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Visualization method for scanning sonar images

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Abstract

The acoustic methods for underwater penetration are developing due to a constant need for more detailed sea floor imaging for hydrotechnics, navigation and geology. High frequency scanning sonar allows registering the reflected echo as traditional line images. Despite the high resolution, the lines display causes issues related to their polar arrangement and the raster nature of digital imaging. The proposed method shows different, nonlinear approach to sonar beam representation. The chosen solution improves overall readability of the image, its objects discrimination and, consequently, an interpretational gain.

Keywords: scanning sonar, sonar imaging, beam representation.

Metoda wizualizacji dla obrazu sonaru skanującego

Streszczenie

Akustyczne metody badań podwodnych rozwijają się ze względu na ciągłą potrzebę bardziej szczegółowego obrazowania dna dla zastosowań w hydrotechnice, nawigacji czy geologii. Wysokoczęstotliwościowy sonar skanujący pracujący jako samodzielne, stacjonarne, obrotowe urządzenie pozwala na rejestrację odbitego echa jako tradycyjnych linii sonarowych. Pomimo wysokiej rozdzielczości, wyświetlanie linii powoduje problemy związane z ich biegunowym rozkładem oraz rastrowym charakterem obrazów cyfrowych. Proponowana metoda prezentuje inne, nieliniowe podejście do reprezentacji odbitej wiązki sonarowej biorąc pod uwagę sposób rozchodzenia się fali dźwiękowej w środowisku wodnym. Metoda wizualizacji podejmuje problem pustych przestrzeni na brzegach obrazów oraz nadmiarowości informacji w ich centrum. Wybrane rozwiązanie poprawia ogólną czytelność obrazu, rozróżnialność obiektów i w efekcie zwiększa jego potencjał interpretacyjny, konieczny do prawidłowej analizy zobrazowanej sonarowo rzeczywistego charakteru dna.

Słowa kluczowe: sonar skanujący, zobrazowania sonarowe.

1. Introduction

Due to much worse light than sound wave propagation in water, the acousting methods for bottom examination are still the best way to aquire information about the seabed[1]. Lately a new solution for the detailed bottom imaging has been found. The high frequency stand-alone stationary scanning sonar is used for detecting objects not bigger than a can of soda. Thanks to its independence of the survey unit, which eliminates vast numbers of issues caused by its movement and a high frequency transducer, this sonar gives an opportunity to visualize underwater terrain almost as it was photographed.[2] However, the digital display of the sonar beams causes problems due to the comination of their polar character and the raster nature of digital imaging. The proper representation is not self-evident. The interpretational potencial of the image depends on a visualization method.

2. Scanning sonar

A scanning sonar is a technologically advanced device for direct sea bottom imaging, which allows representing the detailed lay of a bottom terrain avoiding signal distortion caused by the survey unit movement [3]. A high frequency transducer works in a polar mode while hanged on a tripod and placed 30 cm above the seabed. It slowly rotates (every specific angle) sending beams and receiving the reflected echo. The sonar software allows regulating the range, gain and scan speed (the angle at which the transducer is moved each time) of the scanning beam in clockwise or counter-clockwise direction [4].

Due to its completely underwater stand-alone way of work, the exact position of the transducer is unknown. However, this information, not like in traditional side scan sonar imaging, does not influence the appearance of later representation. Moreover, its stationary mode of work guarantees that all sonar lines have the beginning at the same position and the same length which form an exact circle. Image orientation towards the north is defined by a sonar build-in compass.

With a high frequency transducer (675 kHz) and ability to shorten the beam range to 10 meters the scanning sonar permits the mapping of objects of the size of a few centimetres (depending on the range).

a) b)

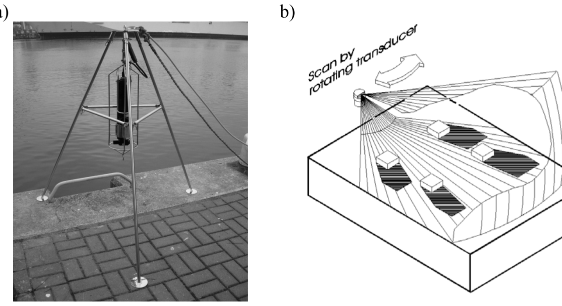


Fig. 1. Scanning sonar on a tripod (a), rotating scan scheme (b) [5]
Rys. 1. Sonar skanujący na tripodzie (a), idea sondażu obrotowego (b) [5]

3. Signal visualization problem

Each sonar beam is digitized and transformed to a singular line representing the scanned terrain with fixed number of pixels. Each line has to be visualized according to the angle under which the signal was received.

