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Machine learning method - decision trees

I'm going to tell you about one of the machine learning methods which are called decision trees method. The last decade has seen considerable growth in interest in Artificial Intelligence and Machine Learning. First, let's decipher at what is machine learning. Machine Learning (ML) is a branch of the artificial intelligence theory, the subject of which is the search for solving tasks methods by learning in the process of solving similar tasks.

The decision trees method is one of the most popular methods for solving classification and forecasting tasks. A decision tree is a set of rules ("If – then") that can be combined into some hierarchy.

The structure of the tree consists of "leaves" and "branches":

- The edges ("branches") of the solution tree contain the attributes which the target function depends on;
- The "leaves" contain the values of the target function;
- The other nodes contain the attributes by which the cases differ.

Classifying a new case is going down the tree to the desired leaf and determining the appropriate value. To understand better what a decision tree represents, we can consider a funny example. Let's say we need to answer the question: "Go to a lecture?".

To solve a task, that is, to make a decision whether to go to a lecture, one should classify the current situation as one of the well-known classes - in this case, "Go" or "Don't go". This requires answering a number of questions that are located in the nodes of this tree, starting from its root (Figure 1).

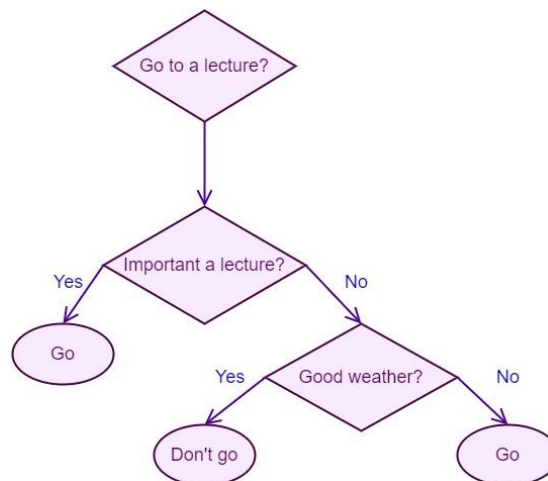


Figure 1: Example of a decision tree.

Well, it becomes clear that the top question is the root node, the answer options "Yes" or "No" are branches and our classes "Go" or "Don't go" these are leaves.

Now let's consider at a more complex real-world example. So, we will have a look what the decision tree looks like using the famous Iris dataset. By the way, this dataset is almost 85 years old. It has already become classical and is often used in the literature to illustrate the work of various statistical algorithms.

If we talk more detail about this set, it is worth noting that the Iris Fisher dataset, or simply the iris flower dataset, is a multidimensional dataset that biologist Ronald Fisher introduced in 1936 his article as an example of linear discriminate analysis. Just for the record the dataset consists of 150

samples whose characteristics are the length and width of sepals and petals in centimeters. With the help of these samples, you can determine to which class a particular Iris belongs to. Dataset includes Iris species such as Iris setosa, Iris virginica and Iris versicolor (Figure2). Using these four characteristics, Fischer was able to develop a linear discriminate model to be able to classify and distinguish species from each other (Figure3).

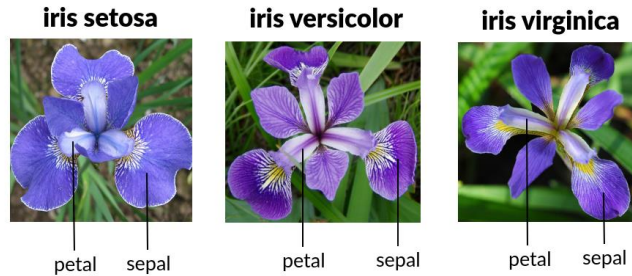


Figure2: Types of iris.

