywords: *Computer devices, Intelligent Edge microcontrollers, smart sensors.*

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Introduction

Intelligent edge, built into computer means and devices, provides them with the kind of analytical and computational capabilities previously found in remote or cloud data centers [Bradicich, 2024]. The application of Intelligent edge in Internet of Things (IoT) technology, which includes means of data acquisition and primary data processing, means of visualization and data transmission, and also, in many cases, means of managing objects, is especially important. The basic structure of IoT technology is sensor networks, both wired and wireless. A fragment of the traditional sensor network structure is shown in Fig. 1 [Murphy, 2023]. Note that the use of so-called intelligent or smart sensors makes it possible to connect such a sensor directly to the cloud or a remote server.

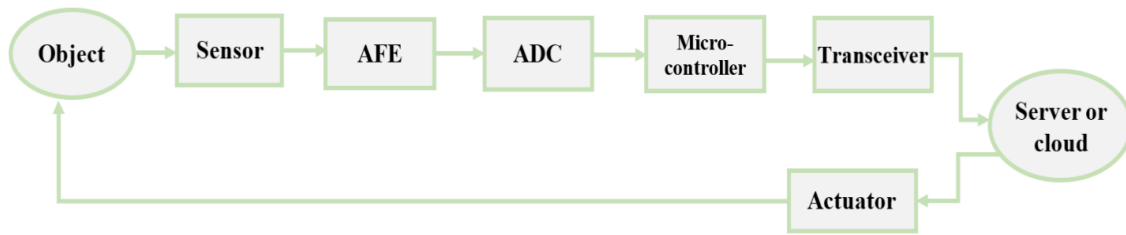


Figure 1. Fragment of a traditional sensor network

This is the advantage of smart sensors and sensor nodes based on them. However, in addition to its advantages, such a structure has some disadvantages. These include the following: a large amount of data needs to be transferred to the cloud; when a control command is generated in the cloud and transmitted to the actuator, significant delays occur; to increase capability, greater network capacity is required; the higher the data transfer rate to the cloud needs the greater energy consumption of the self-powered sensor node. In addition, it is necessary to solve the problem of data protection in the communication channel. The use of Intelligent Edge in autonomous computer devices and sensor networks allows solving these problems. Shifting the computational pressure to the target data will ensure greater response and efficiency in supporting decision making. When using Intelligent Edge a limited amount of data (ideally 2-3%) necessary for storage and archiving can be transferred to the cloud or remote server. The main data can be located in Intelligent Edge, which does not require protection from external interference and external attacks. The actuator control command is generated directly in Intelligent Edge in a minimum period of time and is received by it with virtually no delay. Energy consumption in this case is minimized, which increases the service life of the battery of a smart sensor or computer device without recharging. The functional diagram of such sensor network is shown in Fig. 2. The advantages are especially important if smart sensors are in field operating conditions with limited access for maintenance.

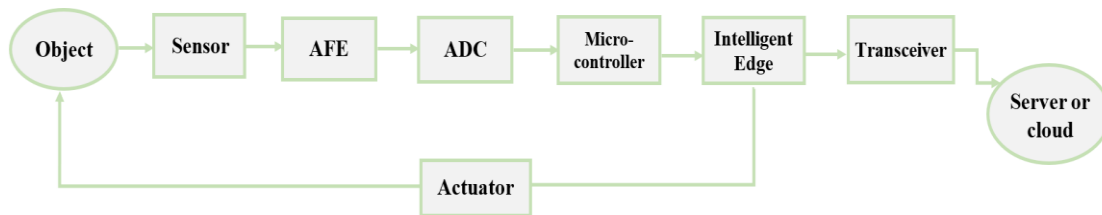


Figure 2. Fragment of a sensor network with Intelligent Edge

Literature review

There are three categories of Intelligent Edge: Intelligent Edge of operational technologies (OT), Intelligent Edge of IoT and Intelligent Edge of IT. Operational technology interfaces are designed to accommodate intelligent and control elements, rather than traditionally limiting communicational and computational capability. Applications of various operating technologies include power plants, oil derricks, etc. IoT is connected to data acquisition sensors and actuator, for example, to control artificial irrigation and fertilizer application in agriculture.

