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Some Aspects of Visual Detection of Dumps

Andrey Alexandrovich Richter

The chapter describes some aspects of the method of visual detection of landfills from space images as one of the directions of remote monitoring of landfills.

Abstract

Waste location objects (unauthorized landfills, landfills, waste heaps, etc.) from the point of view of visual detection have deciphering characteristics, primarily shapes and textures that distinguish them from objects of the earth's surface of other types in space images. The technology of visual detection of landfills includes a number of issues, in particular: the definition, presentation, and analysis of deciphering features in visible images, algorithms and approaches for visual detection of landfills, deductive analysis as a way to get the maximum of productive information from the minimum “raw” only on the images themselves, research and mapping of landfills through interactive maps (Google, Yandex, etc.), and classification, texture, and structure of landfills and the environment from the point of view of visual detection from space images, etc. This chapter considers only some aspects.

Keywords: dump, landfill, littering, visual detection, visual interpretation, space monitoring, space image, logical analysis, deciphering signs, mapping

1. Introduction

Littering “incarnates” in various forms—from chaotically debris scattered over some surface to the “civilized” garbage Everest towering above the cities. The beauty of nature is truly extraordinary and unique; it can be described by countless many paintings, unique, emphasizing more and more of its shades. With the development of scientific and technological progress, a new phenomenon appeared that has an anthropogenic character but adorns nature along with its natural “colors,” such as birch groves, fresh lakes, flood meadows, etc. Dumps can be a truly fascinating, spectacular spectacle, and the landscapes painted from them can claim painting exhibitions in galleries as a whole art direction. However, when you see a large dump and a small grove in one projection, something inside suggests the unnaturalness and absurdity of such interaction of artistic images. Such landscapes are surreal, i.e., some introduced, unnatural shade.

An absurd combination takes place in many aspects of modern human existence, for example, in the human consciousness, where completely dissimilar, incompatible components accumulate. And with all this, the processes of this consciousness are continuously occurring, due to which the activity of the unpredictable kind is “released.” The physicochemical processes in landfills are similar; in particular, the

composition of substances released from them in a liquid, solid, or gaseous state is just as unpredictable. This, i.e., a wide range of options for their “behavior,” is dangerous, first of all.

Visual detection is one of the simplest and most widely available methods of monitoring, first of all, space monitoring. The essence of it is to study object on the image in an interactive mode, without developing and using special programs that automate this process. Images can be aerial photographs, space images, or fragments thereof; photographs of objects of study, taken with cameras; maps of objects on various maps, etc.

2. Dumps on high-resolution space images

2.1 Texture of dumps in images of high resolution

Dumps (waste location objects, WLO) refer to the observed objects, and they can be detected by the methods of space monitoring. In addition, WLO is easily detected in visible images, because they stand out against the background of *ambient environment* (AE) and have a characteristic texture.

At the same time, the *texture* of dumps is variable and diverse; it depends, first of all, on (1) the time of year and the day (the angle of incidence of the sun’s rays), (2) the size, (3) the class of WLO, (4) component composition, (5) location region, (6) screening of the WLO surface, and (7) spatial resolution, which in Google Earth is regulated by scaling.

From the point of view of visual detection, the texture is characterized by some verbal description. For example, a typical WLO and its texture are shown in **Figure 1**. A *typical* WLO texture can be specified as follows: a combination of random and close shades from white to dark gray, in some places—with a small admixture of red. The first group of shades (from white to dark gray) is the main one, the dominant one, the second (red)—non-main, secondary. When red is applied in some places, various impurities are formed on the basic shades, such as pink, reddish, lilac, etc.

2.2 WLO and its structure in the Google Earth

We will show the structure of WLO and its AE in the example of the Torbeevo landfill—**Figure 2**: WLO (1) and its AE (2), conditionally allocated as a rectangle. In the AE zone, there is a settlement of the same name—the Torbeevo village. Also the landfill is surrounded by the villages Rusavkino-Romanovo, Rusavkino-Popovschino, Polushkino, Novy Milet, and Michurinets and other settlements of Balashikha and Lyubertsy districts. Many of them, it turns out, are located in the sanitary zone of the landfill, which is a direct violation of the rules *for planning*,

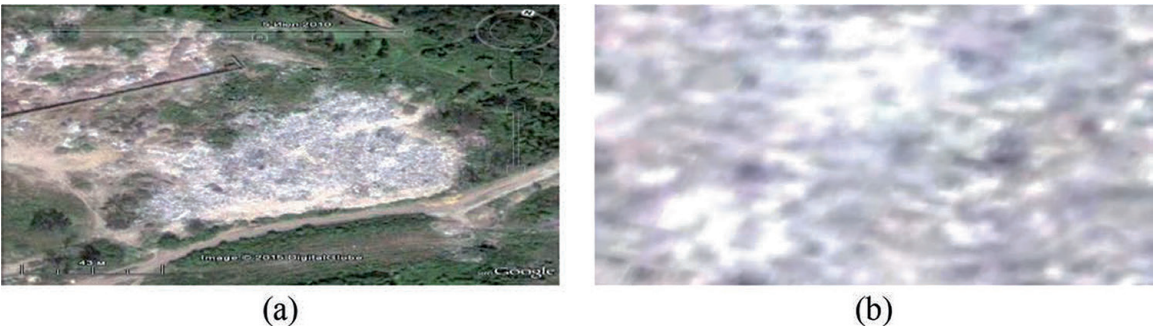


Figure 1. Typical WLO (a) and typical waste texture (b) WLO in the vicinity of the Kuchino landfill in the Moscow region, July 5, 2010 (Google Earth).



Figure 2.
Isolation of WLO and its surroundings by the example of the Torbeevo landfill (Lyubertsy district, Google Earth).

operation, and recultivation (POR) of landfills [1]; by the rules the nearest apartment house to the landfill should be no less than 1 km from it. In fact, this is a minor violation compared to others, which are also observed by visual detection in the Google Earth program (this will be discussed later) [2–4].

The surface of the Earth has changed technologically very strongly over the past few years (**Figure 3**). In particular, (1) the dump itself has grown several times; (2) where there were farms, now there is the economic zone of the landfill with all the consequences; (3) the production of soil for storing waste and expanding the landfill occurs in large areas; (4) the thin forest belt has been cut down and large areas of fertile land have been destroyed; (5) the seizure of new areas under construction and production of soil and there are other features of the changes. It should be noted that the area covered by vegetation (forest, shrubby, grassy) steadily decreases with time in principle, replacing anthropogenic objects. So, the areas of forest plantations are insignificant in comparison with the areas of forest harvesting. A stable decrease in the area of vegetation coverage is also seen in the vicinity of the WLO (not shown in the figures).

The composition of the AE of the WLO Torbeevo landfill includes (see **Figure 2**) a high incidence of human settlements, a “dirty” storage area (I), a polluted river Chernaya (II), shaky roads (III), the remains of the former livestock farm—stable (IV), fading agricultural fields (V), and other objects of natural and anthropogenic origins.

