# DATA COMPRESSION AND PANORAMIC IMAGES FORMATION IN UAV MILITARY TV-MONITORING SYSTEM

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## Abstract

UAVs are unmanned aerial vehicles. UAVs with qualities of robots are called "drones" and are used mostly for acquisition and transmission of TV image for observation missions in enemy territories or guarding of objects and large land areas. TV images acquired by these drones are converted into compressed data and then transmitted to the ground via radio - communications. If the monitored area is large or the observed object is big, then more drones buy pieces from the total image. The paper shows the results of the analysis of experimental data compression standard methods and Method of panoramic images formation in the conditions of initial frames with low detail is offered. Method saves perspective of base frame.

**Keywords:** UAV, monitoring system, data compression, images, RANSAC

## 1. Introduction

The technical requirements can be defined by autonomous tack-off, flying and landing (Eck, 2001). UAVs are mostly used in military applications for recognition, environmental observation, maritime surveillance and mine removal activities. In the beginning of the 21st century they gained substantial press due to their heavyuse in Operation Enduring Freedom in Afghanistan and Operation Iraqi Freedom in Iraq.

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**Table 1. Extract of UAV categories defined by UVS international.**

| CATEGORY | Masss [Kg] | Range [Km] | Flight altitude [m] | Endurance [hours] |
|---|---|---|---|---|
| Micro Range | <5 | <10 | 250 | 1 |
| Mini Range | <25/30 | <10 | 150/250 | <2 |
| Close Range | 25 . . .150 | 10. . . 30 | 3000 | 2 . . . 4 |
| Medium Range | 50 . . .250 | 30. . . 70 | 3000 | 3 . . . 6 |
| High altitude Long Endurance | >250 | >70 | > 3000 | >6 |

Thanks to the continual news coverage of these conflicts and the release of UAV video streams, UAV technologies were thrust into the public consciousness. In World War II Nazi Germany developed the V-1 Rocket, which did not gather intelligence information, but was one of the first successful unmanned aerialvehicles in production. U.S. research continued in waves and during the Vietnam Conflict UAVs were secretly flown over China, Laos, North Vietnam, and other South Asian countries. These UAVs performed tasks similar to 'modern' UAVs: collected photographs, took electronic measurements, made damage assessments, and dropped propaganda leaflets. In 2000 the global military UAV market was estimated at $2 billion and predicted to grow to $42 billion by 2014. With the U.S. then consuming a third of this market, it was anticipated to spend $13.5 billion in 2014. More recently it was estimated that from 2014 to 2015 the U.S. will spend at least $62 billion on UAV technology (roughly $12.5 billion per year).
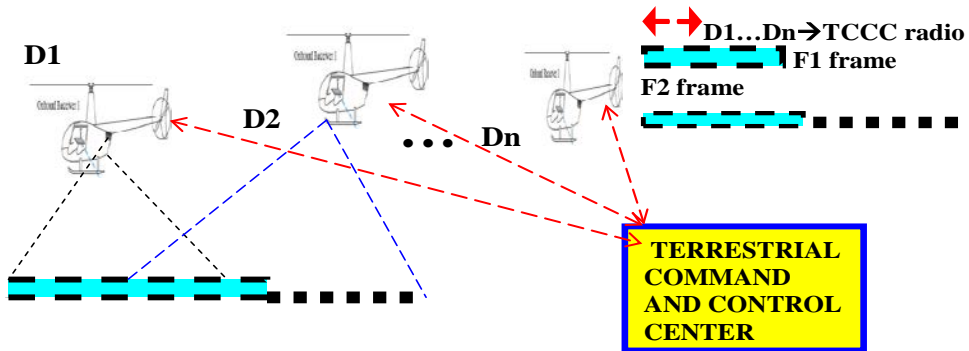


**Fig 1. Tv-monitoring system of military structures of drones**

This substantial investment not only provided cutting-edge military systems that help keep U.S. service members safe, but also spurred on research and development. Similarly to how NASA's Space Race investment helped produce integrated circuits, the definition of the UVS community, in which the helicopters fit, are listed in Table 1. All other kinds of aircrafts are generalized in the "High Altitude Long Endurance" group (Conway, 1995).

