Local video-positioning system for industrial GPR

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Abstract. This article presents a local positioning system working with the industrial GPR OKO-2 (LOGIS) in the process of radio measurements. Here we discuss principles of the positioning system and the method of transferring location data into the GPR system as satellite data. The location uses a video recording of special tapes, which limit the scanning area. Tapes contain the special periodic pattern. A pair of video cameras are placed directly on the GPR body, cameras will register images of the limiting tapes. Results of experimental approbation of the GPR complex confirm the applicability of the system.

1. Introduction

Now mobile GPR capable to restore shape and position of objects, which hides under the surface of the earth. In such type of devices, transmission and reception of radio wave (scattered by objects) carried out when an operator manual pushes GPR on a surface under research. After measurements, the processing of received radio data will recovers an image of hidden objects. Nevertheless, recovering of radio images possible only if a position of receivers and transmitters is known, in each moment of measurement. There are many options of local positioning systems, which could locate a position of the GPR during it, moving. Location an object by positioners produce with using laser, radio wave or ultrasonic radiation [1–3]. The common feature thing is all these systems have a high cost and complexity of the equipment. The wide distribution of cheap video cameras makes it possible to create simple and inexpensive video positioning systems for GPR. The common feature thing is all these systems have a high cost and complexity of the equipment. The wide distribution of cheap video cameras makes it possible to create simple and inexpensive video positioning systems for GPR

The paper proposes one of the variants of a video positioner, which we design to locate of GPR during radio measurements. In addition, the paper contain results of experimental approbation of the proposed GPR complex

2. Video Positioner

Our system includes a pair of cameras, which installs on the GPR. The rectangular scan region limit by two ribbons that contain a special periodic pattern. Video camera orients to the ribbon. So that each camera would see "their" tape. A portable computer is processing video streams coming from cameras such a way as to calculate the distance between the camera lens and the ribbon. Therefore, two images (one image from each camera) is enough for the determination of GPR position within a limited region.

Consider the procedure of computing the location of GPR. The first stage is the recognition of a periodic pattern inside the frame. The criterion for recognition is a periodic structure in an image of the tape (picture on the tape). Let $f(\xi, \eta)$ denote as the discrete function of pixels intensity in a video frame, where ξ determines the number of pixels in a line, and η - the number of lines. The first step of the image recognition algorithm of the tape in the video frame is the one-dimensional discrete Fourier

transform of the function $f(\xi, \eta)$, which is computes with using the variable ξ. The result of the transformation denotes as $F(\alpha, \eta)$. The periodic structure of the tape image will create a maximum in the $F(\alpha, \eta)$ spectrum at frequency $\alpha_{max}(\eta)$, this peak will correspond to the image period. This maximum located on the interval $\eta \epsilon [\eta_1, \eta_2]$, where values η_1, η_2 is the beginning and end of the interval. They determined by the position of the tape edges, its top, and bottom. We denote by γ the most probably value of $\alpha_{max}(\eta)$. At the last step of the recognition, as lines containing the image of the tape, we accept all lines satisfied the next condition:

$$\gamma - \Delta < \alpha_{max}(\eta) < \gamma + \Delta,$$

where Δ is an empiric value, and equal 2.5.

The second stage of the procedure is the finding of distances x and y. Distances between tapes and GPR has strong depends with frequency α_0. If you know frequencies α_{0_1} and α_{0_2}, then distances x,y from each of camera to the corresponding tape are calculated using the formulas:

$$x = \frac{\alpha_{0_1} T}{2\pi} \tan\left(\frac{\theta}{2}\right),$$

$$y = \frac{\alpha_{0_2} T}{2\pi} \tan\left(\frac{\theta}{2}\right),$$

where T is the previously known period of the tape image, θ is a horizontal viewing angle of used cameras. The values of α_{0_1} and α_{0_2} estimates as a position of the maximum of the modulus of the sum of the spectra:

$$\alpha_{0_{1,2}} = \max \left| \sum_{\eta=\eta_s}^{\eta_e} F_{1,2}(\alpha, \eta) \right|,$$