It is noteworthy that many objects of the same class are attached to the environment of various landfills, such as cemeteries (AE of the landfills Kuchino, Dolgoprudny, etc.) and agricultural areas (AE of the landfills Lisy Gora, Torbeevo, etc.).

In general, AE can be represented by objects of numerous classes: (1) *natural objects*—water (rivers, reservoirs), forest (forest massifs, plantings), grassy (meadows, glades), and other zones; (2) *anthropogenic objects*—settlements (villages, settlements), *industrial* (factories, plants), *agricultural* (animal farms, agricultural fields), service areas (filling stations, parking lots), *transport* (roads, railways), and other zones.



Figure 3.
Changes in the vicinity of the Torbeevo landfill: (a) June 2003 and (b) April 2014 (Google Earth).

In this case, you can select objects of different levels—objects of a lower level enter objects of a higher level. So, trees are objects of the lower level; a forestry array made up of trees is an object of a higher one; house is the object of the lower level, the village—the upper one.

Similarly, WLO are structurally complex objects (top-level objects) made up of “cubes” of simpler objects (lower-level objects). Let us consider in more detail the structure of a WLO in the example of the Torbeevo landfill (**Figure 4a**).

The *structural object* can be cut in the first approximation, as shown in **Figure 4a**. The structure can be represented by polygonal areas and/or corresponding labels (1–4). We have four zones (sections): (1) storage area, (2) landfill area for storage of waste, (3) economic zone, and (4) zone for expanding the boundaries of the landfill for storage of waste (presumably).

In turn, each zone is divided and/or contains more private objects. For example, the economic zone is represented by numerous *technoobjects* (office, industrial buildings, warehouses, residential objects—“trailers,” parking lots, etc.) and other territories (in particular, for the disposal of specialized waste).

Thus the territory of the WLO and its AE can be represented in the form of a map consisting of many layers. For the WLO map, the Torbeevo landfill is one of the layers—dividing it into the main zones. You can create other layers, for example, “cluttering the vicinity of the WLO” (**Figure 4b**), “transport system” (**Figure 4c**), “anomalous zones,” “territories with a homogeneous texture,” etc.

In **Figure 4c**: (1) access roads to the landfill (outer part of the transport system), (2) main road, (3) serpentine, (4) secondary roads, (5) road junctions of the economic zone, (6) roads on the surface of the landfill, (7) transportation nodes. The transport system establishes routes, first of all, for garbage trucks, bunker trucks, scrapers, and other garbage equipment. Each road leads in different ways, one of which is optimal in length (see the theory of dynamic programming and other applications of the theory of optimization), from the external environment to this or that object, be it building, cluttering, sand mounds, etc.

The *WLO card of a private area* is a map of the land surface on which an WLO array is located within the territory of the possession of individuals or legal entities (enterprises, organizations, cooperatives, etc.) and relationships with infrastructure objects (roads, fences, buildings, structures, etc.). **Figure 5** shows examples of WLO maps showing the WLOs within the general and internal boundaries of a private area. The locations of the landfills in the observation area are marked in red tags: the territory of the business park to the west of vil. Motyakovo, northern (a) and southern (b) parts.

2.3 The dynamics of WLO and the environment of the WLO

The state of the NSO from the point of view of visual detection can be estimated in various ways, for example: (1) areas occupied by vegetation and their variation over time; (2) soil degradation—bogging, salinization, etc.; (3) changes in the object



Figure 4. Structure of the Torbeevo landfill: (a) the division of the territory in the first approximation, (b) the main dumps in the vicinity, and (c) transport system (Google Earth).



Figure 5. Maps of the WLO of private territories on the example of industrial zones near the Motyakovo village, Lyubertsy district of the Moscow region (red tags) [Google Earth].

composition of the territory; (4) anomalous zones in the vicinity of the WLO; (5) compliance with the rules of the POR of the WLO; and (6) quality of vegetation. To study the state of territories, not necessarily WLO, in addition to the “visual” method, methods of *inductive* and *deductive analysis*, combining space and field visual detection, etc., are used.

We will analyze the state of AE on the example of a WLO Kuchino landfill, Moscow region, the Balashikha district, in the common people—the Fenino dump in honor of the adjoining inhabited locality of the Fenino village.

Figure 6 shows the areas of general changes in the vicinity of the landfill: (1–4) vegetation reduction, (5–8) vegetation increase, (9–13) landfill expansion (breadth and height), and (14, 15) expansion of the Fenino cemetery. Every change has its own cause. For example, changes 3 have anthropogenic reasons: the need for deforestation to prepare additional areas for the development of soil for backfilling. Then the working zone can be conditionally divided into the current (4) and reserve (technologically still unchanged natural areas in the vicinity of the landfill). Changes (5–8) have a natural (natural) cause: overgrowing of the slopes of the landfill by vegetation. In general, *overgrowing* is one of the protective functions of the environment from various negative impacts on it, such as WLO.

The warehousing section itself has a lot of structural elements, the so-called storage cards (see **Figure 7**). Waste is filled in by cards “line by line,” i.e., successively first in width, and then filled to the next level of height. The structure of cards of one level differs from the structure of the maps of the other—like brickwork, where the bricks of the lower level are lapped by bricks of the uppermost for greater stability of the structure. Due to the duration of the filling of certain cards, other cards (already filled) begin to overgrow with vegetation (see **Figure 6b**)

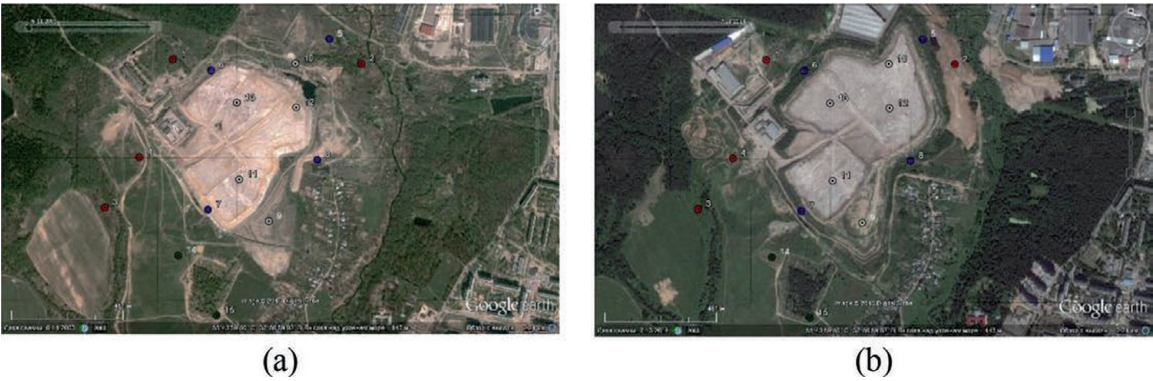


Figure 6. Changes in the vicinity of the Kuchino landfill site from June 11, 2003 (a) to July 13, 2014 (b) (Google Earth).

