ON THE HISTORY OF THERMOVISION MONITORING OF GROUND ENVIRONMENT

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ABSTRACT

The rapid development of opto-electronic, computer, aviation technologies opens up new opportunities to improve both train safety and labor productivity on the railways. Unmanned aerial vehicles equipped with means of machine vision become indispensable assistants, especially in emergency situations. To choose the right technical solutions it is useful to consider the history of this scientific direction.

ENGLISH SUMMARY

Background. *Machine vision is intended to supplement or replace conventional vision of the human operator. Its emergence can be attributed to the time of appearance of the first photovoltaic cells in the early twentieth century.*

Such a vision is primarily television (TV) – «vision at a distance». Railways started to use it in 1947, though it was invented in 1907 by professor of Polytechnic Institute (St. Petersburg) B. L. Rozin. His patent for an invention was entitled «Transferring images over a distance». Prominent Soviet scientists before the Great Patriotic War foresaw the importance of radio electronics and television for the national economy, including rail transport. S. A. Vekshinsky, future academician, wrote in 1940 to the Soviet authorities: «The ability to control the operation of railways, to communicate at any distance ... – that's what a vacuum tube is...». One of the pioneers of national television V. I. Arhangelsky foresaw prospects of industrial television: night, underwater, stereoscopic and other.

In [1] it is concluded that «modern technology of electronic tacheometry, satellite detection, technology of aerospace sensing, laser scanning, etc., should certainly be classified as geoinformational technologies that are designed for application of geoinformatics of transport» (emphasis added). Technologies of aerospace sending include highly sensitive onboard television system, night vision and thermal imaging. They can provide round- the- clock monitoring of ground situation, including in cases of critical situations on the railways.

In the near future, they will be supplemented by passive systems of «radiovision» of submillimeter (terahertz) and millimeter ranges, as there are many situations where it is necessary to obtain an adequate visual image of objects that are not distinguishable in the visible or infrared light – in a dense fog, smoke, clouds, dust (sand) storm, conditions of intense fighting, etc. Currently, it is clearly shown that, based on millimeter (microwave) and submillimeter ranges the hidden objects can be clearly seen through fogged atmosphere. These radio waves almost freely pass through non-metallic covers and have a wavelength sufficient to form the image of the object with a resolution of a few millimeters near (at distances of several meters) and up to several meters at large distances (hundreds or thousands of meters).

Objective. *These technologies belong to important areas that arise in various fields of knowledge [2, 3]. It is important to trace the historical paths of their development in order to correctly evaluate the possibilities and choose the optimal construction scheme [4].*

Methods. *The authors use historical retrospective analysis concerning stages of development of thermal infrared and imaging devices as well as their comparative features.*

Results. *The literature describes attempts to conduct daily reconnaissance using balloons – hot air balloons, and then – aircraft. World War II demonstrated the relevance of night reconnaissance using infrared (IR) rays. During the Vietnam War, Americans began to use thermal imaging to detect from the air disguised enemy targets. On the other hand, some Vietnamese MiG-15 were equipped with IR radars [5,6,7].*

Since the beginning of the development in the Soviet Union in the 1950s, of sensitive and high-speed semiconductor infrared detectors (IR) on the basis of lead selenide, and then based on indium antimonide, the opportunity arose to create not only IR radars but thermal imagers operating in the atmospheric transparency window of 3–5 microns, and then 8–13 microns.

Thermovision is a kind of machine vision, which uses its own heat radiation of objects. Creation of thermal imaging both abroad and in our country belongs to the 50th years of the twentieth century. Soon it was actively used in transport.

In our country the first thermal imagers have been created in Leningrad State Optical Institute (GOI) and Moscow All-Union institute of electrical engineering (VEI). Already in the early 1960s, there were devices that were specifically designed for installation on the aircraft. Naturally, the range of vision depends on the weather, season, time of day. At night, it is necessary to use night vision devices, primarily low-visibility cameras, sensitive in the near infrared region, and thermal imagers. Research in this field is carried out in MIIT.