In Fig.1 is presented a TV-monitoring system Conway of military structures of drones, where a group of **n** drones (D1...Dn) directed from the command and control center (TCCC), meets monitoring missions. For an object too long, Tv pictures is acquired in frames (F1, F2) from the drones D1 and D2. Data procured by D1 and D2 are *compressed* and submitted to TCCC where occures the surgery to rebuild the entire picture based on information purchased from the drones D1 and D2. This restore the entire picture on the bases of pieces represent *panoramic images formation.*

The paper have four sections. **Section 1** is the goal of the paper and introduction. **Section 2** present the results of the experimental analysis of data compression standard methods. **Section 3** is to propose to construct panoramic image for the TV monitoring system used all matching pairs, but talking into account a priori estimate of their reliability. The goal of **Section 3** is to preserve the reference frame perspective in the generated panoramic image using the transformation equations based on the model of perspective transformation. **Section 4** conclusions and a list of references complete the paper.

## 2. Data compresion metods, experimental analisis

The purpose of data compression is to improve the performance of subsequent operations performed on these data: storage, transmission, etc.. All compression systems require two algorithms: one for data compression/decompression data source and one for the recipient. Data compression is intended that, by using certain procedures, to make a change (transformation) of a file F, the length L bits, in a file Fc, the length Lc<L. Decompression of the compressed file Fc changes to the same as the original one in the F or F are very close in terms of content. Compression and decompression algorithms that show some asymmetry in their performance requirements depending on the application's data files. For example, in many applications, a multimedia document will be encoded only once (at the source) and decoded thousands of times (the destination). So, this asymmetry provides a way encryption algorithm to be slow, while decoding algorithm should be fast. In many compression systems have made efforts to make the decoding simple, and to be as fast even by slowing and codification. This is not true for real-time applications (e.g. a video conference). A real-time encoding algorithm is different from those used for storage systems (storage) of video data files, where algorithms can be slower than real-time system (Henri, 2011). When you compress a file - program or text file after decompression want to get exactly the original down to the last bit. For multimedia files this requirement does not arise. Usually we accept after decoding a little different from the original signal. When the decoded output is identical to the original entry system is lossy. Systems losses are important

because accepting a small number of information loss can provide a huge advantage in terms of compression rate. All compression system contains an encoder and a decoder. The encoder converts source data from the compressed data and the decoder attempts to reception, to reconstruct the original data based on tablets. Be reconstructed by decoding data coincide with data from the source or differ insignificantly for a purpose. This difference between the length in bits of the file compressed and uncompressed compression system should be evaluated and adjusted according to the intended purpose. To evaluate the qualities of a compression system we define a unit called compression ratio:

$$\frac{The\ size\ of\ data\ emitted\ from\ the\ source\ in\ bytes}{The\ size\ of\ compressed\ data\ in\ bytes} = r$$

(1)

A compression ratio of "2 to 1" signifies that the size of compressed data is half of the size of data emitted from the source. A high compression ratio will designate a better compression system.

Data compression procedures are used for a long time, being related firstly to the storage of texts written in electronic format. Even in this area the progress was very spectacular, the performance of compression algorithm improving quickly. But these techniques that allow by the reverse operation, decompression, the exact restoration (lossless) of the original assembly provide a low compression rate because they are based only on elimination of natural redundancy of information source which, even if it exists, has a limited value. Higher compression rates can be achieved if we give up of restoring the exact information signal, but then we have to accept a compromise between the compression factor and the precision with which the restoration is done.

The main purpose of scientific research whose results are presented in this section is the experimental testing of the main compression methods of data files and evaluating their behavior for different types of files: TXT, EXE, C++, Pascal, sound, video. The evaluation of these methods is based on the compression ratio.

**The JPEG standard used for continuous-tone images compression**. The JPEG standard (Joint Photographic Experts Group) used for continuous-tone images compression was developed by photography experts. It is important for multimedia, because, to first approximation, the multimedia standard for movies, MPEG, represents the JPED encoding of each frame separately, plus a few features for compression between frames and motion detection. JPEG is defined in International Standard 10918. JPEG has four modes and many options, being normally used to encode 24-bit RGB video images. We will deal more with sequential mode that has

losses. Figure 1 presents the structure and content of the procedure, in 6 coding steps, using JPEG, of a RGB image.