sepal length (cm)	sepal width (cm)	petal length (cm)	petal width (cm)	target
5.1	3.5	1.4	0.2	Iris-setosa
4.9	3.0	1.4	0.2	Iris-setosa
4.7	3.2	1.3	0.2	Iris-setosa
4.6	3.1	1.5	0.2	Iris-setosa
5.0	3.6	1.4	0.2	Iris-setosa
7.0	3.2	4.7	1.4	Iris-versicolor
6.4	3.2	4.5	1.5	Iris-versicolor
6.9	3.1	4.9	1.5	Iris-versicolor
5.5	2.3	4.0	1.3	Iris-versicolor
6.5	2.8	4.6	1.5	Iris-versicolor
6.3	3.3	6.0	2.5	Iris-virginica
5.8	2.7	5.1	1.9	Iris-virginica
7.1	3.0	5.9	2.1	Iris-virginica
6.3	2.9	5.6	1.8	Iris-virginica
6.5	3.0	5.8	2.2	Iris-virginica

Figure3: Few part of the Iris dataset.

Well, based on the Iris dataset, a decision tree is built, the purpose of which is to divide the dataset, where there is only one type of Iris, in accordance with the specified features: here, the width of the petal (Figure4).

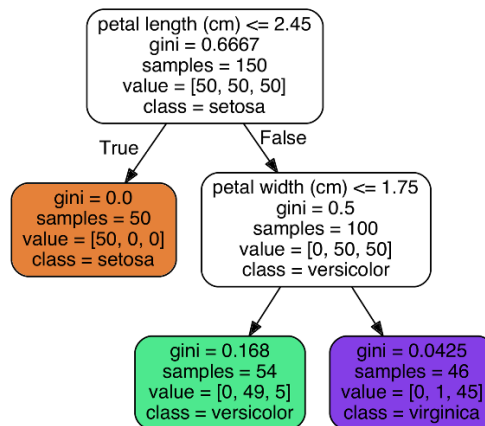


Figure4: Example of a decision tree.

In conclusion, it is necessary to underline that in data mining, a decision tree describes data and as we said before decision trees are the most popular machine learning algorithms because they are intelligible and simple.

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The MathMax Application as a Way of Computerizing Production Processes

“The need to implement automation systems has long been taken into account”. In the age of information technology, many organizations automate some of their production processes, transferring them to software. As for education, “a lot of digital products available today feature elements of adaptive learning. The level and methods of adaptation may differ, being largely contingent on the context of software application and the specific aspects of a particular learning process” [1, 2, 3].

After reviewing existing mathematical apps [4, 5], such disadvantages as an overloaded interface and dependence on the Internet connection were identified. We have created a stand-alone program that has an intuitive interface, even for an inexperienced user, which can greatly simplify the work with the application.

MathMax can perform complex mathematical calculations visualizing them in the form of a graph. It enables a user to select a mathematical function, calculate and display the values of each variable, and draw the exact graph of the selected function based on the received values.

This program is developed with the use of language C# in the Microsoft Visual Studio 2019 Community Edition environment. It is implemented as a Windows Forms application for the runtime environment (.NET Framework).

The MathMax application can be employed in educational institutions to facilitate visualizing mathematical functions in the form of graphs and improve the assimilation of learning material. It can also be used in enterprises for calculating statistical indicators and analyzing economic and physical processes.

Литература

1. Krechetov I., Romanenko V. Implementing the Adaptive Learning Techniques // Вопросы образования. 2020. №2 [Электронный ресурс] // Режим доступа: <https://cyberleninka.ru/article/n/implementing-the-adaptive-learning-techniques-1>
2. Клокотов И. Ю. Актуальность внедрения автоматизации технологических процессов и производств на современном этапе развития нашего общества // Международный журнал прикладных наук и технологий «Integral». 2020. №1 [Электронный ресурс] // Режим доступа: <https://cyberleninka.ru/article/n/aktualnost-vnedreniya-avtomatizatsii-tehnologicheskikh-protsessov-i-proizvodstv-na-sovremennom-etape-razvitiya-nashego-obschestva>
3. Клокотов И. Ю. Автоматизация технологических процессов // Международный журнал прикладных наук и технологий «Integral». 2019. №4-1 [Электронный ресурс] // Режим доступа: <https://cyberleninka.ru/article/n/avtomatizatsiya-tehnologicheskikh-protsessov>
4. <http://www.yotx.ru/>
5. <https://www.mathway.com/ru/graph>

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Fractals

The term fractal has many different definitions. Fractal is a set which has self-similar property. Fractal is an object which almost or exactly looks like itself.