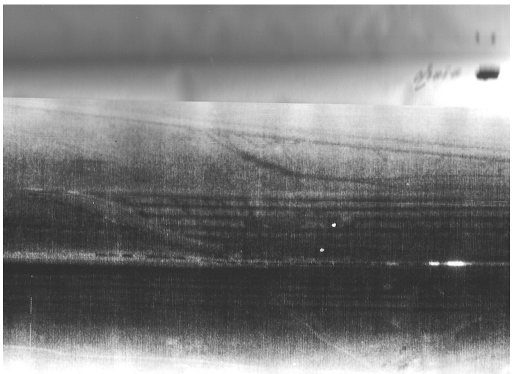
First thermal imagers were bulky, mechanical scanning and cooling of receivers with liquid nitrogen were used. Modern thermal imagers on their weight and size characteristics and ease of use are a little different from conventional camcorders, but their cost is many times as large. This is due to the high cost of matrix IR detectors and optics. The ways of solving this problem begin to show. Work is underway to improve the measuring features of thermal imagers.

In [6] it was noted that thermal imaging was used mainly for two purposes.

1. High quality passive night vision,

2. Obtaining representation of the temperature state of the object by its thermal field.

Pic. 1. Allocation of thermal imager «Prostor»:
1 – optical-mechanical assembly;
2 – signal processing and recording assembly.



Pic. 2. Night thermal image of rail tracks with a train and diesel locomotive. 1973.

The same author [6] divides devices forming the thermal images into three groups:

– Thermographic cameras for medical and research purposes;

– Thermal imagers operating in real time, including the forward looking infrared system FLIR;

– Downward systems for getting thermal maps of the area; the authors consider them in detail.

In the devices of GOI [8] photoresistor made of lead selenide was used, which was cooled with liquid nitrogen. Thermal dimensional map of the area was formed by the optical-mechanical scanning across the motion of carrier aircraft (the first dimension) and by its movement in the longitudinal direction (the second dimension). The shooting took place in 1967. The researchers obtained sufficiently clear images of swampy river valley, volcano' crater, fire, cracks in the ice, a herd of cows, pipeline with warm water. The main disadvantage of this equipment, from the standpoint of our time, was its weight – about 300 kg.

If projects of GOI are sufficiently highlighted in the journal «Optical-mechanical industry» and other publications, the air thermal imagers of VEI are virtually unknown. After declassification of VEI archive documents upon the expiry of a set term an opportunity has appeared to introduce for scientific use new, previously unknown materials on the history of infrared technology.

In 1964, the development of the thermal imager «Gradus-M» for installation on a helicopter was completed [9]. Work on «Gradus» was launched in 1961. Its goal was to create installations for thermal aerial reconnaissance of targets. The current experimental model of «Gradus II» was created in 1961 and was intended to be placed on the helicopter MI-4. In this experimental model a parabolic mirror lens with diameter of 200 mm and F = 270 mm and line scanning – horizontal were applied.

Parameters of an experimental model were such that at altitudes below 320 m helicopter speed should be less than 80 km / h. However, achieving such speeds by helicopter MI-4 is impracticable, that is why the experimental model «Gradus II» was equipped with a tracking device that allowed rotation of the camera with different angular velocity in the direction opposite to the flight.

Tests were carried out, which showed that the installation provided an opportunity for aerial reconnaissance from the heights of 200–400 m not only to detect, but in most cases to identify and decode standard tactical targets (tanks, artillery tractor with a 100-mm gun, a car, a helicopter) on their thermal radiation, and also to get from a height of 400–600 m a thermal map of the area with its elements: highways, natural roads, railroads, settlements, rivers, lakes, forests, etc.

In 1962–1964 an improved version of the apparatus «Gradus M» with IR detectors of indium antimonide was developed and was successfully tested. Line scanning was performed with the use of rotating four-sided mirror pyramid made of polished stainless steel. Frame scanning was performed by movement of a carrier. Two variants of application of this equipment were provided: on a high-speed carrier and a helicopter, but the equipment was tested only on a helicopter. Observation and photographing of thermal maps of the area was carried out by a monitor device on board of the helicopter.