MPEG standard (Motion Picture Experts Group). The main algorithms of MPEG family are designed for video compression and are international standards since 1993. Because movies contain both images and sounds, MPEG can compress both. The first finalized standard was MPEG-1. His goal was to produce output videos that have a quality compared with video recorders (352x240), using a bitrate of l,2 Mbps. An uncompressed video can reach 472 Mbps, its reduction to 1.2 Mbps being significant, even at this low resolution. MPEG-1 can be transmitted on twisted lines at low distances. The next MPEG standard was MPEG-2 that was initially designed to compress videos designed for broadcast with a quality between 4 and 6 Mbps. MPEG was later extended to support higher resolutions. MPEG-4 is designed for video conferences with medium resolution, using low speed frames (10 frames/sec) and low bandwidths (64 Kbps).

MPEG audio compression is done by sampling the waveform at 33 kHz, 44.1 kHz or 48 kHz. It can handle mono, stereo disjunct (each channel separate) or stereo together (is operated redundancy between channels). It is organized on three levels, each applying additional optimizations to achieve higher compression. Level 1 is the basic scheme. This level is used, for example, in the DCC band system. Layer 2 adds to the basic scheme, advanced bit allocation. It is used for audio CD-ROMs and by the film soundtracks. Level 3 adds hybrid filters, ununiform quantification, Huffman coding and other advanced techniques.

Audio MPEG can compress a music CD to 96Kbps without perceptible loss of quality. The number varies from one music to another for different signal to noise ratio. Audio compression is achieved by Fast Fourier Transform to convert the audio signal from the time domain to the frequency. Spectrum is divided into 32 frequency bands each processed separately. When there are two stereo channels, the inherent redundancy in having two overlapping audio source is also operated. MPEG-1 audio stream output is adjustable from 32Kbps to 448Kbps.

There is a large variety of compression algorithms and variations thereof. We make a comparative analysis on several files of different sizes and with different algorithms. In analysis we use the following 8 types of files: dll: dynamic libraries; step: Pascal files; txt: text files; exe: executable files; WAV: audio files; bmp: bitmap files; cpp: C + + files; img: image files.

**Table 2 - Results for different file types**

| File type used in the test | Huffman Standard | Shannon – Fano | Huffman Dynamic | Arithmetic compression | LZW |
|---|---|---|---|---|---|
| *dynamic libraries* | 33% | 23% | 24% | 25% | 50% |
| *Pascal sources* | 37% | 36% | 38% | 38% | 56% |
| *TXT* | 35% | 37% | 40% | 41% | 54% |
| **exe** | 26% | 20% | 25% | 25% | 22% |
| **WAV (sound)** | 19% | 14% | 48% | 38% | 48% |
| *bmp (Bitmap)* | 49% | 47% | 55% | 51% | 52% |
| **CPP type (C++** | 30% | 29% | 37% | 35% | 44% |
| **IMG (image)** | 23% | 22% | 25% | 33% | 46% |

We make the analysis using the following algorithms: ***Huffman standard compression; Shannon-Fano compression: Huffman dynamic compression; arithmetic compression of order; LZW compression.***

***The calculation of compression`s degree:*** the defining relationship of compression`s degree, used for experimental data processing is:

$$g = \left( 1 - \frac{L'}{L} \right) * 100 \qquad (2)$$

Where: L' - the length of compressed file through a compression algorithm selected from the set of test; L - the length of the original uncompressed file.
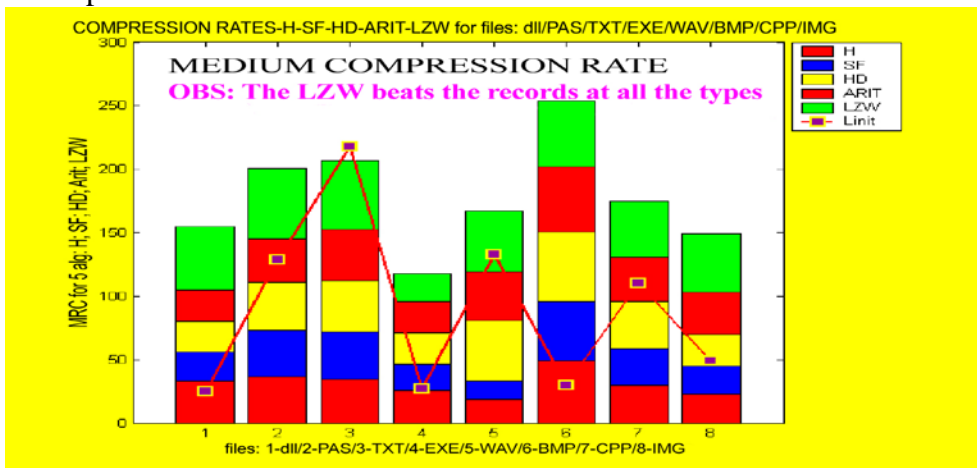