First fractal geometry ideas appeared in nineteenth century. Cantor has made a set of unrelated points from a line by using a simple recursive procedure. He takes a line and copies it in under first line and divides it in three similar parts and gets rid of the middle one.

Fractals are often appeared in nature. Tree can be related to examples. There are smaller branches from a small branch as well as from the trunk tree and smaller and smaller. In other words, tree looks like itself in zooming. Hence, tree has a fractal structure.

The Sierpinski triangle.

It is named after the Polish mathematician Waclaw Sierpinski. There are two algorithms to build this triangle, namely iterative method and random method. Iterative method: the side middles of equilateral triangle are connected by lines. We have four new triangles. Remove the middle triangle from the source triangle. And repeat this endlessly. We have got the fractal, namely The Sierpinski triangle.

The Koch snowflake.

It is named after the Swedish mathematician Helge von Koch. The Koch snowflake can be constructed by starting with an equilateral triangle, then recursive altering each line segment as follows:

1. Divide the line into three segments of equal length;
2. Draw an equilateral triangle that has middle segment from step 1 as its base and points outward;
3. Remove the line segment that is the base of the triangle from step 2.

And while repeating this endlessly, we get the fractal, namely The Koch snowflake.

The Pythagoras tree

It is invented by the Dutch mathematics teacher Albert E. Bosman in 1942. It is named after the ancient Greek mathematician Pythagoras because each triple of touching squares encloses a right triangle, in a configuration traditionally used to depict the Pythagorean theorem. It is easy to construct this fractal. The construction begins with a square. Two squares are constructed upon this square, each scaled down by a linear factor $\sqrt{2}/2$. If we keep to do it endlessly then we get the Pythagoras tree.

Fractal has many practical uses. For examples, fractals help in producing realistic computer graphics, in computer file compression systems, in architecture of the networks.

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Smart home technology

Smart home technologies evolved many years ago and for a long time they have been considered something fantastic or very expensive pleasure. Thanks to the advent of modern technologies, the development of artificial intelligence and home electronics, creating smart homes has become easy, comfortable and practically without impressive costs.

A modern automation system can be fully adapted to suit your lifestyle.

Every professional or you yourself are able to customize the system according to your needs.

Smart home technology allows you to control your smart systems with your mobile device or personal computer, even at a distance from home.

For example, turning on the air conditioner on the way to the house.

The electronic door lock and LED light will automatically work when you return home.

According to Bill Gates, in the future, homes without smart home systems will be as unfashionable as homes without Internet access today.

Let's find out more about smart home!

Let's model a smart home with our own hands using the Arduino software.

Smart home capabilities that will be presented to your attention:

1. LED blinking - imitation of switching on and off the LED;
2. Breathing light - PWM technology, to simulate the effect of breathing;
3. LED control by means of a button module - simulation of switching on and off a button;
4. Passive buzzer - sound indication simulation;
5. 1-channel relay module - simulation of an automatic switch;
6. Photocell sensor - imitation of the illumination level;
7. Angle adjustment - imitation in the creation of automatic rotation;
8. Servo motor - imitation of turning doors and windows;
9. Fan module - simulation of control of the direction of rotation and speed of the motor;
10. Steam sensor - imitation of humidity level;
11. PIP motion sensor - imitation of human or animal detection;
12. Analog sensor - imitation of a gas sensor;
13. Soil moisture sensor - imitation of a sensor for tracking the water level in the soil.

The smart home concept assumes that everyone can enjoy life.

