Development of digital models and information systems for machine-building enterprises

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Abstract. The paper considers the use of artificial intelligence systems based on neural systems for the automatic construction of a digital model of a machine-building enterprise. For this purpose it is proposed to split the task into two parts: automated design of a digital model of a terrain and three-dimensional terrain objects. Besides, for the automated construction of three-dimensional objects, they must be previously classified. Accordingly, we solve three problems simultaneously. As a result of the described techniques, the Geoinformation System can be used to automate the enterprise plan in real time.

1. Introduction

Digital terrain models are now widely used everywhere. They can be used for a wide range of tasks, for example, to build routes of equipment and unmanned aerial vehicles. However, at present, both the relief and the terrain as a whole are changing quite quickly. New buildings and engineering structures appear [1]. This is especially true in cities and suburbs. In this regard, the tasks of automated construction of three-dimensional maps, which are essentially the DSM, are quite relevant.

The construction of the DSM can be divided into two large stages:

• Construction or update of the terrain;
• Construction of terrain models and their placement on the constructed terrain.

2. Construction of digital terrain models

The following input data can be used to perform this task:

• vector maps of the area;
• raster maps of the area;
• aerial laser scanning data;
• ALS data of a given area;
• ground laser scanning data;
• total station data;
• GPS/GLONASS receiver data.

It shall be noted that more than one data source is frequently used. Let us consider the main methods of constructing the DTM currently used:
Construction of a basic DTM according to vector maps:
Under office-compiled conditions, scanned raster images of maps are first geopositioned. For this purpose points are placed on the edges of a map and their spatial coordinates taken on margin design of each sheet are entered. After that, the margins are cut off and the sheet is transformed according to the coordinates. Then the diagonals are vectorized (this is a fairly simple operation, which consists in circling the contours with lines and then assigning them heights). The GIS builds a digital relief model by interpolation over the vectorized contours. If the maps are too old, and there has been any activity in the area recently, there is a need to specify the surface. To do this, surveyors go to the field and make additional measurements using laser scanners or total stations. In parallel, the obtained data is linked to characteristic relief points using GPS/GLONASS receivers [2, 3]. When surveyors return from the field, all this data is transferred to GIS, geo-positioned and tied to the existing DTM. The following procedure is performed to recalculate the terrain model at the points of its deviation. This method is suitable for the construction and design of road sections with a small length (up to 20-30 km).

Construction of the basic DTM according to aerial laser location data:
To do this, a flight route is being built along the entire length of the future route. Then an aircraft with a laser scanner on board flies through it. The laser scanner makes shooting of a terrain with a laser rangefinder and an aerial camera. It should be noted that the aerial laser scanning data (including aerial photography) are already geo-positioned and can be directly loaded into GIS. Since the point clouds contain a number of errors before constructing the DTM, they are filtered for gross errors. Then, according to them, by interpolation, the DTM is built and covered with an aerial photograph for clarity. A point cloud is no longer needed and is excluded from future use in GIS [4]. This method is quite expensive, accordingly it is used mainly in the design and construction of road sections of several tens of kilometers in length.

Construction of the base DTM according to the ALS:
To do this, a flight route is being built along the entire length of the future road. Then an airplane with a camera on board flies along it and performs aerial photography. Under office-compiled conditions, all photos are stitched together by means of matching characteristic points on each picture. This is followed by orthophototransformation of pictures. After that, the sewn sheets must be geopositioned. Geo-positioning is done due to the same characteristic points with the following options:
- field definitions of geospatial coordinates of these points using GPS/GLONASS receivers;
- obtaining coordinates from vector/raster maps.

In both cases, points from transformed photos are assigned the value of reference points from maps or GPS receivers, after which all images in the geospatial coordinate system are recalculated. Further, in the stereo mode, operators place heights on the images [5]. The DTM construction is then started.

This method is somewhat cheaper than the air laser scanning, but the work takes a longer time. It makes sense to use this method when designing and constructing large area facilities.

Construction DTM according to projects
The vector project is loaded into GIS as an additional layer. Geo-positioning of the project into a spatial coordinate system is usually required. This procedure is performed using datum points and mapping them to the basic DTM. Further, over the entire length of the route, excesses or heights are placed relative to the DTM (taken from the plan references). Based on the obtained data, a digital model of the layer is being built. This operation is either repeated for the remaining layers, or copies of this layer are made with the required design excess [6].
3. **Construction of terrain objects**

As mentioned earlier, this task in its automated solution consists of 2 stages:

To learn how to find objects (classify them) using an artificial intelligence system;

To get the most appropriate objects from the repository and bring them as close as possible in geometry to existing objects.