Fig 3. Medium values of compression rates for 5 algorithms and 8 file types

Table 2 contains the experimental results of testing the five algorithms tested for 100 different file types of different lengths. In Fig 3, the 8 files are ordered ascending by initial length. The conclusion is that, the best behaviour has LZW algorithm who practically shows highest compression ratio for all files, whatever is their length.
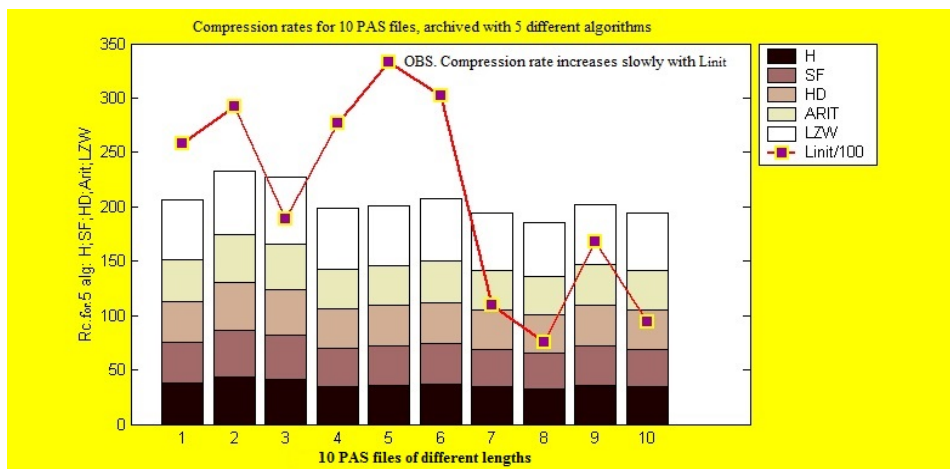
**Fig 4. The five algorithms tested on 10 files of the same type PASCAL but different lengths submitted in the table above**

In Fig 4 and 5 are submitted the results of testing the 5 algorithms on 100 files by different lengths but the same type, **PASCAL** and **WAV**.
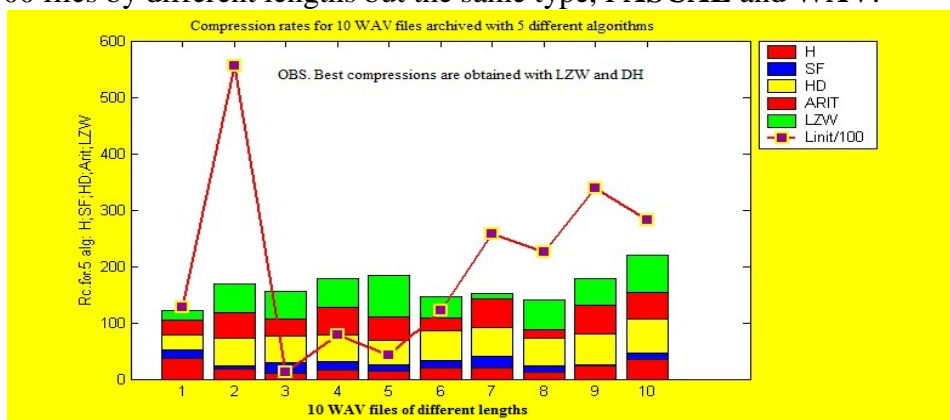


Fig 5. The 5 algorithms tested on 10 files of the same type WAV but different lengths

From Fig 5, it fallows that for all algorithms, the compression ratio increases with length files, and **LZW, HD** algorithms provides best results in compression of sound files.

