ANNUAL OF NAVIGATION 10/2005

Tomasz Praczyk
Naval University of Gdynia

RADAR IMAGES COMPRESSION IN A PROJECT OF THE MARITIME COASTAL POSITIONING SYSTEM – AN INVARIANT METHOD

ABSTRACT The article describes one of the radar image compression methods – the “invariant” method. Furthermore, evaluation of the “invariant” method in the context of its application in the designed maritime coastal positioning system is presented. Influence of the “threshold”, the median filter and FFT transform to a final form of compressed image is also considered.

INTRODUCTION

Radar images have been used in the maritime navigation for a long time. In order to fix position, a navigator needs to identify characteristic point (points) of a coast present on the image and subsequently determine bearing and distance to it. However, frequently even the most experienced navigator has problems with faultless identity assigning to a point that is designated to serve as a reference point in the fixing position process. In such situations tools are helpful that substitute the navigator and fix rough position on the basis of the radar image. There are well known comparative navigation methods, which fix the position on the strength of a simple comparison of the registered radar image with memorizing patterns.

Another potential in this area, proposed in the designed positioning system, is an artificial neural networks application. In case of a networks software implementation and lack of super fast computers, however with such situation we will deal the most frequently, taking advantage of crude radar images causes not to little problems. They incorporate as much information that we are not able to fully exploit it. Computation duration both during a reasoning phase (memorizing methods such as GRNN) and during a learning phase (parametric methods such as multilayered perceptron), in case of the unprocessed radar images application, would be too long. In order to make possible the neural networks application that would work on the strength of radar images to positioning, it is necessary an application of feature extraction methods (leading to the image compression) that extract salient and eliminate unimportant elements.

There are a lot of image compression methods but there is a problem with estimation of their usefulness in the radar images processing and position approximation methods. Presented in [Praczyk, 2003a, 2003b] results are based on estimating the compressing Kohonen neural network using position accuracy achieved by the positioning system based on radar images compressed by this neural network. Thus, we have the estimation of the given solution without the knowledge about contribution of each part of the system to the final result.

Just, for that reason, it was necessary to find the universal criterion of estimation of the radar image compression algorithms, with reference to the position approximation systems. The most important question was to determine what kind of compression will help and what can be considered as an obstacle in the process of fixing the position by approximation system. It was proved that in the case when the learning process of the positioning system will use original compressed radar images – we will have a large set of examples of original radar images taken from the coast area under consideration – then the goal at the compression phase is to save all relations between original radar images in the compressed images domain. This means the situation, when similar radar images will possess representatives in the compressed images domain also similar to each other. Solutions, which would disperse compressed radar images equivalents from positions close to them, would increase the speed of the changeability of the approximating position function in the areas where data are similar to each other but simultaneously are characterized by the considerably different value of the position function. The position function can be presented by the following [Praczyk, 2004]:

$$f(\mathbf{d}) = \mathbf{p} \tag{1}$$

where, **d** is an compressed radar image and **p** is a latitude and longitude vector.

To ensure appropriate accuracy of positioning system these areas would have to be represented by greater number of learning data extending simultaneously calculation time in the learning or conclusion stage. The evaluation function of radar images is as follows:

$$E = \frac{1}{c}\sum_{i<j}^{n}\left[\left(a_{ij} - a_{ij}^{*}\right)^{2} / a_{ij}\right] \tag{2}$$

$$c = \frac{n(n-1)}{2} \tag{3}$$

where: n is number of test radar images with corresponding features vectors;

i, j – indexes of consecutive radar images and their compressed equivalents;

a_{ij} – normalized Euclidean distance between two radar images;

a^{*}_{ij} – normalized Euclidean distance between two compressed images;

IMAGES IN POLAR COORDINATE SYSTEM. INVARIANT OF THE IMAGE

The radar image registered in Cartesian coordinate system could be described with the aid of a complex vector [Kuchariev, 1999]:

$$\boldsymbol{Z} = [z_1, z_2, z_3, ..., z_K] \tag{4}$$

Every element of $\boldsymbol{Z}$ could be presented as follows:

$$z_i = \left(x_i^{OR} - x_o^{OR}\right) + j\left(y_i^{OR} - y_o^{OR}\right), \quad i = 1,2,3,...K \tag{5}$$

where:

x_i^{OR}, y_i^{OR} *are* coordinates of radar image elements (pixels) in the Cartesian coordinate system;

x_o^{OR}, y_o^{OR} - coordinates of the central element (pixel) of the radar image in the Cartesian coordinate system;

K - number of radar image elements (pixels).

