Exploring the possibilities of using machine vision in the construction industry

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Abstract. In many areas of the economy, including the construction industry, new IT technologies are being successfully introduced - Cloud computing, Big Data, Internet of Things etc. A significant place among these technologies is taken by the direction of "Machine Vision". This technology allows to bring to a qualitatively different level a number of important applications in the construction industry and therefore deserves the close attention of specialists. For example, with the help of machine vision it is possible to consider and analyze the smallest defects invisible to the human eye (for example, when controlling the quality of an important element of construction structures - welds). The result is not affected by fatigue or inattention of the staff, you can work 24 hours, there are other advantages discussed in the article. The best effect is achieved with the complex application of new IT technologies. The most promising is the use of machine vision in combination with IoT and Big Data technologies. The paper explores the possibility of using machine vision in the construction industry as a stand-alone solution and in combination with other new IT technologies. The possibility of using unmanned aerial vehicles (drones) equipped with a machine vision system is being considered - for monitoring construction sites and surrounding areas.

1. Introduction
In IT technologies there are two similar concepts: machine vision and computer vision [1,2]. However, there is a certain difference in the interpretation of these concepts. Machine vision is the use of computer vision for production purposes. While computer vision is a common set of methods that allow computers to see. In the context of the issues under consideration, we will be interested in the engineering direction of "machine vision" and related topics: digital devices, computer networks, hardware and software tools designed for technical quality control of products and work done. There are a number of applications in the construction industry where the use of machine vision seems very promising. These areas include: smart house, smart city, quality control of welds, use of unmanned aerial vehicles (drones) to control construction etc., these and other areas will be considered in the article.

2. Materials and Methods
In the article, the material is located in the next sequence. First, the main components of machine vision are considered, and the features that should be taken into account when using this technology in the construction industry. Then we look at specific machine vision applications in the construction industry.
3. Components of the machine vision system.
The machine vision system should include one or more cameras. Cameras can be black and white and color, digital and analog, have different resolution parameters. Until recently, machine vision systems used mainly "black and white" cameras, now color cameras are increasingly used. Another trend in this area: previously cameras used cameras with separate invader frames. There is now a trend towards digital cameras with a built-in frame invader, which reduces costs and simplifies the system. (The Frame Invader is a device that converts output from a camera into a digital format that stores a digital image in one of the memory devices - so that it can be processed using machine vision software).

In the creation of machine vision systems, so-called "smart cameras" are increasingly used, including a personnel invader, a specialized processor, etc. Integrated solution is often cheaper and more convenient than using an individual component. The downside of this approach is that the hardware and software parts of the computer are much more dynamic than the rest of the system. Therefore, in the variant, when individual components are used, only the computer is enough to be replaced for modernization.

The problem of choosing the type of camera is quite complex, because in addition to technical and economic issues, it is necessary to take into account the difficult operating conditions in the construction environment, the problem of safety and other points.

The obligatory component of the machine vision system is a computer with quite powerful computing resources, constructively the computer can be executed in a variety of ways, in particular can be built-in.

The so-called digital signal processors dsp (digital signal processor) - a specialized microprocessor designed to process digitized signals (usually in real time) are very popular. Dsp has a number of features that reflect the desire of developers to speed up the implementation of typical digital signal processing tasks, such as digital filtering, Fourier conversion, signal search, etc.

As far as software is concerned, specific applications are used to process images and detect properties in addition to conventional software. These tools implement the following imaging techniques:
- Calculating the number of light or dark pixels
- Converting a half-ton image into black and white (binary)
- Image segmentation (dividing a digital image into multiple segments to make it easier to analyze is implemented by tagging each pixel of an image, pixels with the same labels have common visual characteristics.)
- Methods for detecting local features: methods of detecting angles; point detection methods; spot detection methods of finding edges.
- Pattern recognition
- Barcode reading, automatic character recognition
- Measuring the size of an object
- Culling the part according to the specified criteria. If the part is defective, the software sends a signal to the mechanical device to reject the part; there are other options, such as the system can stop the production line, alert the employee and report what led to the failure.