## 3. Panoramic images formation method for TV-monitoring systems

Since the panoramic technique was discovered by Paatero in 1952, dentists in a variety of dental specialties have used panoramic radiography imaging, in spite of the new techniques that have emerged on the market. Panoramic radiography is a simple method of obtaining images by synchronous rotation of the x-ray source and image receptor around the stationary patient (Tab 3).

**Table 3 Several applications from the history of panoramic images obtaining based**

|  | **A  P  P  L  I  C  A  T  I  O  N** |
|---|---|
| **1952** | The panoramic technique was discovered by Paatero in 1952, dentists in a variety of dental specialties have used panoramic radiography imaging, in spite of the new techniques that have emerged on the market (Oboukhova, 2011). Panoramic radiography is a simple method of obtaining images by synchronous rotation of the x-ray source and image receptor around the stationary patient. However, there is a magnifying factor associated with image formation, due to the distance between the radiation source, object and image receptor, which can produce image distortion. |
| **1972** | The tomographic method (Reindel, 2002) |
| **1987** | Determine surface from motion (S-J. Bae , 2012) |

**The common method characteristic.** Features of video panoramic formation in transport monitoring TV systems are:

- *moving objects presence in source images;*
- *source images has low level of details;*
- *it is  need to preserve the perspective of the reference frame*.

The  method involves the following steps:

- *static background creation  from  images of each camera;*
- *the feature points selection in the source  frames;*
- *matching feature points (matching pairs creation);*
- *the transformation equation parameters identification*.

Moving objects exception and static background formation is carried out on the basis of temporal filtering (Fig. 6). To find the characteristic points the modified algorithm based on the Harris detector is used (Oboukhova, 2011).



a)                                                                                b)

**Fig 1. The initial frame (a) and static background obtained by temporal filtering (b)**

Its basis is the definition for each point, located in the part of image with high level of detail, the matrix **H**:

$$\mathbf{H} = \begin{bmatrix} \sum (dL/dx)^2 & \sum [(dL/dx)\cdot(dL/dy)] \\ \sum [(dL/dx)\cdot(dL/dy)] & \sum (dL/dy)^2 \end{bmatrix} \quad (3)$$

where $(dL/dx)(dL/dy)$ - the brightness derivatives in the horizontal and vertical directions, respectively (these values are calculated for the fragment of 5x5 elements).

Characteristic point on the image, the physical prototype of which is usually a corner, has a high value of brightness derivatives, both horizontally and vertically, so the eigenvalues are relatively large, and the coefficient $cond(\mathbf{H})$ of a matrix $\mathbf{H}$ is close to one. A feature of the developed method is the additional filtration introduction in the local fragment of image with characteristic points. Its aim: for local fragment with a high level of detail to find the points that have a maximum luminance value of the derivative. As a result the starting points for Harris detector are not all the centers of the fragments with high detail, but only the points corresponding to local maximum brightness derivative. Found the characteristic points of the first and second image is formed in two sets $P = \{p_1, p_2 .. p_n\}$ and $Q = \{q_1, q_2 .. q_n\}$.

The stage of the characteristic points matching in pairs is carried out according to correlation for blocks with centers at these points. Each block of the first image is compared with all blocks of the second image. This allows each point of the set $P$ match point of the set $Q$ and form a set of matching pairs $PQ$.

**A priori estimation of matching pairs reliability.** The presence of noise, the difference in perspectives leads to the formation in the images wrong matching pairs. Typically, to reduce their filtering is used. In the images with low detail, this leads to a small number of matching pairs,
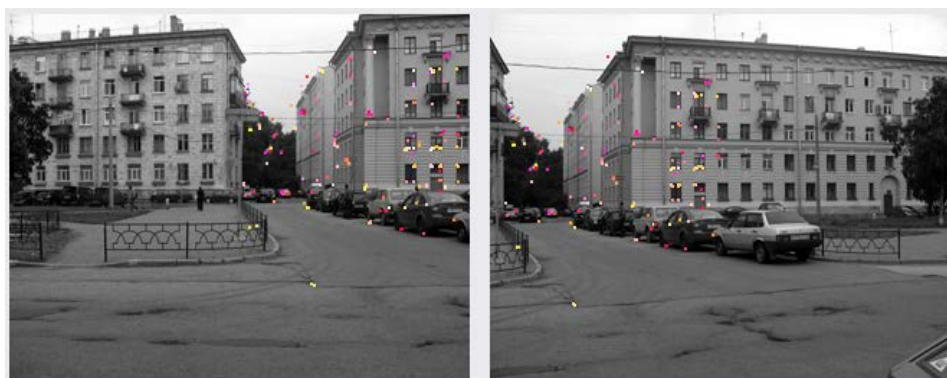