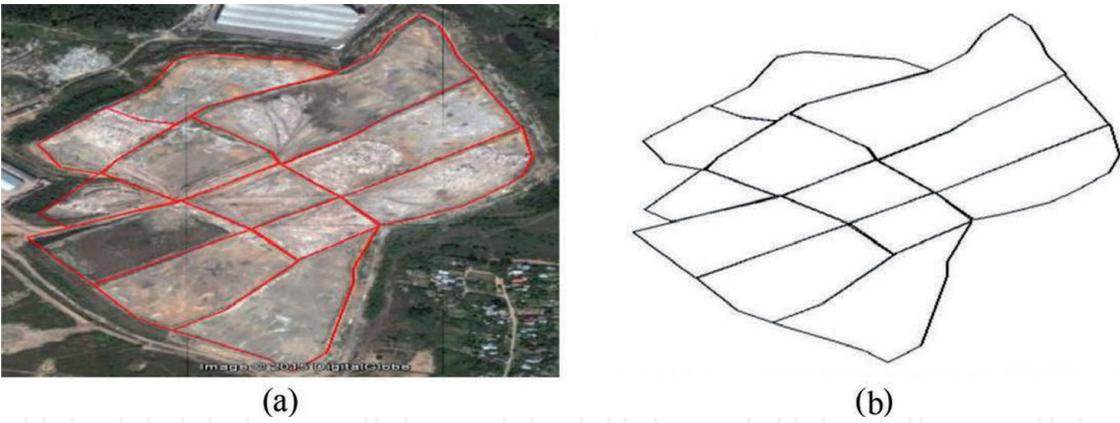


Figure 7. Structure of the landfill site for the Kuchino landfill, August 16, 2011: (a) on the map (Google Earth) and (b) schematically.

and change their texture. But—for a while, because subsequently, the overgrown map will be covered by a new storage map. So at different periods of the life of the landfill, it consists of the current storage zone and the overgrowing zone where storage does not occur.

Parallel to this, the filling of the landfill takes place in the queues of storage. This explains the unevenness of the polygon contour, more precisely, the fragments of the storage site carried out in different directions (see 9 and 10 for **Figure 6b**). These fragments, mainly, are caused by the queues of storage—new territories adjacent to the landfill, planned and prepared for a new “portion” of waste disposal. Knowing these “bulges,” we can assume a story, i.e., the order of waste storage in retrospect. In **Figure 6a**, the storage in site 9 is at the initial stage—this state of the site can be called an extension of the landfill boundaries.

By the principle of storage queues, not only NEOs are expanding but almost all anthropogenic objects, such as populated areas, cemeteries, agricultural and park areas, etc. In particular, the Fenino cemetery for 11 years has expanded in two directions: to the northwest and southeast—see plots 14 and 15 in **Figure 6b**.

Many anthropogenic objects are close to each other and in structure (**Figure 8**). In particular, the structure of the cemetery (a) is similar to the structure of the settlement (b).

In the figure, for example, three classes of objects are distinguished: (1) ownership areas, (2) plantations, and (3) access roads. The difference is only in the sizes of structural cells—for cemeteries these areas are smaller than for settlements.

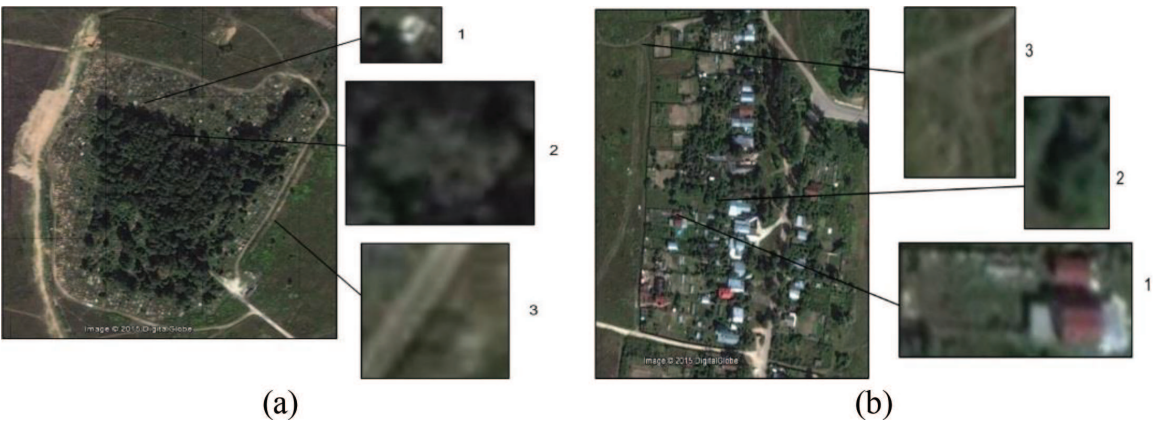


Figure 8. Structural objects: (a) Fenino cemetery and (b) the Fenino village (fragment) [Google Earth].

From the point of view of visual detection, the state of the soil is characterized by (1) technological changes in the territory (changes in infrastructure); (2) the state of vegetation as a sign of the state of the soil; (3) change in the state of the soil, improvement (enrichment) or deterioration (degradation); (4) the surface state as a sign of internal processes in the soil; and (5) abnormal zones on the surface as a sure sign of a negative impact on the soil.

The landfill arose in the 1960s, but satellite imagery of high resolution arose only in the 1980's. And it is not possible to investigate the landfill from space at birth from the very beginning. Therefore, historical references and opinions of history eyewitnesses (in particular, the residents of Fenino) are resorted to. According to their opinions, the dump is formed on the site of the former clay quarries. And the quarry was deep water and represented a resort zone, popular among the inhabitants of the Moscow region (in **Figure 6a**, the rest of the former water quarry is visible). It was an ecologically clean and favorable area.

The Fenino village is an ancient landfill, at least because the formation of a village on the site of an already existing landfill is less likely than the formation of a landfill in place of an already existing village.

If we confine ourselves to a narrow interval of time (from 2003 to 2014), then **Figure 6** shows that a number of technological changes occurred. And most intensively technologically the neighborhoods of the landfill have changed and not the remote neighborhoods. This range includes the expansion of the village and the landfill, the emergence of new buildings (in the expansion zones and former village areas and landfills), new roads, etc.

Technological degradation, we believe, occurs where the natural root system of the soil is disturbed (see Sections 2 and 4 in **Figure 6**). In general, the forms of degradation associated with the WLO include (1) technological (including deforestation), (2) bogging, (3) salinity, (4) desertification, and (5) littering. But unlike other forms, technological degradation arises abruptly. The source of technological degradation may be utilities or the private sector. In the first case, technological degradation occurs on a large territory and in the second—on an insignificant (e.g., within the limits of its garden plot).