Intelligent Edge on IT technologies is common in the telecommunications and media industries for distributed transmission and data processing [Bradicich, 2024, Murphy, 2023].

It should be noted that the challenges of how best to manage the movement of data from the front end to the remote server involve a number of choices regarding application architecture, communication protocols, storage, processing power, and other considerations. There is no one approach for gateways, devices, and points of presence. The advantages of computer devices and means with built-in Intelligent Edge include the following:

- **increased speed** of data processing - edge computing reduces latency because data does not have to be transmitted via a network to a remote data center or cloud, after which there is additional latency because actuators are managed from the cloud;
- **network independence** and its deployment advantages; edge computing makes it possible to work regardless of network availability, dramatically reduce

data transfer rates, and allows to control which data remains on the edge and which data is sent to the cloud;

- **integrated processing of events** can be transferred to the edge. In this case, task-specific processing models can be rapidly deployed at the edge. Data processing at the edge has the ability to go directly from data to decision making. So-called container technologies, such as Docker and others, are becoming very important because it is possible to get solutions at the edge, not in the cloud. Computing at the edge is inherently distributed computing. This means they have improved resistance and reduce network load, and can be more efficient when processing data at the point of receipt. All this reduces the total cost of the system. Data transfer costs are lower because the amount of data transferred to a remote server or cloud is reduced. Computing at the edge enables digital solutions with greater autonomy, reliability and security;

- **the physical security** of a computer device or mean becomes more important, since the main data is stored at the edge. One common example of the use of edge computing is the transfer of wind power station data to the cloud: wind power station can consist of hundreds of wind turbines that generate huge amounts of data. According to research firm Wikibon, a typical wind power station is equipped with security cameras and other sensors, and the distance between a wind power stations and a cloud data center can reach hundreds of kilometers. By processing data in real-time at the edge and sending aggregated data to cloud centers, one wind farm reduced data traffic by 95% and reduced management and processing costs by 64% over three years [Maguire et al, 2022].

The technology of Intelligent Edge makes it possible to better manage and increase the yield of agricultural crops in conditions of long-term weather changes. Based on Intelligent Edge, closed-loop solutions can be created to monitor the condition of agricultural crops, for example, to quickly respond to irrigation and fertilizer needs of plants in real time. New farming technologies that can sense changes in weather and microclimate and react instantly to them

allow to control technological processes and have a guarantee that crops are properly watered and fertilized regardless of weather conditions. Using Intelligent Edge, for example, based on the MAX78000 microcontroller, the monitoring system not only optimally manages these processes, but also learns and improves its ability to optimize the level of water for artificial irrigation, the amount of applied microelements and the level of soil pH in response to the smallest environmental influences [Maguire et al, 2022].

Proposed solution

In V. M. Glushkov` Institute of Cybernetics of the National Academy of Sciences of Ukraine, computer devices and sensor networks with smart sensors and wireless communication modules have been developed and brought to serial production [Romanov et al, 2023]. These computer devices and means with appropriate sets of sensors can serve as sensory organs of data acquisition systems for various purposes, in particular for digital and precision agriculture, ecological monitoring and environmental protection, medicine, quality control of beverages, food and biological substances, etc. The developed software of these smart sensors already makes it possible to assess in real time the state of various biological objects, for example, plants under the influence of various stress factors or the quality of wine during the production process. Health monitors, which are built on the basis of the proposed systems and wearable smart sensors, already today make it possible to create a reliable support system for chronic patients, increase the speed and safety of the rehabilitation period, monitor medical parameters in the hospital or outside it, and also help the doctor in making a diagnosis.