As part of the study, a complete algorithm for identifying local objects was developed, including introductory data of various types and specification of context information through machine reading methods. The algorithm provides for an automated neurointelligence system with reinforcements.

The classifier method based on a random forest completed with the CNN light network is used here as the basis of the system for determining objects according to snapshots. Some algorithms and methods included in this general algorithm require further study in the following research areas:

- Training reinforcement subsystem;
- Data refinement subsystem from various sources;
- Topographical survey data loading subsystem;
- Validation system of terrain objects determination.

For correct training of the neural AI system, it is necessary to create and refine a classifier. Taking into account several options for possible data acquisition for the recognition system, data for analysis are collected and classified from different positions:

- Aerial photography (meaning images from both an orbit and aircrafts);
- Land survey.

For each type of data, a multi-stage classifier was created, according to which, in the future, AI training bases were formed.

1. For processing high-altitude survey data, the classifier contains the following units:
   - Vegetation (shrubs and trees);
   - Constructions (buildings, structures, etc.);
   - Infrastructure facilities (roads, railways, squares, parking lots, transformer platforms, airfields, bridges, power lines);
   - Land surfaces (fields, beaches);
   - Water (rivers, lakes);
   - Factories.

2. To process ground survey data, the classifier is modified to include the following units:
   - Vegetation (shrubs, trees);
   - Buildings (1, 2, n-storey buildings);
   - Factories;
   - Infrastructure (bridges, roads, tunnels);
   - Other infrastructure (fences, pillars, electric poles).

The difference in classifiers is explained by the impracticality of using some classes for some types of information (for example, it is impossible to recognize road signs on altitude survey) and vice versa. Besides, on land survey it is possible to determine the height of buildings (in storeys) and according to studies, on altitude survey it is only possible to separate high-rise buildings from low-rise ones.

All objects that fall into classes must be clearly visible in snapshots. Since the task of recognizing cartographic objects is not entirely trivial (the comparison was made by a set of images in the libraries TensorFlow, IMAGINET (http://www.image-net.org) and others, it turned out that the ratio of images of people, objects, clothes in relation to houses, plants, etc., is approximately 200 to 1). In some classes, there were no training images in these libraries. This comparison suggests that there are currently no full training libraries (like TensorFlow). The primary assembly of the library was carried out in the manual mode, at least 100 photographs, based on different directions of the training systems:

- Aerial photography (footage from satellites, aircraft, UAVs, quadrocopters).

The following applications were used to get snapshots:

- Google Earth Pro 7.3.3.7786. Sampling of images from 2014 to 2020;
- SASPlanet 200606 (https://sasplanet.ru);
The images were uploaded to various territories with maps for more convenient testing of recognition quality by comparing objects outlined by neurointelligence (tested by the system) and already mapped in the manual mode:

- Land survey (data collected from machines and on foot). For the test, pictures were taken from the Yandex Panorama using a parser in the network. The data selection condition is similar to space imagery. In this case the data was checked manually.

For the automated collection of the library, we used a specially designed parser. All classes were created as a tree file directory (in the root of the file tree of the main classes with subclasses inserted into them). A parser found and processed open photos of the library on the Internet (including using Google, Yandex) according to a written (contextual) description and placed the corresponding pictures in folders as *.jpeg files.

Searching and downloading (parsing) of pictures from the Internet for subsequent training was carried out using automatic algorithms and manually (50/50). For these purposes, we used the Yandex.Pictures tool (https://yandex.ru/images/), where in the search results next to most images you can see the link “similar”, which opens a page with images similar to the one available when clicking. Accordingly, we used both currently existing image search directions – the sample picture was searched manually for meta-information, and similar images using image search technology for their content and their automatic download.

In all libraries, the images must follow the following principle: in each class, at least 1400 images that meet the following requirements: image file type: *.JPEG, resolution up to 1920x1200, file size up to 2 MB.

Next, you must manually mark all snapshots and conduct a training procedure for the artificial intelligence system. There is a lot of information about this in the Internet, hence we will not focus our attention on it here.

Upon completion of the training, we will get a system that can identify objects at the input information (in our case, snapshots) and classify them. If there is a finished library of such three-dimensional objects, the AI is able to select terrain objects from this library of the model (by recognition) and place them on the previously built DTM.

4. Conclusion
Pictures of the Moscow region were used as tests, the percentage of guessing objects and their correct placement ranged around 89-94%, which for the current stage of research is quite sufficient. In the future, it is planned to train AI to create textures of real objects according to incoming shots, geometrically select similar objects in the library and place prepared textures directly on them. Thus, the maximum visual similarity of the built digital models of the terrain to real objects will be achieved.

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