Adaptation of the machine vision system for the construction industry is necessary in the implementation of "detection techniques," "size measurement" and "cull."

Thus, when developing detection methods to control the quality of welds, it is necessary to ensure the identification of weld cracks, undercuts, pores, fistulas, burnages, as well as to assess the location of seam scales on its surface.

When implementing a "size measurement" item, you need to take into account the scale of the task and the required accuracy. Let's explain what we're saying on two specific examples. First, let's give an example - the use of machine vision in an unmanned aerial vehicle (drone) for observation and analysis of the construction site. The second example is the use of this technology to verify the size of
edges and seams of welded compounds correspond to regulatory documents. Obviously, the approaches to the solution for both cases are quite different.

As for the cull, this refers to the direction associated with building materials. For example, the use of machine vision allows to ensure high accuracy of sizes and no chipping on the corners and edges of building bricks.

It is worth noting the use of one of the latest IT technology in image processing - deep learning. The results of this technology are impressive due to the advancement in the field of artificial neural networks. The advantage of deep learning technology compared to traditional solutions used in machine vision systems is that it can reduce the time it takes to develop machine vision programs.

The complex "Machine Vision" usually includes specialized light sources (LEDs, fluorescent and halogen lamps, etc.). LEDs, fluorescent and halogen lamps are characterized by a large light-giving, long life. LEDs have a number of additional advantages that are important for machine vision systems: the ability to vary the frequency of the spectrum and the angle of radiation. The size and location of led panels at a particular construction site are carefully selected - to highlight the necessary and if possible hide unnecessary or interfering moments (e.g. shadows).

Another element that is included in the machine vision system is the synchronization sensor. The "classic" version is used to control details on the conveyor belt: the sensor detects when a detail that moves on a conveyor belt is in a position to be inspected. Then the sensor launches the camera and generates momentum for the lighting system to make a clear image. The most obvious use of such a sensor is the control of building materials (brick, finishing tiles, etc.). For example, if you need a careful cull of a large number of finishing tiles, bricks, etc., you can use a system built on the basis of moving tape (transporter, conveyor) and machine vision system.

So we've been researching the main components of the machine vision system in the context of using this technology in the construction industry.

Let's consider now specific applications, where, in our opinion, it is advisable to use this IT technology.

4. Smart home and smart city
This is the most obvious area of use of Machine Vision technology. It is clear that motion, movement sensors, etc. in the Smart House can be replaced by a more powerful and intelligent system "Machine Vision". Then you can get effects that are unattainable with traditional sensors. Here is a specific example. In the office of the construction company, under electronic locks stored various documents: technical documentation, contracts, etc. With the help of machine vision can automatically leave closed documents, which are not allowed access to the staff present in the office. Options for the use of machine vision in a "smart home" can be offered a lot, but their implementation should take into account the economic component, first of all the cost of implementation and maintenance.

In our opinion, the use of machine vision in "Smart City" is more promising [3]. Here you can use well-designed algorithms of intelligent video analysis and recognition, automatically record and signal the occurrence of emergencies. Thanks to the special storyboard function, you can almost instantly find and analyze the most successful frame from the video recorded by the system. Such a system is effective for monitoring and analyzing the traffic situation in the city (work of traffic lights, traffic jams, traffic violations, drainage, lighting, etc.). As a result, this will help to make the right operational decisions in a particular situation, and mayors will be able to make more informed strategic decisions. Machine vision can be used effectively in other problems of the city. The important point is that with the thoughtful use of machine vision, in the scale of the city is justified by economic costs.

5. Control of the quality of welding structures
The basis of many construction structures are welded structures: beams, farms, columns, masts, frames.