where the image lines (recognized at the first stage as containing the tape image) sums from the top η_s to the bottom edge η_e of the periodic tapes.
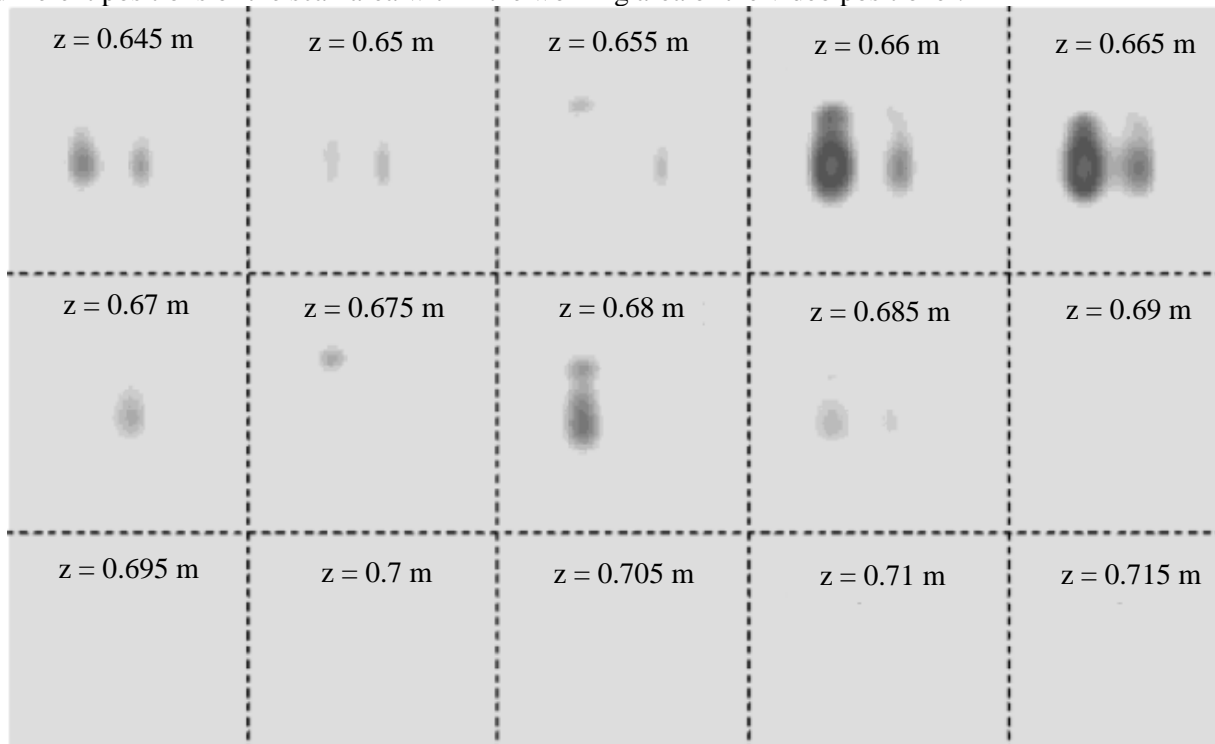
3. Experiments