Different forms of soil degradation are shown on the fragment of the AE landfill—**Figure 9**: (1) *water logging*, (2 and 3) unknown forms of degradation



Figure 9.
Forms of soil degradation in the vicinity of the Kuchino landfill, July 5, 2010 (Google Earth).

(presumably *desertification* and *salinization* of the soil), (4) *littering*, and (5) *technological* degradation. For the degradation of the soil is characterized by an unnatural color of the earth's surface, violet (1), white (4), or brown (2, 3, 5). The presence of brown shades, especially in the summer season, against the background of green, means a reduced density of vegetation, i.e., inability of its full reproduction by soil.

Dilution of the vicinity of the WLO is caused, first of all, by the release of the filtrate to the surface of the earth, due to the excess of moisture in the soil and low reproduction of vegetation by soil. As can be seen from **Figure 10**, the filtration water flows from the base of the landfill and spreads in certain directions in the environment. In addition to the filtration reservoirs (1) and streams (2), they form traces of their current (3), and on the shores (4) of these reservoirs, virtually no vegetation grows (see also photo 2 in **Figure 11**). To reduce waterlogging, the soil is loaded with an additional layer of soil (5), which gives a temporary effect, due to the continuous accumulation of filtration in the soil (6). The filtration liquid can also take the form of channels (7), along the bottom of the storage site. Even in winter, numerous traces (8) of filtration processes remain on the surface of the earth (see **Figure 10**).



Figure 10.
Components of filtration processes in the vicinity of the Kuchino landfill (Google Earth).

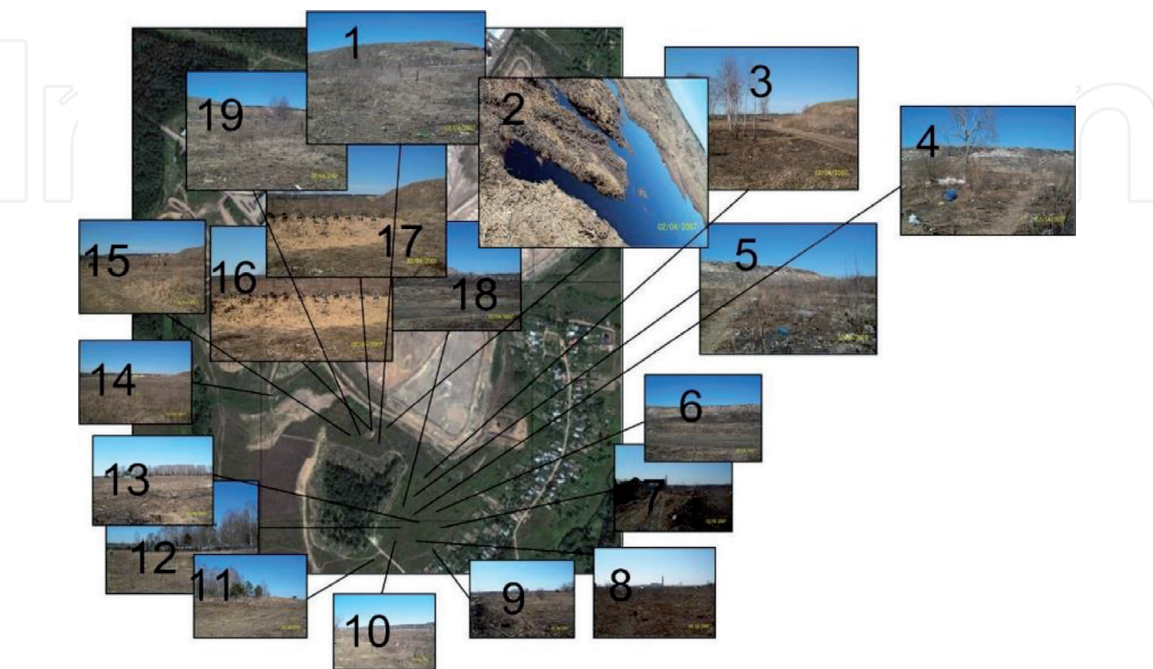


Figure 11.
Photographs taken around the vicinity of the Kuchino landfill.

Visual observations on images can be verified by conducting verification, i.e., comparison of space and field (terrestrial) visualization data. For example, you can take a picture of the neighborhood of the landfill at its various points and compare the information obtained with the visual detection data in the Google Earth (**Figure 11**).

Figure 11 shows photographs of two anomalous areas: surface filtrate (2) and unknown graves with number plates (16 and 17).

3. The method of deductive analysis of space images

3.1 Features of the method of deductive analysis of images

Most, if not all, image processing methods and algorithms solve a very limited range of space monitoring tasks. In particular, in problems of region detection, some developed algorithm selects objects of a given type located in a certain territory at a certain point in time from the source image. In addition, automated and automatic algorithms are associated, mainly, with the detection, allocation, marking, and mapping of land surface areas and are not associated with the analysis of information on these images. Because types of natural and anthropogenic objects are huge, for each of them, algorithms are developed that are loaded onto cosmic images or their series, and a full and complete analysis of the space image and the given field of observation does not take place.

The advantage of classical algorithms of space monitoring is the automation of image processing, i.e., a large-scale survey of the area of observation using space images. But the reverse side of this “coin” is their main disadvantage—the limited possibilities for examining the area. Most of the information is not extracted from the image.

To solve this problem, we propose a technique of *logical (deductive) analysis* of cosmic images, using the principles of logical reasoning on images and normalization of the results obtained. The proposed technique for the study of space images is based on visual observation of the image (using your own vision and reasoning for its interpretation). Logical analysis is obtaining the maximum amount of information from the minimum of initial data on a space image without the use of image processing algorithms.

The merits of the method of deductive (*logical*) analysis of space images include the following: (1) the implementation of the methodology which does not require knowledge of programming, theory, and practice of image processing; (2) extraction of information that cannot be obtained by modern methods of image processing; and (3) no binding to the type of images; deduction methods are the same for images of any kind.

The disadvantages of the technique are (1) individual work with each image and the impossibility of partial or complete automation to date, (2) the need for manual and detailed image viewing, and (3) the inability to obtain the distribution of surface state parameters, which is achieved by image processing.

The purpose of deductive analysis is as follows: (1) restoration of the history of the image; (2) restoration of information about the current picture; (3) predicting future processes on the surface of the earth, based on the given image; and (4) restoration of intermediate information (between neighboring shooting dates). Otherwise, the goal is some expansion of the space-time boundaries of the image.