Because of the common beginning of lines and polar propagation, one pixel is likely to represent more than one beam (Fig. 2b).

That causes a problem of what to do with this redundant information. The solution can be either to average the pixels value or to choose one value out of all that overlap. The usual approach is to choose the last registered value.

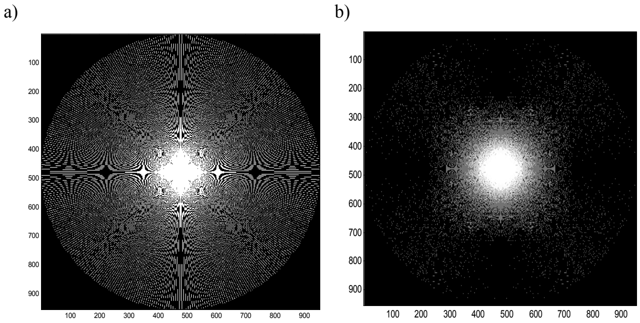


Fig. 2. Pixels coverage (a), distribution of overlap (b)
Rys. 2. Pokrycie obrazu (a), rozkład nakładania się punktów (b)

Even if the scanning speed is relatively slow (the angle is small), the further the lines go the more they come apart from each other. That causes large empty spaces in a scanning sonar polar image. Their areas depend on the fixed angle and the image matrix size. (Fig. 3) A similar problem of empty spaces between the lines was observed in the area of automatic mosaicing of the sonar image [7].

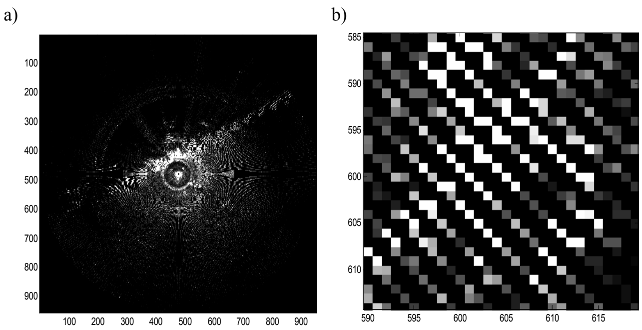


Fig. 3. Original scanning sonar image (a) and its magnified fragment (b)
Rys. 3. Oryginalny obraz sonaru skanującego (a) i jego powiększony fragment (b)

4. Methods for beam visualization

In any sonar imaging system the registered echo is represented as a pixel line. Knowing the nature of sound waves propagation, each of the pixels carries the information on echo from a much larger area than a particular pixel represents by its size. The line representation in case of a rotating beam is maybe the simplest but not an adequate solution. To improve the visualization process three different methods were considered.

The first approach was to fill the empty spaces by simple interpolation. Convolution as an averaging filter is commonly used to interpolate values in an image. In sonar imaging using this method for the whole image is not appropriate as it would average the key information carried in individual pixels causing the blur effect and having negative impact on object discrimination. The convolution matrix based on the adjacent values was applied only to the empty pixels.

The two other approaches are built on the basic assumption: the sonar beam is not indefinitely narrow because a sound wave expands while increasing the distance from its source. Every sonar line then should be considered as an image of a sector-shaped part of the bottom, so it should be visualized as a sector as well, instead of drawing it as a line (Fig. 4) (along which the transducer is moved each time) of the scanning beam in clockwise or counter-clockwise direction [4].

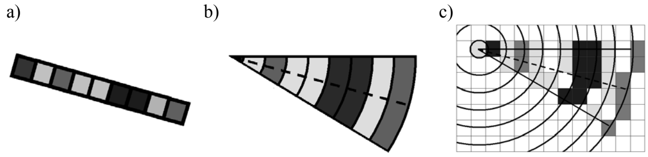


Fig. 4. Approaches to visualizing the line of the scanning sonar image; drawing a line (a), drawing a sector (b), sector drawn on a raster image (c)
Rys. 4. Metody wizualizacji pojedynczej linii obrazu sonaru skanującego; rysowanie linii (a), rysowanie sektora (b), sektor na obrazie rastrowym (c)

The sector angle is defined by a sonar scan speed while its symmetry axis direction should reflect the transducer direction. Visualizing successive lines should then give a completely covered, round image. The main problem is to draw samples as arc-shaped areas on a raster image avoiding aliasing effects. The simple algorithms resulted in images containing small empty spaces. Another visual effect, which one could expect, is that the samples lying far from the center of an image formed arcs (Fig. 5).