Михеева С.А

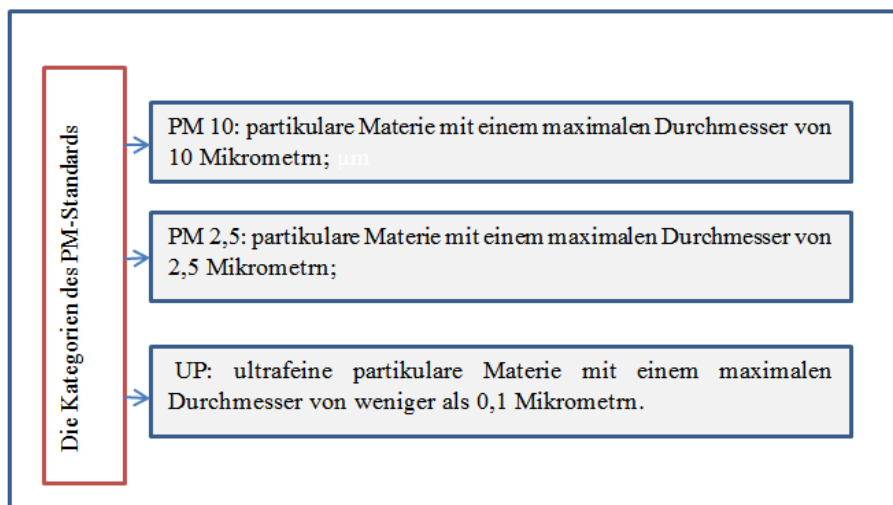
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Luftverunreinigung in Europa

Jedes Jahr beobachten Wissenschaftler die Ergebnisse von Forschungen des aktuellen Zustands der Luftverunreinigung in Europa. Laut Experten sterben in den Ländern Europas jährlich ungefähr 430000 die Menschen vorzeitig wegen der Luftverschmutzung.

Die Luftverunreinigung ist das Zusammenspiel vieler Faktoren. Diese führen zu einer gefährlichen Entwicklung auf der Welt. Einer der gefährlichsten Luftschadstoffe ist feine Staub. Er ist ein Sammelbegriff für ein komplexes Gemisch, welches aus festen und flüssigen Partikeln besteht. Außerdem der feine Staub ist ein Teil des schwimmenden Staubes. Feinstaub schadet nicht immer der Gesundheit, beispielsweise, Meerfeinstaub befreit die Atemwege und erleichtert das Atmen. Die Betriebe bearbeiten sie zu Bädern und anderen Erholungsmitteln.

Der negative feine Staub aber, der sich aus Abgasen und anderen Partikel zusammensetzt, ist gefährlich. Im Jahr 1987 eine US-amerikanische Umweltschutzbehörde eingeführt der «nationalen Luftqualitätsstandard für partikulare Materie». Der sogenannte PM-Standard hat mehrere Kategorien. Die Kategorien des PM-Standards sind (Abb.1) darstellt.



Die Abbildung 1. Die Kategorien des PM-Standards [1].

Der Begriff feine Staub unterscheidet sich in primär emittierte und sekundär gebildete Partikel. Primärer Staub entsteht an einer Quelle wie es etwa bei Verbrennungen der Fall ist. Sekundärer Staub wird so bezeichnet, weil er sich aufgrund von gasförmigen Vorläufersubstanzen bildet.

Feine Staub und letztendlich die Luftverschmutzung entstehen primär durch Emissionen aus Verbrennungskraftwerken, Wohnungs-Hausheizungen, aus Verbrennungsmotoren von Kraftfahrzeugen sowie durch die Abgase von Industrieanlagen. Bei der Verbrennung fossiler Brennstoffe entstehen neben den ungiftigen Verbrennungsprodukten Kohlendioxid und feine Staub, die gesundheitsschädlichen Stoffe Schwefeldioxid, Stickoxide, Kohlenmonoxid und Kohlenwasserstoffe. Diese Stoffe gefährden die Gesundheit und das Wohlbefinden der Menschen (Kopfschmerzen, Ermüdung, Übelkeit, Entzünden der Atemwege, Krebserkrankungen) und schädigen die Pflanzen, insbesondere die Bäume (Waldsterben). Sie verursachen auch große volkswirtschaftliche Schäden durch die Korrosion von Maschinen und Kraftfahrzeugen sowie die Zerstörung von Bauwerken und Baudenkmalern.