Fig 7. Matching pairs of characteristic points

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insufficient for correct identification of the parameters transformation equations. Proposed to construct panoramic image for the transport system used all matching pairs, but taking into account a priori estimate of their reliability. Each matching pair of points $(p_i, q_i)$ the support measure $\xi$ is given

$$\xi = \frac{1}{N-1}\sum_{j=1}^{N} \frac{\min(\frac{\Delta x_i}{\Delta x_j}, \frac{\Delta x_j}{\Delta x_i}) + \min(\frac{\Delta y_i}{\Delta y_j}, \frac{\Delta y_j}{\Delta y_i})}{2} \quad (4)$$

where $j \neq i$, $\Delta x_i = (x_{p,i} - x_{q,i})$, $\Delta y_i = (y_{p,i} - y_{q,i})$,

$\Delta y_j = (y_{p,j} - y_{q,j})$, $(x_{qi}, y_{qi})$ - the coordinates of the $i$-th point from the set $Q$ (the set of characteristic points for the first image);

$(x_{qj}, y_{qj})$ - coordinates of the $j$-th point of the set $Q$;

$(x_{pi}, y_{pi})$ - the coordinates of the $i$-th point of the set $P$ (the set of characteristic points for the second picture)

$(x_{pj}, y_{pj})$ - coordinates of the $j$-th point of the set $P$. From the set of matching points pairs $PQ$ with the help of an iterative algorithm form a subset $PQ_{opt}$ with a high measure of support ($\xi = 0.9..1$). For each pair $PQ$, which does not belong to determine $PQ_{opt}$ the support $\xi$ on the basis of reliable compatible pairs $PQ_{opt}$, according to (S-J. Bae, 2012) is determined. This quantity is considered as a priori estimate of reliability.

**Identification parameters of transformation equations.** To preserve the reference frame perspective in the generated panoramic image using the transformation equations based on the model of perspective transformation (Reindel, 2002):

$$\begin{pmatrix} x' \\ y' \\ 1 \end{pmatrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \cdot \begin{pmatrix} x \\ y \\ 1 \end{pmatrix} \quad (5)$$

where $x', y', 1$ and $x, y, 1$ - homogeneous coordinates of the corresponding points in transitional and in the reference image $\{h_{11}, \dots, h_{33}\}$ - parameters of the equation to be determined. If pairs of matching points $\{(x_{i,1}, y_{i,1}), (x_{i,2}, y_{i,2})\}$, $i = 1$, $N \geq 5$ are given then transformation parameters of the equation (2) can be determined using singular value decomposition of the matrix as the singular vectors matrix ninth column value. To estimate the parameters of equation (Reindel, 2002) we apply the robust estimation algorithm (RANSAC), taking into account a priori

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estimates of the reliability for points pairs obtained above. Introduced modification of RANSAC: the hypotheses are ranked according to two criteria: the number of satisfactory points and, additional, the average reliability of satisfactory points. According to the resulting parameters of the equation the transformation of images and cross-linking videopanoramy are performed.