Tests of a thermal imager led to positive results. According to the results, it was decided to create more perfect equipment for installation on a high-speed aircraft carrier. Such equipment with the code «Prostor» was created under the leadership of I. A. Lobanev and unlike thermal imagers of GOI and «Gradus-M», this equipment provided not only the onboard recording of thermal maps, but also their transfer over the air to a distance of several tens of kilometers. Weight of the thermal imager «Prostor» did not exceed 75 kg [10]. In VEI thermal imagers with optical-mechanical scanning applied photovoltaic IR detectors based on indium antimonide, cooled by liquid nitrogen were applied.

«Prostor» had such basic parameters:

1. Energy resolution power – 1 degree Celsius on the temperature background + 20 degrees (in the middle of the viewing angle).

2. Geometric angular resolution power- 1,5 milliradians (also in the middle of the viewing angle).

3. Number of displayable black and white brightness gradations – not less than 5.

4. Swath ground – not less than 2, 5 H, where H is altitude.

These parameters corresponded to typical samples of the U.S. equipment at that time.

Pic. 1 shows the thermal imager «Prostor» in a typical suspension unit.

Pic. 2 shows an example of the thermal map, obtained by the thermal imager «Prostor», transmitted by radio to a ground receiving center and recorded on a film using serial devices TARK-2. The test flight took *place at night on the 14th of August 1973 at an altitude of 200 meters at a speed of 600 kilometers per hour. Test observer – decorder recognized rail tracks with a twin-unit diesel locomotive (two light rectangles) and a train of 18–20 cars (dark rectangles). Testers noted in the report deficiencies of an image: thermal blanket exposure at the top and at the bottom of a picture. Probably blanket exposure was caused by coming parts of a suspension unit body in view of a thermal imager. These and other disadvantages of the equipment were soon eliminated, and in 1975 it was adopted by the Air Force.*

Modern machine vision, based on opto-electronic systems in different spectral ranges, is designed to promote the safety of train movement, including in critical situations. This is especially relevant now since railways are becoming intellectual. [11]

Several organizations successfully use significantly improved scanning thermal imagers ("Vulcan-4000», «IRTIS» etc.) similar to «Prostor» for air monitoring of pipelines, power lines, forest fires, environmental monitoring. They have a high resolution power and provide an opportunity for accurate measurement of temperature fields.

Nowadays opto-electronic devices become smaller, communication channels and control systems are improved. It is possible to equip fire, repair, snow removal and other special trains with unmanned aerial vehicles (UAV) with the possibility of roun-the-clock monitoring. In this case, such features of scanning thermal imagers as the uniformity across the field of view, high measuring feature, fade into the background. UAV should be equipped with uncooled thermal imaging cameras on microbolometer matrices. It is desirable to use an IR lens with variable focal length. The creation of electric UAV is possible.

The authors foresee a great future for radiovision – direction boundary between thermal imaging and radar-location. Development of this area in the literature is hardly highlighted, and yet its potential for rail transport is significant. For safe train driving it is advisable to obtain an adequate visual image of objects that are not distinguishable in the visible or infrared light – in a thick fog, snowfall in the smoke, dust (sand) storm etc. In addition, the range of action of thermal imagers decreases in case of rain, as the water membrane on the object reduces energy contrast. Currently, it is shown that radio waves of millimeter (microwave) and submillimeter (terahertz) ranges have a wavelength sufficient to form an image of an object with a resolution power of up to several meters over distances of hundreds or thousands of meters. Such operations are conducted in the laboratory of Moscow State University and a number of other domestic and foreign organizations.

Considering the current state and prospects of machine vision, authors note that for several years at Institute of Space Research Institute annual scientific and technical conference «Machine vision in control systems» is held. Conference topics cover various aspects of the design and construction of machine vision systems in control systems. Particular attention is paid to onboard vision systems, which are parts of mobile objects and are designed to solve the tasks of an independent and automated control in a complex, uncertain and rapidly changing external environment that fully meets the requirements of rail transport.

Conclusions.

1. Our country has an extensive experience in creating systems of machine vision, including thermal imaging systems of aerial reconnaissance and monitoring. These systems improve safety and labor productivity in transport.

2. Interbranch scientific cooperation in this area is also fruitful.

3. Scientists and engineers should pay increased attention to the development of radiovision systems for rail transport.

Keywords: *transport, aerial reconnaissance, machine vision, unmanned aerial vehicles.*

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