The quality of welding structures is regulated by regulations. For example, the size of the edges and seams of welds should strictly correspond to the norm. Visual analysis of the welding compound
reveals welding cracks, undercuts, pores, fistulas, etc. Most of these defects are unacceptable and need to be corrected. Visually - measuring non-destructive quality control of welds in construction structures was carried out before, but the introduction of machine vision systems brings this work to a qualitatively higher level. The following reasons contribute to this:

- impressive progress made in each of the component of machine vision: cameras, processors, light sources, software, etc;
- system use of all components; First of all, we are talking about intelligent methods of data processing, in particular Big Data technology [4-10]. This technology allows you to quickly process a huge number of different types of data. For example, Big Data may take into account the information contained in project documentation, regulatory documents, etc. For a specific Big Data implementation, you can use cloud-based solutions (allow you to significantly reduce costs) [11], edge computing (allowing you to solve the information security problem to a large extent) [12].

6. Monitoring the state of the building's cracks

Another important area of use of machine vision is monitoring the condition of the cracks of the building. Cracks in construction structures can indicate a serious safety risk. Indeed, every crack in the structure has its own cause - marriage in construction, deformation of foundations during operation, etc. The cracks are usually monitored by «lighthouses». In some cases it is advisable to use machine vision. Here it is necessary to give a number of explanations.

When deciding on the use of this technology, you should be sure that there are clear advantages over the traditional «lighthouse-based» approach. It is necessary to take into account not only technical and economic characteristics, but also security considerations (information security, equipment safety).

The use of machine vision in this direction is particularly attractive when combined with other new IT technologies, especially with IIoT technology - the Industrial Internet of Things. [13,14]. IIoT technology differs from IoT (Internet of Things) technology in that it involves home use: light, heating, surveillance cameras, etc. Both technologies are based on the use of radio frequency communication tools to communicate physical objects with each other and with the external environment. Often the term "Internet of Things” and the acronym IoT are used in both directions (IoT and IIoT).

At first glance, the use of IoT is not new, as electronic measuring sensors in lighthouses were previously used, which can transmit information remotely. However, the technology of the Internet of Things offered effective methods and tools, which allow to bring the solution to a qualitatively different level. Thus, in the technology IoT in the modern key solved the whole range of problems related to identification, the transition to the Internet protocol IPv6 allows to remove the problem of address space when identifying sensors in the Internet space, which faced the previous version of IPv4. Issues relating to the means of measuring and transmitting data have been resolved. In particular, it is proposed to use for wireless communication standard IEEE 802.15.4., and protocols based on it, ZigBee, MiWi, etc., which are characterized by low energy consumption, reliable work in low-speed conditions, adaptability, ability to organize themselves.

The combination of machine vision and IoT technology seems to be very promising in controlling the cracks of the building, as machine vision allows to supplement the general information base with information that is difficult or impossible to obtain by other methods. Thus, to control the cracks of high-rise buildings and structures, can be used machine vision system installed on a drone (see below).

7. Culling of building materials

Machine vision can be used if you need a careful cull of a large amount of finishing tiles, bricks, etc. The automated system is built on the basis of a moving tape (transporter, conveyor) and includes as a mandatory element a synchronization sensor.

The synchronization sensor detects when an object moving on a conveyor belt is in the right position. The sensor then launches the camera to take a picture of the object as it passes under the
camera and signals to the light source to make a clear image. After initial processing, the program measures the size of the object, identifies defects and deviations of characteristics. Then the system misses or culls the object in accordance with the established criteria. If the object is culled, the program sends a signal to the mechanical device. If an object is selected, the program sends a signal to the mechanical device. In this case, the system may work differently: remove the object; stop the pipeline, report the problem, etc.

It should be noted that when deciding to use a machine vision system for culling products should be carefully weighed technical and economic factors - in order to "not shoot a cannon at sparrows".

The use of machine vision in unmanned aerial vehicles (drones).

This direction is extremely promising and can be used in the construction and control of the state of large-scale construction sites: high-rise buildings, bridges, etc. One of the applications - monitoring the state of cracks in high-rise construction was noted above.

This technical solution allows results to be achieved in unattainable other ways. Using machine vision systems installed on a drone, you can study hard-to-reach parts of the bridge (Figure 1).

![Figure. 1. Using machine vision to monitor the condition of the bridge.](image)

Machine vision can be used not only to study the construction site itself, but also the surrounding area. This allows, for example, to determine the possible danger of construction in: forest fire, dam break, etc. More prosaic tasks can be solved, in particular, to control vehicles delivering building materials.