Coordinates in polar system are following parameters;

$$d_i = |z_i|, \tag{6}$$

$$\alpha_i = \operatorname{Arg} z_i \tag{7}$$

The radar image in the polar system is depicted in Fig. 1.

The rotated polar system is frequently used in the maritime navigation. The axis of such system determine latitude (φ) and longitude (λ). In such system α is identified as *bearing (NR)* and d is the same as before (see Fig. 2.).

For radar images, for the sake of their specificity, it is convenient to save them in the „contour invariant" form (see Fig. 3.).

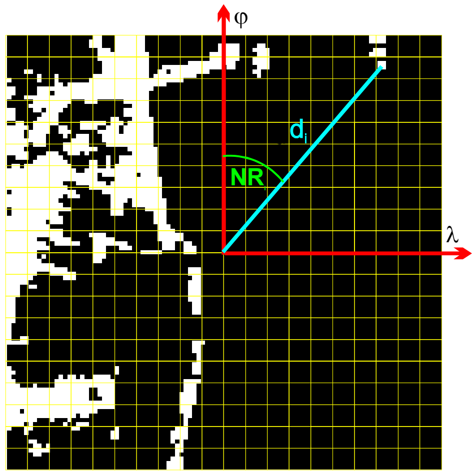


Fig. 1. Presentation of the polar coordinate system

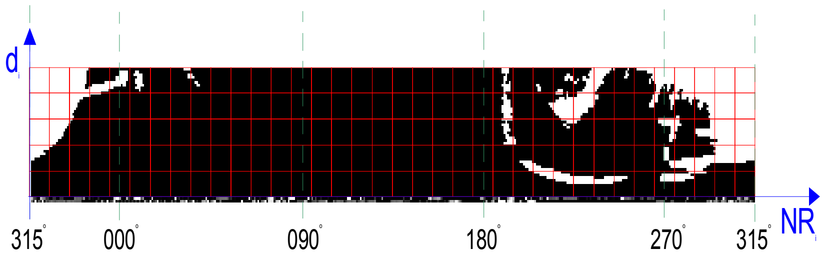


Fig. 2. „Invariant” of the sample radar image

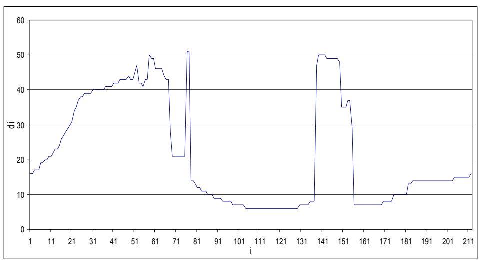


Fig. 3. „Contour invariant” of the sample radar image

A disadvantage of the invariant method is its large sensitivity to the image rotation. The invariant representation of the radar image and its narrowly rotated copy could significantly differ. In the radar images domain differences caused by the image rotation at a not large angle are barely noticeable. In the usage of the invariant representation case, the insignificant rotation of the radar image could unfortunately lead to disparities between the original and the rotated copy.

The approximation position system will receive radar images from the navigation radar where preserving of a radar image orientation according to the N-S direction is obtained with the aid of gyroscope devices. It is assumed in the maritime navigation that maximal acceptable gyroscope error is ±3°. It is not large angle however it could significantly influence the compressed form of the radar image. In order to become not dependant on the rotation of the image one could apply FFT transform. During the experiments an application of FFT transform in relation to invariants of radar images was tested. It was examined haw FFT transform works in conjunction with the invariant representation of the radar image and haw this combination affects the concentration preserving in the compressed images domain.

By virtue of omitting deepen situated areas of land by the invariant representation it could be successfully used also in the positioning systems in which learning, for the sake of the lack of sufficient number of real radar images, would take place on the basis of simulated images from an electronic or paper chart. Such images significantly differ from these we could observe on the navigational radar. It particularly concerns fragments of land that are present on the paper chart but invisible on the radar image. In such case an outline of the coastline is taken only into account.

FILTERS

Except the rotation, ships echoes occurring on the given sea area and present on the image, could also have large influence on the invariant of the radar image. It concerns echoes coming from moving ships as well as from motionless ships. Pattern images will not posses such echoes. The only visible objects on the pattern images will be echoes coming from land and from buoys. The more additional echoes on the radar image and the closer they will be located from the center of the image the more will be their impact on the resultant invariant of the considered image.