We created software and hardware complex to conduct experiments and tests of proposed video positioner in GPR measurements. As the base of hardware complex for radio wave measurement, we used the industrially GPR OKO-2 [4], which located on the two-axis scanner. The scanner provided an accurate positioning of GPR to any point in area of 1.5×1.5 m^2 (Figure 1). We strictly installed two Logitech C270 video cameras on the GPR and oriented them at right angles to each other in the scanning plane. Workspace of video positioner limited to two tapes of banner fabric, which located at right angles to each other in the scanning plane. The length of each of the tape was 6 m. The periodic pattern on the tape was a sequence of vertical stripes of black color with a width of 0.05 m and a height of 0.2 m. The sequence period was 0.1 m. The results of radio wave measurements and video frames from video cameras processed on a personal computer. The recovery of radio images based on measurement results was figured out by using the migration method in the time domain [5]. As a test object, we used two parallel metal strips, which fixed in a plane parallel to the scanning plane, at a distance of 0.66 m. The width of each strip was 0.05 m, height –0.25 m, the distance between the bands - 0.11 m. We made a series of the same type experiments, in each of them radio measurements performed in the equidistant grid nodes 0.3×0.3 m^2 with a step of 0.01 m, in x and y coordinates. During processing of received signals, we focused on different distances z from the scanning plane. The experiments differed in an arrangement of a scanning area inside the working area limited by tapes for the video positioner.
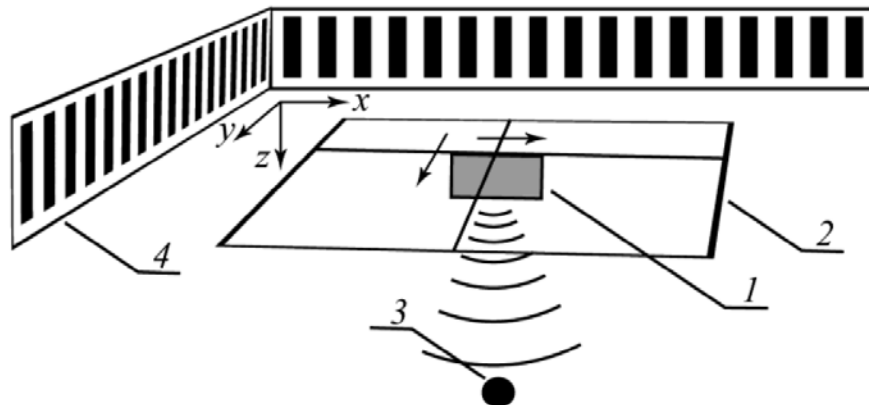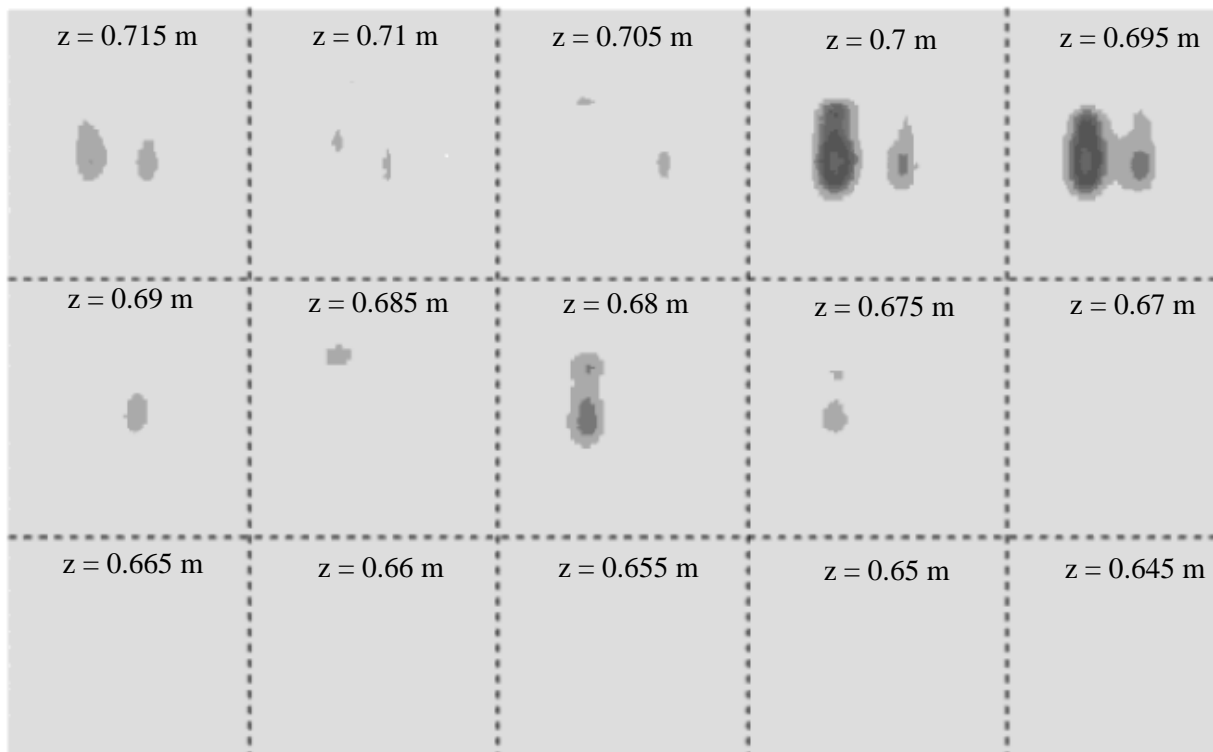
Figure 1. The positioning system scheme during radio measurement:
1 – GPR OKO-2, 2 – two-dimensional scanner,3 – research object, 4 – tapes with the periodic pattern