Computer devices and sensor networks developed at the Institute of Cybernetics receive corresponding dependences in the form of two-dimensional curves at the output. For example, to assess the state of plants in the field, it is the curve of the chlorophyll fluorescence induction, to assess the quality of water or drinks, it is the curve of the concentration of harmful substances in a controlled liquid, in medicine, it is photoplethysmograms, which allow to assess the patient's hemodynamic state. All these dependencies have characteristic

points or areas, by which the state of the controlled object is determined. But in order to interpret the diagnosis based on the results of monitoring and make management decisions, these devices and networks transmit relevant data to a remote server or cloud [Romanov et al, 2023]. With the appearance on the world market of electronic components of microcontrollers and microprocessors with Intelligent Edge, it became possible not only to evaluate in express mode the influence of various factors on the state of the monitoring object in the mentioned computer means, but also, thanks to the embedded Intelligent Edge, to develop appropriate management decisions aimed at real-time compensation of the negative effects of these factors. This was impossible to provide when these operations were placed on a remote server or cloud.

It should be noted that the use of artificial intelligence is beginning to spread rapidly in various fields of human activity. Leading companies such as Intel, AMD, IBM, NXP, Samsung, ADI, TI, Huawei, Fujitsu and others have already manufacture processors and controllers with artificial intelligence. This processors and controllers are used in robotics, artificial vision systems, pattern recognition, unmanned aerial vehicles, and even home personal computers. The tools to support the work of these processors and controllers are neural networks of various classes. In [Dreessen, 2023, Part 1] it is shown how the execution of a classical linear program in an ordinary microprocessor differs from the operation of a convolution neural network and what advantages this network has. In [Dreessen, 2023, Part 2] it is shown how a convolution neural network can be trained to solve specific problems. Special datasets are used to train neural networks. The CIFAR-10 is one such dataset, which is commonly used for training CIFAR-type neural networks for pattern recognition. It consists of different layers of neurons [Dreessen, 2023, Part 2]. Image data (or a two-dimensional dependence) with 32×32 pixels in size are loaded to the neural network through network layers. The first step of the network is to identify and explore the unique features of the objects to be identified. Filter matrices are used for this. After the CIFAR neural network is modeled, the filter matrices are not yet defined, and the network is unable to detect patterns and objects at this stage. Therefore, it is first necessary to determine all the parameters and elements of the matrices in order to maximize the accuracy with which the objects are identified and to minimize the loss function. This process is called

neural network training. For common applications, neural networks are trained once during development and testing. After that, they are ready for use and do not need to configure parameters anymore. If the system classifies familiar objects (in our case, corresponding two-dimensional dependencies with characteristic points or areas), no additional training is required. Training is only necessary when the system needs to classify completely new objects (characteristic points or areas on the resulting curve for new objects). The training process is organized according to the principle of reverse distribution; the neural network is sequentially provided with numerical images, and each time a target value (for example, a characteristic point on a curve) to be determined is simultaneously transmitted. After completing this process, the network can also detect objects in images that it did not see during training.

During the training process, characteristic points or areas of the process, marked by selected classes of objects, such as the plant state in drought, or an exceeded level of harmful substances in a liquid, etc., are transmitted to the neural network. For training given in [Dreessen, 2023, Part 2], the existing CIFAR-10 data set was used. In practice, artificial intelligence can be applied to various similar objects. If a new program needs to be developed to determine, for example, the quality of wine during the production process, then the network must also be trained using the training data to detect normal concentrations of the relevant trace elements. After the dataset is compiled, it is split into training and test data. Test data is used to verify the performance of the trained network.

Conclusion

Thus, if previously artificial intelligence tools required expensive complex equipment such as remote servers or the cloud, today, with the Intelligent Edge based for example on microcontrollers MAX7800x, computer devices or sensor networks can solve artificial intelligence tasks almost without exchanging data with a remote server or cloud.

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