     **Experimental results.** Experimental research of proposed method allows to give the following conclusions. Panoramic image has perspective of initial reference image. Unlike analogues (known modern software solutions - Hugin, Canon photo stitcher), which reproduce some averaged perspective for each adjacent images, and if the number of fragments growing do not save unified perspective at all. Proposed method allows to use the resulting panoramic image in video processing tasks that require unified perspective for all the fragments - for example, to estimate the speed of moving objects. The method shows better results than the analogues in the panoramas synthesis based on video sequence, typical for road observation (a few highly-detailed areas, small scale features) (Fig. 8).
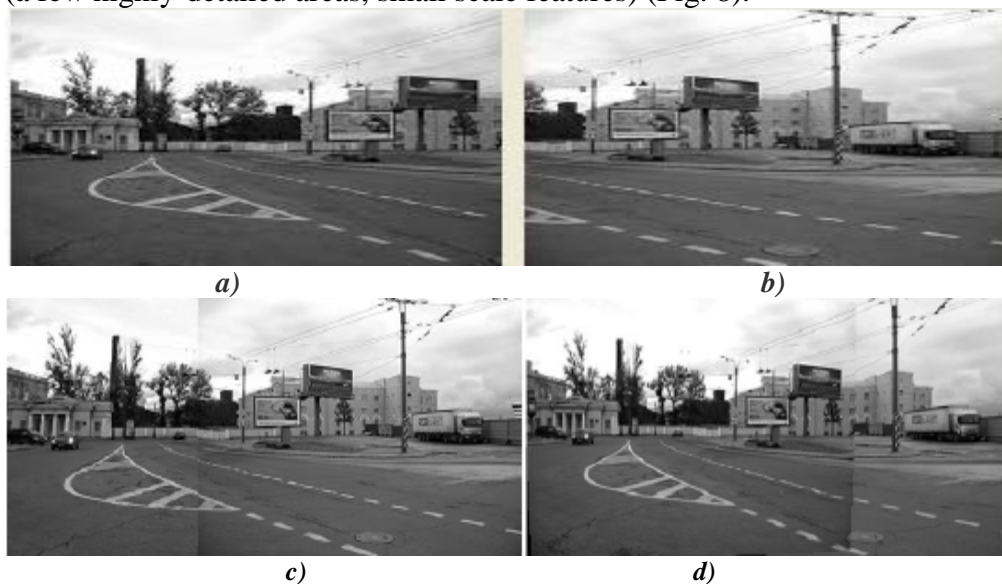


*a)*                  *b)*

*c)*                  *d)*

**Fig.8 Video sequence, typical for road observation**

     The maximum error (the most important for visual perception) is lower in average up to 25%, the average error - 15%. On video images with a large number of characteristic points the method ensures the panoramic formation with overlapping error, corresponding to modern analogues. The maximum error does not exceed 2.4 pixels, the average error - no more than 1 pixel. The method provides panoramic formation with initial image having mismatch in the scale and rotation. In the case of simultaneous factors influence, the scale change does not exceed 3%, the rotation angle of 2

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degrees. In the case of separate factors effects - the scale change up to 4%, the rotation angle up to 4 degrees. The method allows the construction of video panorama in real time.

## 4. Conclusion

Data compression is used in storage systems or transmission systems to the distance, for text data type, sound or image represented in digital format. The applications developed in the centralized management of robots with artificial vision, as well in the case of unmanned spy planes, is required to transmit video data in a compressed form for shorten ground data acquisition and transmission. This explains the importance given for data compression by researchers. Techniques for image compression are dominated by signal processing in information technology domain. Rapid increase in applications which use 2D and 3D representations and especially the transfer of grafic files on Internet required the development of special techniques and especially specialized standards. Image compression procedures are complex, associating more algorithms. Therefore, the distortion rate is decisive in choosing the level of compression, because according to application it can go up to very high compression rates, if the image details are not important or working with binaries images. Another important aspect is the running times of compression/decompression algorithms, certain procedures are not indicated for distance transmission, but storage only, due too long time because the compression is. Finally, an issue that can not be neglected is that there are applications where the image compression it have to be associated with the audio signal and possibly of process data or text files, which raises issues of frames and especially to harmonize the flow of information. Sound files with dimension relatively small, their compression is carried out in good conditions and in a short time using Huffman Standard algorithm even if the compression ratio for these files is quite low 35%.

Thus, the main features of the proposed Panoramic images formation method are:

- *selection of characteristic points using filtration, localizing their position in local fragment of image;*
- *lack of thresholding during points matching in pairs;*
- *identification for each pair of feature points reliability estimation;*
- *identification of the transformation equations parameters using all matching pairs with taking in account  their reliability estimation;*
- *using the transformation equations based on the model of perspective transformation.*

*Method allows to construct panoramic images in conditional of low detail source image and preserved perspective of reference image.*

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