8. Results

The work examines the main components of machine vision, clarifies their features, which should be taken into account when using machine vision in the construction industry.

Specific applications are given where it is advisable to use this IT technology. Among these applications are "Smart House" and "Smart City." It is indicated that for the direction of "Smart House" systems based on the use of motion, movement sensors, etc. can be replaced by a more powerful system "Machine Vision." In this regard, the use of machine vision in the "Smart City" is more promising, in particular in the observation and analysis of the traffic situation (work of traffic lights, traffic jams, parking, traffic violations, drains, lighting, etc.). The implementation should take into account the economic component, especially the cost of implementation and maintenance.

As a second direction of use of machine vision in building is proposed control of welded structures. Machine vision allows to check the conformity of the size of edges and seams of welding joints to strict regulatory requirements, to identify welding cracks, cuts, pores, fistulas, burns, etc.

Big Data technology can be used for better processing of information. This allows you to take into account not only the data of the machine vision system, but also the information contained in the design documentation, regulatory documents, etc.

It is further proposed to use machine vision to monitor the condition of the cracks of the building. It is noted that when deciding on the use of this technology, it should be made to ensure that there are clear advantages over the traditional "beacon-based" approach. The prospect of a machine-looking approach with another new IT technology, the Industrial Internet of Things IIoT, is indicated.
It is noted that you can use machine vision if you need to select a large number of finishing tiles, bricks, etc. The automated system is created on the basis of moving tape (transporter, conveyor). The synchronization sensor is activated as a mandatory element. It is noted that technical and economic factors should be carefully considered when deciding whether to use a machine vision system.

The promising direction is considered - the use of machine vision in unmanned aerial vehicles (drones). This technical solution is especially effective in the construction and control of large-scale construction sites: high-rise buildings, bridges, etc. In addition, machine vision can be used to control the area of construction, nearby area, transport for deliver construction materials.

References
[1] Computer vision: technologies, market, perspectives. TADVISER. Government.Bisiness.IT. 2019. №6 - 26. https:// www.tadviser.com
[2] Lukyanica A.A, A.G. Shishkin. A.G. Digital video processing. M.; “AY-ES-ES-PRESS”. - 2009. 518 p.
[3] Urban Sensor Data Streams: London 2013 // IEEE Internet Computing: 2013. Vol. 17, № 6. p. 1.
[4] Alexandr Konikov, Ekaterina Kulikova and Olga Stifeeva. Research of the possibilities of application of the Data Warehouse in the construction area. MATEC Web of Conferences 251, 03062 (2018)
[5] Konikov A., Konikov G. Big Data is a powerful tool for improving the environment in the construction business. IOP Conference Series: Earth and Environmental Science, 2017, vol. 90, p. 012184.
[6] Konikov A.I. Promising areas in the field of information systems for construction management // Industrial and Civil Engineering, 2019, №6, p. 64-69
[7] A.I. Konikov. Study of a number of aspects of using Big Data technology in construction, BST Journal, 2019, №2, p. 28-29.
[8] Nikolay Ivanov and Maxim Gnevanov. Big data: perspectives of using in urban planning and management.MATEC Web of Conferences 170, 01107 (2018)
[9] Valpeters M., Kireev I., Ivanov N., 2018. Application of machine learning methods in big data analytics at management of contracts in the construction industry. MATEC Web of Conferences, 170, 01106
[10] Gnevanov M. V., Ivanov N. A. Big Data technology - using in urban planning // Industrial and Civil Engineering, 2018. №4, p. 83-87.
[11] Maximov K.V. The effectiveness of the use of cloud computing: methods and models of evaluation //Applied computer science, 2016. № 1(81), p.106-113.
[12] Peripheral calculations (Edge computing). TADVISER. Government.Bisiness.IT. 2019. №11 – 7. https:// www.tadviser.com
[13] Olivier Hersent, David Boswarthick, Omar Elloumi. The Internet of Things: Key Applications and Protocols. — Willey, 2012. — 370 p
[14] L.Chernyak. IoT platform. Open systems. DBMS, 2012. № 7.