3.2 Image information

Each image has several *types of information* (see **Figure 12**): (1) visible information, (2) invisible information, (3) information obtained by image processing, (4)

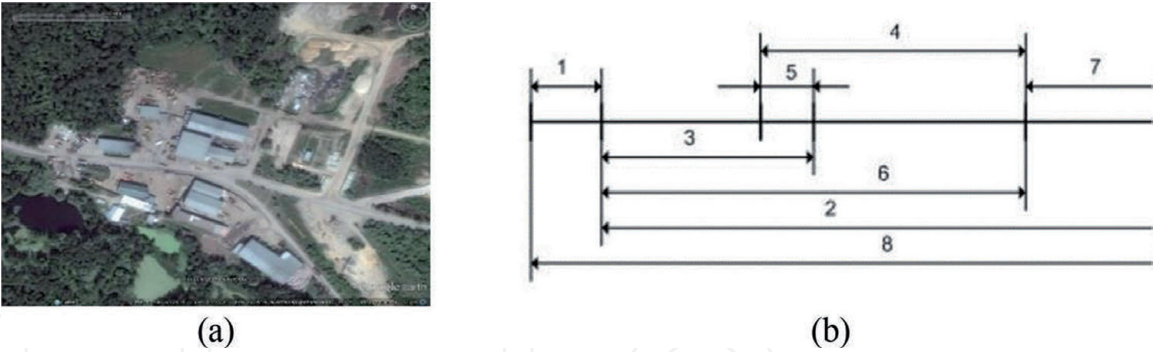


Figure 12. Image information: (a) information field (economic zone of the Timoshovo landfill, Noginsk district, Moscow region, Google Earth) and (b) types of information in the image.

information obtained by deductive analysis, (5) general information obtained by image processing and deductive analysis, (6) recoverable information, (7) non-recoverable information, and (8) all image information.

Deductive analysis is obtaining the maximum amount of information on a space image without the use of automated and automatic image processing algorithms.

To obtain visible information, *reasoning* is not required, but *logical thinking* itself takes place in any case. For example, in order to *see* a house in the image, it is necessary to have different images of houses in the mind, in the limit—a full *spectrum of types* of houses (“manual” method of managed classification). We assume that information 3 and 4 do not include information 1: that something can be simply seen; it is not necessary to resort to additional costs. However, to see something on a large number of images is less advisable than automating the process.

The reasoning behind deductive analysis has the following characteristics: (1) *Variability*—offers options for explaining a particular fact (details on the image). (2) *Distribution*—reasoning has a probabilistic and statistical character. (3) *Chain character*—one detail and one reasoning lead to another detail and another reasoning, etc. (4) *Detailing*—when interpreting one area of reasoning, they pass into its internal subdomain or conjugate domain. (5) *Algorithmization*—reasoning can be carried out on certain algorithms that allow to restore information. (6) *Schematization*—the system of reasoning is filled into some “vessel,” i.e., takes the form of some model.

Deductive analysis (recovery of the maximum amount of hidden information from the image through its detailed observation) is the development of conventional image surveillance.

Deductive analysis is variable—options are offered for explaining a particular fact (details on the image). Those reasoning have a probabilistic-statistical and a chain character, because one detail and one reasoning lead to another detail and another reasoning and so on.

Processing of space images allows you to extract information hidden from the eyes. Human eyes are seen mainly in the visible spectrum, and information in the invisible spectrum is mostly hidden from the eyes. If a person had also seen in an invisible spectrum, he probably could have uncovered all the same information as when processing images but using only logical thinking (vision) and deductive analysis. But the processing would be required to speed up the extraction of information from the images by means of automation.

Deductive analysis, for the most part, allows you to obtain information that cannot be obtained by modern image processing methods. We believe that this “extension” can be used to interpret visible images or images on which most of the objects can be distinguished. However, there is some general information obtained by both methods. The boundaries of deductive analysis end where the boundaries of image processing begin and vice versa.

Information can be visible or invisible and recoverable or non-recoverable. In the process of combining all the modern methods of image processing and *deduction* methods (and *induction*), some of the information on the image remains, in which it is impossible to extract for today—it is non-recoverable information. The limit of deductive analysis is the complete interpretation of the image, the possibility of explaining any details on the image in space and time.

Information field of the image is introduced: information sources (S_i), information objects (O), informational AE of source (IAE), boundary of AE (C) of some radius (r), information signals from the sources to the objects (u), and internal (I) and external (II) objects of a source. The *source of information* is some object in the image, which is known for the most information; it can be seen and recognized. These objects are highlighted in the first step of the analysis. A lot of information sources form an information basis of the image—these are the reference objects of the image, to which all information is bound to the information field. The information is identified in the vicinity of the region $S_1S_2...S_n$, where n is the number of sources. Each source has a certain *neighborhood* (IAE). Internal objects relative to the source belong to its AE and have a *connection* with it; external objects are on the contrary. The boundary separates the internal objects from the external ones. The connection of the source S_i to the object O_{ij} is expressed in the presence of the information signal u_{ij} .

3.3 Objects and events

In the language of *object-oriented programming* (OOP), the Earth model is programmed with objects and classes, events over objects, properties and methods, the principles of OOP (polymorphism, encapsulation, inheritance), etc. are established for it [5]. WLO and AE can be decomposed into many objects at one or another level of accuracy, each of which, in turn, decomposes into objects of a higher level of accuracy, etc. Each object changes its state in time, forming the so-called those or other *events*.

The structure of the event in space images is shown in general in **Figure 13**: A , the earlier *actual state* of the object (or system of objects) O ; B , the later real state; e , the *actual event* that transfers the state A of the object O to the state B ; t , the moment of time (according to the “space” measures—the time interval with some average value); t_i , the i -th reporting time; n , the number of reports; B_i , the *imaginary state* of the object O in the future with the known past state A ; A_i , the imaginary state of the object O in the past at and the future state B ; a_i , the *imaginary event* of the object O in the future, taking the state A of the object O to the state B_i ; b_i , the imaginary event of the object O in the past, transferring the state A_i of the object O to the state B ; and E_i , the latent state of the object O for which there are no pictures, somehow identifying him.

The “drive” of the state change A of the object is internal and/or external *factors* acting on the territory of the object. Internal factors operate from within, and it is difficult for them to identify the source of space images (favorable weather

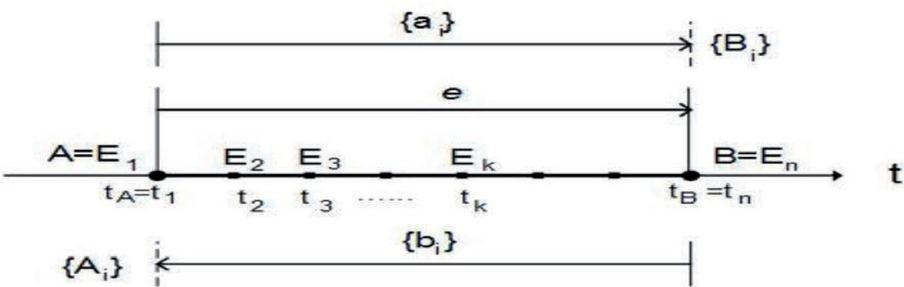


Figure 13.
Events and states on the time axis.

conditions can lead to a thickening of the vegetation cover). External forces act from the outside, and for them a source (impact of a neighboring object) can be identified.