In order to eliminate unwonted echoes coming from moving objects one could sum many radar images from the same position (registered during not to long period of time, our ship should be then in a drift or it should move very slowly). Adding images causes that the resultant image contains a whole route of every ship altering location. However a brightness of pixels corresponding to the moving vessels is less then the brightness of pixels representing constant, motionless elements of the stretch – buoys, land, standing still ships. The weak echoes could be subsequently removed using the straightforward “threshold” filter that switch off all pixels less bright then the threshold. Unfortunately this apply to pixels corresponding to echoes we want to eliminate as well as pixels coming from constant objects generating weak radar echo. Thus fragments of the image, crucial for the further processing, could be removed.

Summing images and the application of “threshold” filter is not able to deal with echoes produced by motionless ships. Such task the median filter could fulfill that belong to the nonlinear filter group. Pixels corresponding to a filter mask are sorted according to the brightness level. One value is selected from an ordered group of points that substitute the central pixel of the mask. In the median filter case the central pixel of the mask receives brightness of the central pixel from the ordered sequence. Simply, the filter removes all values located at the end of the ordered sequence of pixels. If value of any point significantly differs from values of that point neighbors then it will be situated at the end of the sequence and consequently it will be substituted for an average brightness pixel fixed by the filter mask. The median filter should be used very carefully because it removes always all details of the image of size less then the filter mask – it concerns both echoes of standing still ships and useful echoes coming from constant navigational aids present on the stretch. In this case elimination of image details characteristic for the given position is also possible.

EXPERIMENTAL RESULTS

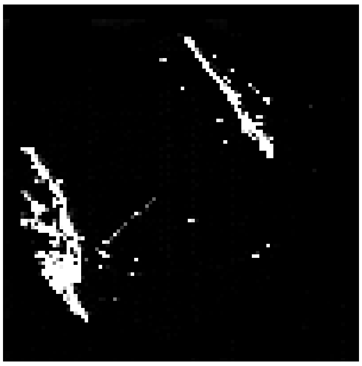
During the experiments evaluation of the following radar images compression methods was conducted:

- invariant of the image;
- invariant of the image + FFT transform;
- „threshold” filter + invariant of the image;
- „threshold” filter + invariant of the image + FFT transform;
- median filter + invariant of the image;
- median filter + invariant of the image + FFT transform.

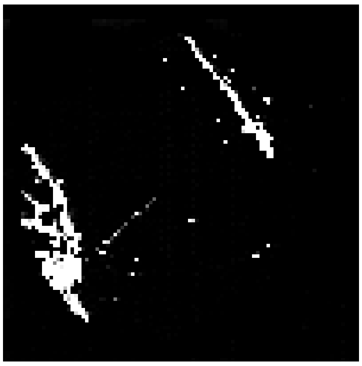
During the experiments, 31 original black and white radar images coming from the Gdansk Bay area were used (distances between consecutive registrations of radar images is about 600 m) and 93 derivatives of these images. Each original image had additionally 3 converted from it equivalents which sums to 4 image series – each consisting of 31 images from different positions (primary series no. 1 with the originals and series no. 2, 3 and 4 with the copies). Images with the same indexes in each of the series corresponded to the same ship position (position registered with GPS). Additional radar images were constructed by the rotation of original images at an angle from the range of <-3°, +3°> and then after the rotation, deformations to original images were introduced. The rotation was used in order to take a gyro compass error into consideration. A gyro compass is envisaged to use in the positioning system to determine a direction – to arrange radar images according to the N – S direction. The magnitude of introduced deformations was different for each of consecutive images series. The smallest differences occurred between series no. 1 and no. 2, next between series no. 1 and no. 3 and the biggest disparity was between images series no.1 and no. 4.

All images were reduced to 100*100 pixels size and next compressed. The original radar images contained 10000 information units, during compression, were reduced to 200 information units size vectors.

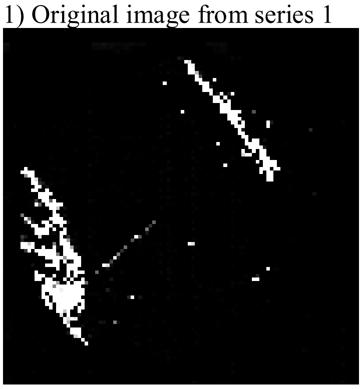
Determination of the image invariant requires following actions. Initially a line from the central point of the image to an actually considered border point is drawn. Subsequently, a distance from the central point to the first encountered "bright" point (counting from the central point) belonging to the previously fixed line is determined.