Die Kraftfahrzeuge sind eine der größten Feinstaubquellen in der Welt. Sie produzieren Abgase, die werden hauptsächlich von Verbrennungsmotoren erzeugt. Dabei entstehen Gase wie Kohlendioxid (CO₂) und Stickstoffdioxid (NO₂). Das sind starke Atemgifte. Die Kohlendioxid-Emissionen sind nicht direkt für die Luftverunreinigung verantwortlich. Vielmehr verändert es das Klima. Das Klima erwärmt sich und Meere versauern. Das Ergebnis ist ein schnelles Wachstum der Pflanzenproduktion, die andere Lebewesen in den Gewässern verdrängen. Es wird auch Kulturgüter der Menschen betreffen. Vor allem der saure Regen, der durch die Kohlendioxid-Emissionen entsteht, greift Gestein und Eisen an. Denkmäler müssen regelmäßig restauriert werden.

Nach dem Luftverschmutzungsgrad sind viele Maßnahmen von den Regierungen der Ländern und den ökologischen Organisationen erarbeitet. Die EU-Kommission entwickelte und koordiniert Grenzwerte. Seit dem 1. Januar 2005 gelten diese Grenzen. Wenn sich der Staat oder seine Politik nicht an seinen vorgegeben Wert hält, kann die EU-Kommission hohe Geldstrafen erlassen. Ab Januar 2020 darf der PM 2,5-Wert nicht über 20 µg/m³ im Jahresmittel steigen, einen zulässigen Jahresmittelwert für PM 10 40 µg / m³ betragen darf.

Maßnahmen zur Verminderung der Luftverunreinigung sollen enthalten: die Reinigung der Großfeuerungsanlagen-Abgase durch Entschwefeln, Entsticken und Staubabscheidung; die Verwendung von Bleifreiem Benzin und die Entgiftung der Benzinmotorenabgase durch Einbau eines Katalysators sowie die Entruzung der Dieselmotorabgase.

Литература

1 Umwelt-Bußgeldkatalog 2021: [Электронный ресурс]. URL: <https://www.bussgeldkatalog.org/ueber-uns/>. (Дата обращения: 07.03.2021).

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Semiconductor devices. Their types and uses

The rapid development and expansion of the fields of electronic devices application is due to the improvement of the element base, which is based on semiconductor devices. Therefore, it is necessary to know the device and the principle of operation of the main types of semiconductor devices and to understand the processes of electronic devices functioning.

Silicon (Si), silicon carbide (SiC), gallium and indium compounds are the main materials for the production of semiconductor devices.

The electrical conductivity of semiconductors depends on the presence of impurities and external energy influences. The current flow is caused by two types of charge carriers—electrons and holes. There are pure and semiconductors with some impurities depending on the chemical composition.

Solid semiconductors with a crystalline structure are used for the manufacture of electronic devices.

Semiconductor devices are devices which operation is based on the use of the properties of semiconductor materials.

Classification of semiconductor devices.

1. Semiconductor resistors are made on the basis of non-transitive semiconductors:

- linear resistor;
- varistor;
- posistor;
- thermistor;
- photoresistor;
- strain gauge;

The principle of operation of most semiconductor devices is based on the properties of the electron-hole p-n junction.

2. A semiconductor diode is a semiconductor device that transmits current in only one direction, from the anode to the cathode.

Depending on the purpose, semiconductor diodes are divided into

- rectifier diodes;
- universal diodes;
- pulse diodes;
- zener diodes and stablistors;
- tunnel and reversed diodes;
- LEDs and photodiodes;

3. A transistor is a semiconductor device designed to amplify, generate, and convert electrical signals, as well as to switch electrical circuits.

The ability to be in the open and closed states under the influence of the control signal is the main property of the transistor.

The transistor allows you to adjust the current in the circuit from zero to the maximum value.

Classification of transistors:

- according to the principle of operation: field-effect (unipolar), bipolar, combined;
- by the value of the power dissipated: small, medium and large;
- by the value of the limit frequency: low-frequency medium-frequency high-frequency and ultra-high-frequency;
- according to the value of the operating voltage: low-voltage and high-voltage;

- by functional purpose: universal, amplifying, key, etc.;
- according to the design: unassembled, in the case design, with rigid and flexible terminals.

Transistors can operate in three modes depending on the functions performed:

- Active mode. It is used to amplify electrical signals in analog devices;
- Saturation mode. A transistor is equivalent to a closed relay contact in this mode, since its resistance tends to zero;
- Cut-off mode. The transistor is closed and has a high resistance, that is, it is equivalent to an open relay contact.