Two events have a *cause-consequence connection* (CCC) $A \Rightarrow B$, if one of them (A) is first before the other (B). If some “quantities” are known, the remaining ones can be calculated: the examples of the calculation schemes are shown in **Figure 14**, where A and B are known events; X, Y, and Z are unknown events; and a, b, x, y, and z are logical connections (known and unknown). In (a) for two known events A and B of object O on two cosmic images taken at different times, it is necessary to find an unknown CCC x that transferred A to B. At the same time, the design scheme can have more than one solution x. It is similar for the remaining examples of schemes. In scheme (b) from the known A, one must find the set of solutions {x, Y}, i.e., assume future events Y and the corresponding connections x. In the scheme (c), on the contrary, according to the known event B, it is necessary to restore the past (X, y).

The connection $A \Rightarrow C \Rightarrow B$ forms a simple logical chain of three events A, B, and C (d–f). It is assumed there is one unknown intermediate event C that occurred chronologically between events A and B. It can be specified if the logical connection between A and B is not “felt” and a link is required. It is similar for more than one intermediate event.

On space images, an event is expressed in a change in the state of an object or system of objects, i.e., some territory. Knowing the two states, we can assume an event (event) that resulted from an earlier event in a later event. Thus the change in the state $a \Rightarrow b$ of the object O in **Figure 16** is probably caused by the slippage of waste from the slope of the Timoshovo landfill site (Noginsk district of the Moscow region) into the water during the year. If the changes on the left side of the reservoir were due to the crushing of the reservoir, then it would be updated from other sides, which did not happen (on the right the contour of the shore line of the reservoir did not change). In addition, the slippage of waste into the reservoir according to Archimedes’ law could not lead to a decrease in the water level; for this there would be other reasons, such as a prolonged absence of precipitation. Thus probably the physical meaning of changes in the texture of the reservoir on the left is the immersion of a part of the waste heap to the bottom of the reservoir.

The picture of events on the time interval $[t_1, t_2]$ can be reconstructed, considering both the main variant of the flow and the less probable one. So, if the height of the landfill was large, the waste could spontaneously fall off the slope (e.g., under wind). But the height of this landfill is small; in addition, the area of the blade is large, i.e., more likely the deliberate littering of a natural object (pond). After the filling of the territory beyond the coastal line of the reservoir, some of the waste spontaneously falls into the reservoir, including to the bottom, leaving room for

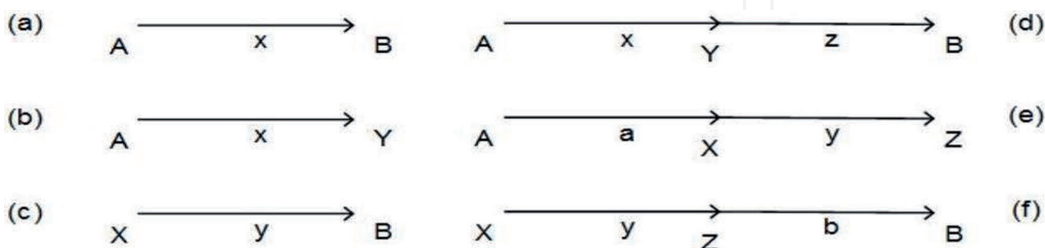


Figure 14. Event (state) equations. The CCC model $A \Rightarrow B$, in which only A is the cause of B and only B is the consequence of A, differs from the real CCC in which there are background connections (**Figure 15**): A and B are events related to each other; C is external event-consequences A; R, external events-causes B; and a, b, and c, logical connections. “a and b” are “scattering” connections, for which the consequences of event A and the cause of event B are difficult to determine, or these consequences and causes are probabilistic. Estimating the probability of a logical connection between A and B by eye, $p = M/N$, where M is the number of logical connections that lead to B and N is the number of all logical connections flowing from A. Depending on the probability value, place such links as “only A led to B,” “from A follows only B,” “although A, but B,” “if A, then B,” etc.

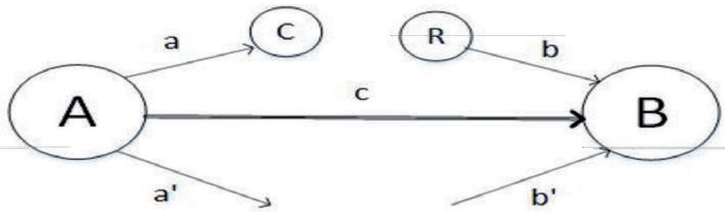


Figure 15.
The structure of the logical connection of real events.

new waste receipts. Under given conditions of survival, this reservoir is practically not suitable for complex life forms; proceeding from state b, one can assume its overgrowing and disappearance as a habitat.

For the possibility of *analyzing events* from images, including in the neighborhood of the interval $[t_1, t_2]$, it is necessary to know at least two different states of the same territory. The more known states, the more accurate the picture of events. Outside the working interval, the construction of the picture of events has greater uncertainty than inside. The wider the neighborhood of the image, the more events in the neighborhood of time ($t < t_1$ and $t > t_2$) can be restored.

Marking objects on the workspace and asking them a lot of event-causes and event-effects (probable, since only part of the event-causes occurred, and event-effects occur), the information picture is analyzed. Because objects and events “fight” on the same information field, it is necessary to establish links between them.

The relationship can be analytically represented as the formula $A \circ B$, where A and B are objects or events, $\circ$ is the operator (link), and $A \circ B$ is the result of the operation (some statement).

Links can be divided into *spatial*, *temporal*, and *logical*. Many of them are verbally given in the form of prepositions, prepositional words, and word combinations, for example, spatial (**Figure 17**).

The time links are A “to” B, A “after” B, A “at one time with” B, “before A, B,” etc. Temporary communications are established not only by the temporal gradation of the images but also by the basis of a single image over spatial relationships. For example, in **Figure 18**, buildings appeared before the objects attached to them (lawn, clutter, parking lot, access roads, outbuildings, entrances, etc.); the fences were installed “on” the parking lot after its asphalt-ing (concreting). In some cases, communications may not be defined in space, time, or cause-effect.

The spatial arrangement of objects in the image allows the image to be set in motion, i.e., restore its history and predict its future. Those on the spatial arrangement of objects, you can set events over these objects, as well as the sequence of events.



Figure 16.
Event on the image (Google Earth).