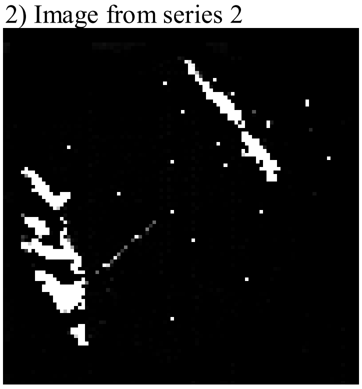
1) Original image from series 1



2) Image from series 2



3) Image from series 3



4) Image from series 4

Fig. 4. Hypothetical radar images used during researches

For the sake of the fact that every image is 100*100 pixels size fixing the invariant for every border point causes that we obtain compressed images of 400 units of information size. Such procedure is performed in case of the application of the image invariant together with FFT transform.

In order to obtain features vectors of 200 units of information size it is necessary to take into account solely first 200 values of the transform. In case of lack of the transform application every second border pixel is taken into consideration. Compression results of 124 radar images obtained from the Gdansk Bay area are presented below. For comparison, compression results of the FFT transform application (alone) and the simple projection method are also depicted.

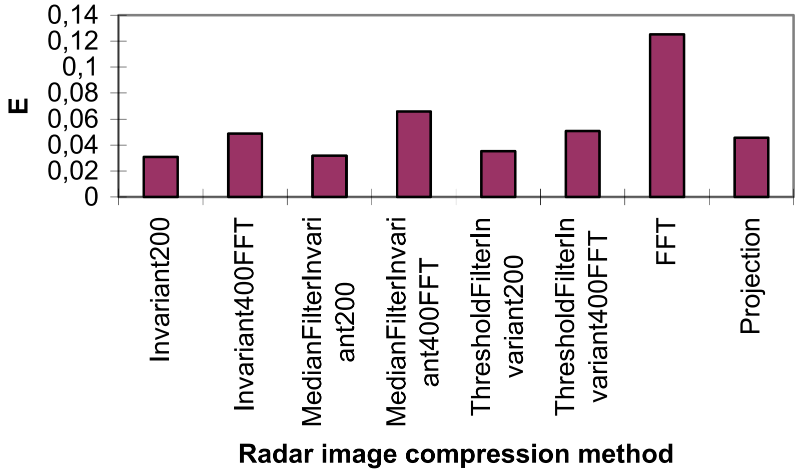


Fig. 5. The error (1) for various methods of radar image compression

CONCLUSIONS

Results presented on Fig 5 demonstrate that FFT transform disperse concentrations occurring in the radar images domain. The influence of the FFT is rather detrimental then positive what is apparent when we compare value of the error (1) for methods with the FFT application and without it. Every time FFT transform is used at the end of the calculation sequence it contributes to deterioration of compression method performance.

The application of filters which main task was elimination echoes of additional objects that could have a negative influence on the form of the compressed image, did not lead to performance improvement of any compression method. Filters did not deteriorate accomplished results but they also did not contribute to better performance.

It means that assuming not large error in the radar image orientating according to the North-South direction as well as a normal traffic on the considered stretch, that do not completely deform the observed area, the best solution among presented in the papaer is the invariant representation of the image without any additional transformations. It the best retains all relations occurring in the radar images domain.

REFERENCES

1. Kuchariew G., 1999: Processing and digital images analysis, Technical University, Szczecin (in Polish).
2. Praczyk T., 2004: Radar images compression for the need of a positioning coastal system and an assessment of this process, Annual of Navigation, no. 8, Gdynia.
3. Praczyk T., 2003a: Kohonen neural network in radar images compression, Scientific Bulletin no. 1, Naval University of Gdynia, (in Polish).
4. Praczyk T., 2003b: GRNN in radar images compression, Scientific Bulletin no. 3, Naval University of Gdynia. (in Polish).
5. Stateczny A., Praczyk T., 2003: Artificial neural networks in radar image compression, International Radar Symposium IRS 2003 Dresden.
6. Stateczny A., Praczyk T., 2002: Artificial neural networks in ships recognition, Gdańsk Scientific Society (in Polish).
7. Tadeusiewicz R., Flesiński M., 1991: Image recognition, PWN, Warszawa (in Polish).

Received September 2005
Reviewed November 2005