A bipolar transistor is a semiconductor device with two p-n junctions and three pins. It provides power amplification of electrical signals.

The plate of a semiconductor, in which three sections are formed with an alternating type of conductivity - electronic and hole, is the basis of a transistor. There are two types of transistor structure depending on the interleaving of layers: n-p-n and p-n-p.

A field-effect transistor is a semiconductor device that regulates the current in a circuit by changing the cross-section of the conducting channel.

There are field-effect transistors with a gate in the form of a p-n junction and with an isolated gate.

In field-effect transistors with an isolated gate, an insulating layer of a dielectric is located between the semiconductor channel and the metal gate.

4. A thyristor is a semiconductor device that operates in two stable states-low conductivity and high conductivity. Structurally, a thyristor has three or more p-n junctions and three outputs: an anode, a cathode, and a control electrode.

Thyristors are used as contactless switches and controlled rectifiers in automation devices and electric current converters. In AC and pulse current circuits, you can change the time of the open state of the thyristor, and therefore the time of current flow through the load. This allows you to adjust the power allocated in the load.

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Algorithmic minimization of requirements for computing resources of technical systems of intelligent information processing in the field of 3d modeling

In the 3d printing industry, urban planning and many other areas, technologies for scanning space using photogrammetry methods are used. This method involves collecting photos and then calculating the intersecting details on them.

At the moment, a large amount of computing resources is spent on 3d scanning of the surrounding world. Moreover, the resulting models contain a large amount of redundant information, such as a huge number of vertices.

It is proposed to apply approximation algorithms and the technique of computing ordinary problems on the GPU for this problem. The result of the optimized algorithm should provide a reduction in the number of processed points of the model, and, consequently, a reduction in the computational complexity of working with them.

In the process of studying the effectiveness of algorithms for processing three-dimensional data, 4 code variants were implemented:

1. Sequential traversal of all data
2. Parallel data traversal using gpgpu
3. Sequential data processing using approximation
4. Parallel data processing using approximation and using gpgpu

For performance testing, sequential implementations of the algorithms were performed on a general-purpose processor. Parallel versions of the algorithms use a GPU.

The results of running all implementations are shown in Figures 1 and 2. As a general-purpose processor, the AMD Ryzen 3 2200G is used, as a graphics processor, the AMD Radeon Vega 8 video core is built into the same processor. It can be seen that on small (less than 4 thousand triangles) three-dimensional models, the processor has an advantage in execution speed. At the same time, with an increase in the number of processed geometries, parallel implementations of algorithms have an increasing gain in execution speed.

Features of the architecture of GPUs, such as a lot of small identical execution units, predictable work with memory, efficient implementation of multithreading, allows parallel implementations of algorithms to work faster with a large amount of similar data. However, at low volumes, the effectiveness of this approach makes no sense, since it takes additional time to transfer data from the general-purpose processor to the video core. In the 3d printing industry, urban planning and many other areas, technologies for scanning space using photogrammetry methods are used. Photogrammetry uses methods and techniques of various disciplines, mainly from optics and geometry.

In the simplest case, the spatial coordinates of the points of the object are determined by measurements made from two or more photos taken from different positions. At the same time, common points are found on each image. The line of sight is then drawn from the camera's location to a point on the object. The intersection of these rays determines the location of the point in space. More complex algorithms can use other information about an object that is known in advance: for example, the symmetry of its constituent elements, which in certain cases allows us to reconstruct the spatial coordinates of points from only one photographic image.

The algorithms used in photogrammetry are designed to minimize the sum of the squares of the error set, which is usually solved using the Levenberg-Marquardt algorithm, which is based on solving nonlinear equations by the least square's method.