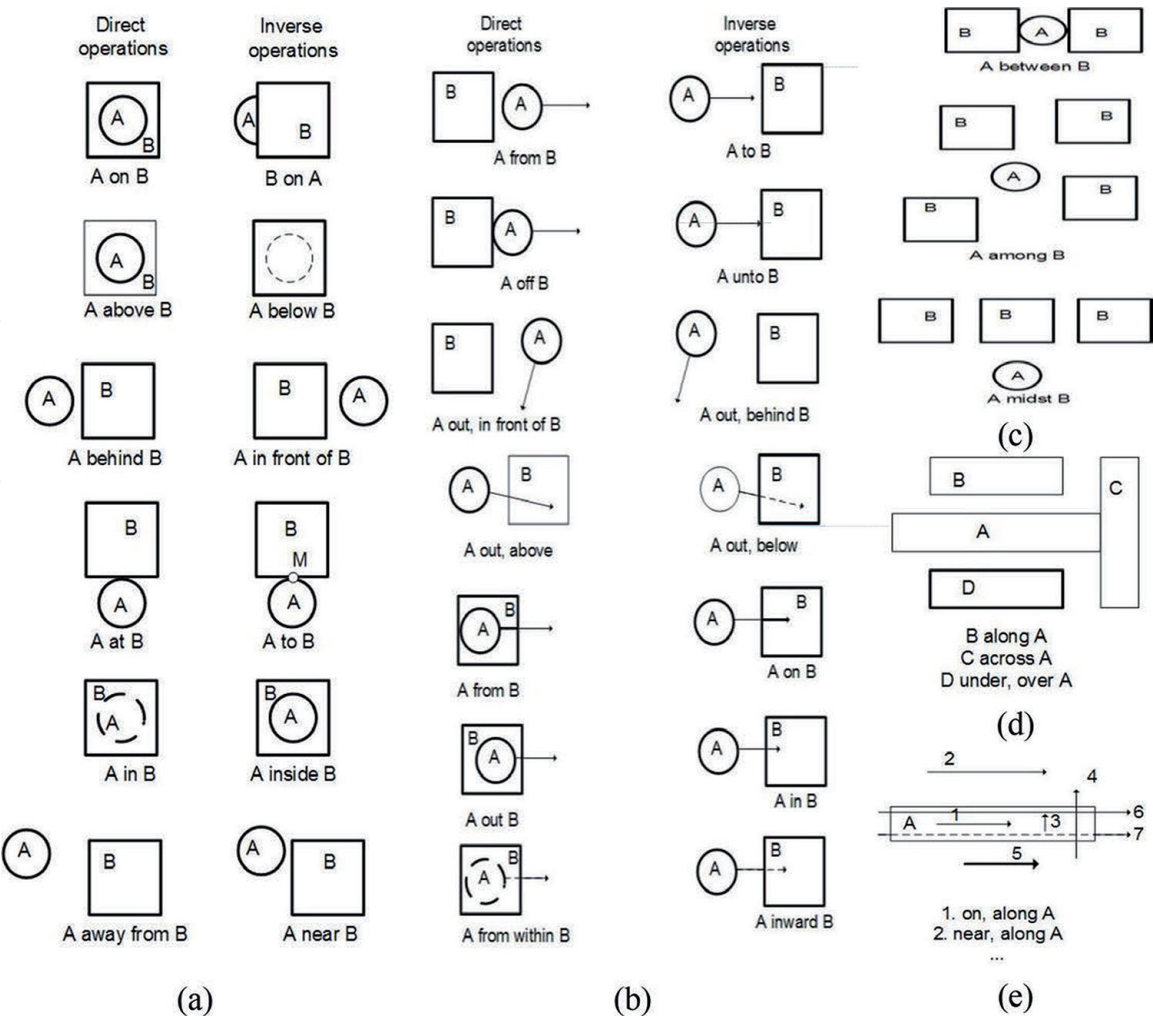


Figure 17.
Relationship of the objects and events: (a, c, d) the relationship of objects in space and (b, e) moving one object relative to another.



Figure 18.
Spatial relations of objects on the image (neighborhood of the building of the economic zone, Timoshovo landfill, Google Earth).

Because logical connection implies a temporal, establishing the chronological state of objects, their individual *event-causes* and *event-consequences* can be “crossed” in pairs and distinguish among them plausible logical connections that can occur with one or another probability.

Each link has an inverse link to it, which is expressed through opposite prepositions such as “on” and “-incl.,” “Above” and “-above” = “under”, etc. *Opposite operations* correspond to “opposite” prepositions, for example, “above” and “under,” “because of” and “from before,” etc. Accordingly, we obtain straight lines A o B and inverse B o A operations on the image.

The object O is a section of the image that is different from its background, i.e., it can be associated with a set of *determinants*, concepts {Ii} i = 1...m, one of which is true (most probable), while others have a lower probability.

From the point of view of images of an event (operations on objects), there are (1) the *appearance* and *disappearance* of an object, (2) growth and decrease of the object, (3) changing the site of the object, and (4) changing the state of the object. For specific types of objects, the type of event is confined to more specific manifestations of it, for example, “appearance”—growth (plants), building (building), movement (car), etc. Each object is “capable” of its own group of events.

3.4 Deductive analysis of images in Google Earth

Let us give an “introduction” to the deductive analysis for a specific WLO—the Timoshovo landfill, the Elektrostal town, the Moscow region. You can conduct (1) at a different level of detail, (2) for a specific image, and (3) for a time series of images.

This test site is one of the largest in the Moscow region and throughout the world. It is much larger than the Kuchino landfill and is located 4 km west of Elektrostal (**Figure 19**). In the first approximation, there are more natural areas in the vicinity than man-made ones.

The objects adjoin the landfill with parts of their borders: natural, large (in the southeast) and smaller (in the northwest) reservoirs; vegetation cover (forest and grass); anthropogenic, economic zone of the landfill in the west of the storage site; and road that fringes the landfill. In the vicinity of the landfill located settlements: cottage cooperative (in the southwest), the village Mechta (in the southeast).

The landfill has a fairly regular shape and a complex transport system installed on the active zone (in the Google Earth). The same overgrowing zone exists for a long time, so the “paths” overgrow on it. The outer part of the transport system is convenient for transport: the entrance to the landfill from three directions, i.e., from different settlements (sources of garbage), and a circumferential road giving access to the entry point (from the side of the economic zone) to the landfill from different directions, along and counterclockwise. From the point of view of visual detection, natural objects differ from anthropogenic ones in that they have an irregular shape—**Figure 20a** and **b**, whereas anthropogenic ones are correct



Figure 19.
Timoshovo landfill, and its surroundings, Elektrostal town (Google Earth).



Figure 20.
Examples of objects: natural, (a) natural forest (internal forest) and (b) a natural water object; anthropogenic, (c) building and (d) pond (artificial pond) [Google Earth].

(**Figure 20c and d**). Accordingly, the signs of natural and anthropogenic operations are reflected on the surface in the form of irregular and regular figures.

Consider a small “piece” of the vicinity of the landfill—**Figure 21a**.

We will give an assessment of how these or other details appeared on the image (in particular (1–8)) and in what order. It would seem that the site is simple enough and understandable (interpreted), but, in fact, the more you delve into its essence, the more questions arise, but more information can be “obtained” from the site. Indeed, everything and every detail in the image, in particular, has its own *causes, signs, and consequences*. If you pay attention to a specific image of the Earth’s surface and mentally go over all its details, you can understand how many causes and consequences are on the image, and they all connect with each other in a complex system of cause-effect relationships hidden from the eyes. “There” can only be penetrated by reasoning.