Figure 2 shows a typical sequence of radio images, which reconstructed from one of the experiment's data. The data received from the two-dimensional scanner became the basis for radio signal processing. Every square on Figure 2 represents one recovery image, which obtained for the specified distance z. The size of each image in the xy plane is $0.5 \times 0.5\ m^2$.

Figure 3 shows the result of the radio image recovering with the same wave measurements, but here we were using coordinates obtained from the video positioner. Similar results obtained for different positions of the scan area within the working area of the video positioner.

z = 0.645 m	z = 0.65 m	z = 0.655 m	z = 0.66 m	z = 0.665 m
z = 0.67 m	z = 0.675 m	z = 0.68 m	z = 0.685 m	z = 0.69 m
z = 0.695 m	z = 0.7 m	z = 0.705 m	z = 0.71 m	z = 0.715 m

Figure 2. Radio images reconstructed with a scanner data of GPR coordinates

z = 0.715 m	z = 0.71 m	z = 0.705 m	z = 0.7 m	z = 0.695 m
z = 0.69 m	z = 0.685 m	z = 0.68 m	z = 0.675 m	z = 0.67 m
z = 0.665 m	z = 0.66 m	z = 0.655 m	z = 0.65 m	z = 0.645 m

Figure 3. Radio images reconstructed with video positioner data of GPR coordinates

4. Transfer positioning data to GPR

Third-party video positional systems cannot connect to the GPR OKO-2. Only a standard GPS tracker can connect to the GPR system via the COM port to the operator's laptop. After connecting the GPS tracker, each radio wave measurement will get local coordinates, which calculated from the start position of the GPR measurements. It is obvious that for experiments with the "custom" positioning system, we had to replace the GPS signal with a replica with our own positioning data. We used the "com0com" software program, which creates two connected virtual COM ports. License GPR software capture one of them as GPS port. Our software for the video positioner captures the second COM port, and after, the soft is warping positioning data into the GPS signal. Positioning data converted to NMEA GPS standard [6]:

$$"\$GPGGA, tthhss.ms, xxxx.xxxxx, N, yyyy.yyyyy, W, 1,06,0.9,0.0, M,,,* 3C";$$

where, $\$GPGGA$ – head of NMEA packet, $tthhss.ms$ – time notation, $xxxx.xxxxx$ – X-axis of location note in angular minutes, $yyyy.yyyyy$ – Y-axis of location note in angular minutes, 06 – number of satellites in vision area. For calculation positioning data in angular minutes, we multiply it with the calculated constant. $MRT = 0.000054$.

5. Conclusion

The paper proposed one of the possible constructions for the video positioning system, which could use with GPR. The system consists of two cheap video cameras installed on the body of GPR and it moves with GPR during wave measurements. Cameras capture limiting tapes inside the area of GPR measurements. Periodically repeating black stripes printed on the limiting tapes. Measuring of range from camera's lens to the tape is an estimating of the period of tape's pattern print that is the estimation of the coordinates of the GPR. The experiments confirmed performance of the proposed video system in the complex with GPR. The resulting coordinate measurements had a linear deviation in the experiments less than

0.007 m. Restored radio images using coordinates from a video positioner and using true coordinates had almost identical.

References
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