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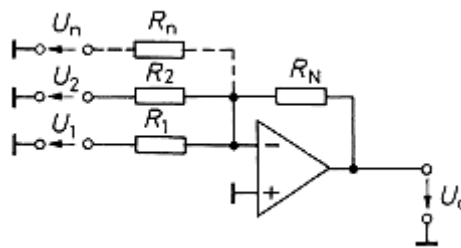
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Linear and nonlinear analog computing circuits

Thanks to the advent of microcomputers and signal processors, it is now possible to perform mathematical operations with almost any accuracy. However, the processed values are often represented as continuous signals, for example, in the form of an analog electrical voltage. In this case, the digital computer additionally requires analog-to-digital and digital-to-analog converters. These devices are advantageous to use only when the requirements for the accuracy of calculations are so high that they cannot be provided with analog computing circuits. Existing analog calculators allow you to get an accuracy of no more than 0.1%.

Next, we will consider analog computing circuits on operational amplifiers that perform addition and subtraction of two or more signals.

1. Adder circuit



Drawing 1 - Inverting adder circuit

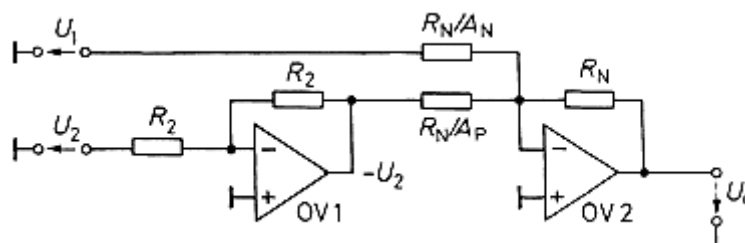
An operational amplifier with inverted input signal is used to sum multiple voltages. Input voltages ($U_1, U_2 \dots U_n$) they are fed through series-connected resistors to the inverting input when the non-inverting input is grounded. Output voltage U_a determined by the formula:

$$-U_a = \frac{R_N}{R_1}U_1 + \frac{R_N}{R_2}U_2 + \dots + \frac{R_N}{R_n}U_n$$

2. Subtraction circuit

There are several schemes for implementing the subtraction of one signal from another:

2.1 Using the adder circuit



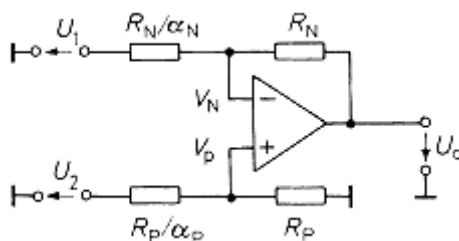
Drawing 2 - Subtraction circuit using the adder circuit

Subtraction can be reduced to addition with inverted subtractable voltages. The op amp OV1 inverts the input voltage U_2 . Output voltage will be determined by the formula:

$$U_a = A_p U_2 - A_n U_1,$$

where A_p, A_N —gain factors.

2.2 The subtraction circuit on the operational amplifier

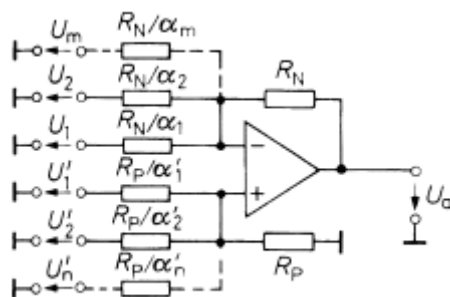


Drawing 3 - The subtraction circuit on the operational amplifier

In this circuit, the principle of operation is the same as in the previous one. Output voltage:

$$U_a = \alpha(U_2 - U_1),$$

where α – gain factor.



Drawing 4 - Subtraction circuit with any number of inputs

This circuit allows you to subtract any number of input voltages. Output voltage:

$$U_a = \sum_{i=1}^n \alpha'_i U'_i - \sum_{i=1}^m \alpha_i U_i.$$

In the input circuits of the considered circuits, there are internal resistances of the signal sources. So that they do not lead to calculation errors, their output resistances must be sufficiently low-resistance. If the signal sources are built on operational amplifiers with negative feedback, this condition is well met in most cases. With other signal sources, it is most often necessary to include a total resistance converter in the form of an electrometric amplifier at the inputs. The resulting circuit is called an electrometric subtractor (instrumental amplifier) and is used primarily in measuring technology.

Литература

1. Полупроводниковая схемотехника. 12е изд. Том II: Пер. с нем. – М.: ДМК Пресс, 2007. – 942 с.: ил.