For convenience, let us imagine deductive analysis schematically. Because lines and structures of reasoning are many, at least part should be reduced to a certain table. The diagram of the analysis of a pair of pictures is made differently; one of the variants is **Table 1**. The table shows the scheme for a *chronological pair*: two objects 1 and 2, one of which appeared before the other (1 before 2—straight pair, 2 before 1—reverse). The columns are added to the table: “arguments for” and “arguments against” the corresponding chronological sequence.

Figure 21b comments on some points in **Table 1**: (1) the epicenter of the group of trees (early trees), (2 and 3) the directions of the group’s growth from the epicenter (the trees grow later), (4–6) the epicenter and the direction of growth (trees grow simultaneously), and (7) elementary trees (grow after 1). Different types of growth of trees on the slope also have their own causes and are due to the features of the soil, the illumination (8), the same slope angle (9), the soil state (10), etc.

The processing of a large amount of information based on chronopairs was carried out, including at a deeper level of chronopairs 1↔2.

One of the assumptions is that on both sides of the road, the plantation formed in the process of its design—from the field—exists now; from the landfill it has disappeared when the landfill has grown but has grown on its slopes. This is due to



Figure 21.
Analyzed region: (a) the section of visual detection and (b) feature sites (Google Earth).

The direct order (1⇒2)
Trees are not elements of road design, because on visible signs are formed by growth and form the wrong (natural) form. Before the design of the road, the trees occupied a larger area than at the time of the survey, but some of them were cut down in the course of the land works for designing the road and the landfill. However, over time, the area of growth expands, and on the slope their age and growth rate are lower than on flat terrain, since on the slope, they began to grow after its formation arbitrarily, whereas at the base of the landfill the trees were not removed and grew simultaneously with the development of the landfill. In addition, the growth rate of trees on a slope is on average lower than on flat terrain (due to the difference in light conditions, properties of the soil structure and its relief).
The inverse order (2⇒1)
Trees are elements of road design, acting as protective screens, just as a body of water is an accompanying element of road design and accumulation of leachate from a landfill, assuming the correct shape. The rate of their growth at the base is lower than on the slope due to the fact that soil pollution by the filtration waters of the landfill spreads more at the base and level terrain than on the slope. Before designing the road, the trees formed an “island” among the field, but with the formation of a landfill and then girdling the road, the main part of the field was cut. This explains the different nature of the growth of trees on the slope (forest belt parallel to the road) and at the base (random distribution of forest area elements).

Table 1.
Chronological pair (1, 2).

the fact that the landfill could not exist without a road (**Figure 21b**), i.e., the road was created before the landfill, and in its place was something else—for example, the continuation of field 5, which was cut off by the road and, in the future, replaced by a testing range. It was a field (an artificial object), not a meadow (natural), because the forest under it was cut along the right lines 6, and in some places the forest grew over the edges and took a less correct form (e.g., line 7). But the agricultural field could not be so small. It turns out that the landfill was formed in an environmentally friendly place. Before the agricultural field, there were meadows, there was more forest, and there were probably water bodies, because on the edges of the landfill, there are many small and cut ponds, as well as elements of the water system regulation (dams, canals, dams, etc.). Accordingly, all elements of the landfill, including vegetation on its slope 8, a path along its perimeter 9, arose after its formation.

The chronology of events (month and year) can be assumed based on a series of events, known times of occurrence (e.g., of dumps), the size and density of trees, the correctness of their shaping (e.g., boundaries), etc.

Thus a certain *chronological chain* of formation of objects is built, which can be represented in the form of a scheme with the designation of the main arguments of *chronological links* (one visual argument)—**Figure 22**.

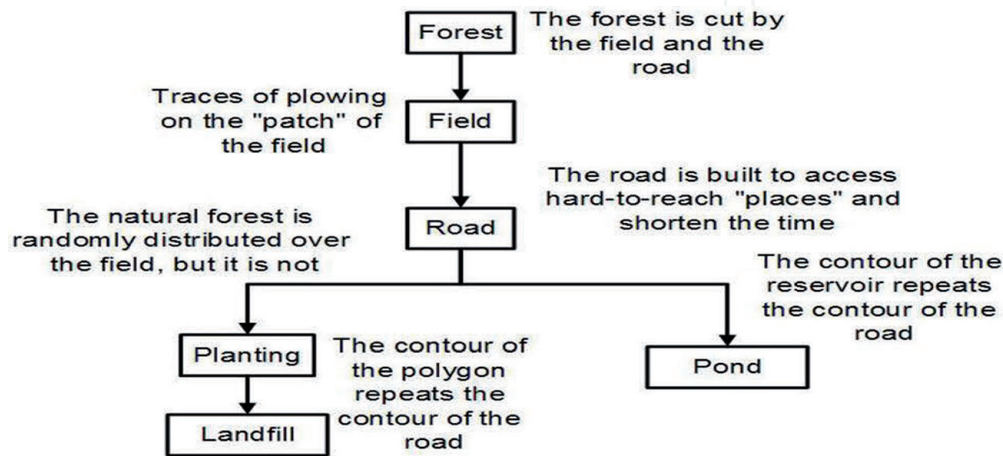


Figure 22.
Chronological chain.

Object identification			Connection of events		
i	p _i	Statement	j	p _j	Statement
1	80	Water object	1	70	Formation of the agricultural field
2	10	Shadow	2	5	Carrying out the road
3	5	Forest mass	3	20	Expanding the boundaries of the landfill
4	40	Rattle, moat	4	5	Cutting out sick trees

Table 2.
Probabilistic scheme.

General arguments are given only for a specific variant of the *chain of events*. Theoretically, there may be other chains in which the appearance sequences of objects will be different. But in many cases the reasoning will be much more complicated, i.e., for a chronological pair, much more reasoning is required.

In deductive analysis, you can use many other algorithms and schemes, such as the *probability scheme* (Table 2). It shows (1) the formalization of the probability of “eye” of any of the identifications of the object 3 in Figure 21a and (2) the events logically associated with the event of felling trees (6, 7). If a complete group of n events (assertions) is given, then the probabilities p_i of this events are reduced to probabilities q_i, the sum of which is 1: $\sum_{i=1}^n q_i = 1, q_i = \frac{p_i}{s}, s = \sum_{i=1}^n p_i$.

4. Conclusion

The solution of the problem of littering will belong to more than one generation of humanity, as its relevance will only grow with time. But it is possible to begin the solution of this prolonged emergency situation right now by setting a point of support inside (i.e., changing the inner world, consciousness) and outside (i.e., changing the external world, i.e., the environment around us).

Internal change is purely individual, and the external one can be given a logical explanation. The second, in particular, includes the monitoring of the WLO with a certain power impulse (at the physical, economic, social levels).

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