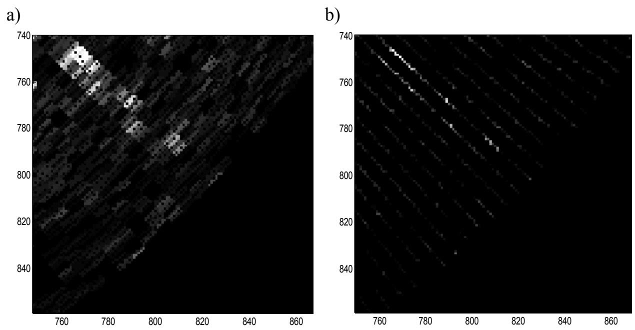


Fig. 5. Arc-shaped areas formed by sector draw (a), linear draw (b)
Rys. 5. Obszary w kształcie łuku powstałe przy rysowaniu sektorów (a), obraz uzyskany dzięki interpolacji (b)

The final approach was to consider the existence of directly adjacent lines and pixel values standing at the same position against the transducer (the image center). The empty area in-between the lines can be interpolated according to both values standing linearly at the same position. The main problem here is to define right pixels for interpolation, remembering the character of slant line representation in digital imaging. The result of this process is schematically shown in Fig. 6b. The effect is obtained by drawing inner lines in-between the originally represented beams. It is necessary to calculate the angle at which the new inner lines will be plotted. Their density depend on the relation:

$$\alpha = \arctan\frac{\gamma}{r}, \tag{1}$$

where: α – needed angle, γ – scan speed, r – lenght of the line.

Similar to the previous approach, the interpolated pixels lie along the arc of a circle crossing correspondent pixels on the adjacent lines (Fig. 6).

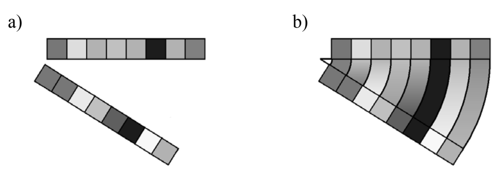


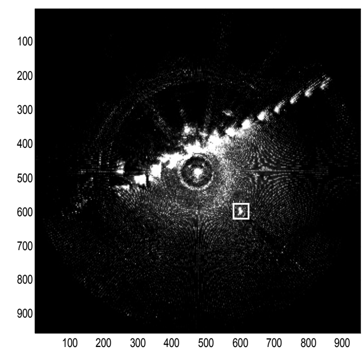
Fig. 6. Polar linear interpolation (a), two adjacent lines (b), interpolation in-between
Rys. 6. Biegunowa interpolacja liniowa (a), dwie sąsiednie linie (b), interpolacja między liniami (c)

5. Results

From comparison of the methods described above (Fig. 7-8) one can state that the best visual effect was reached by polar linear interpolation between the successive lines (Fig 7c, 8c). However, due to the matrix image character, it leaves a small number of pixels with no information. They are single elements and can be easily filled by basic interpolation methods e.g. nearest neighbour algorithm. The other possibility is to develop a more complex algorithm of polar interpolation which fills completely the space between the interpolated lines.

This visualization method for sonar images is consistent with the sonar data nature. It improves object discrimination, which has a significant impact on interpretational potential of an image. Further research should focus on a method for defining right pixel values to represent the image in case of data redundancy, which was mentioned earlier in the paper.

a)



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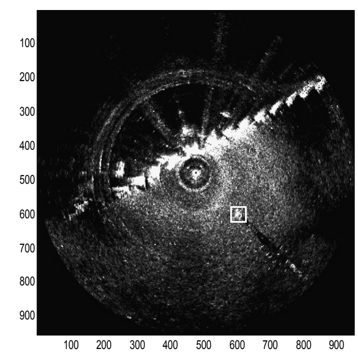

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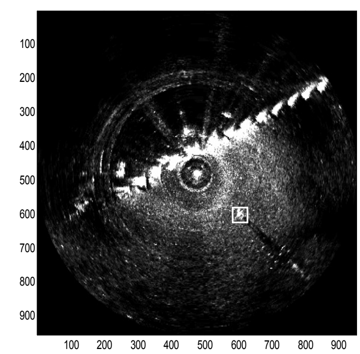
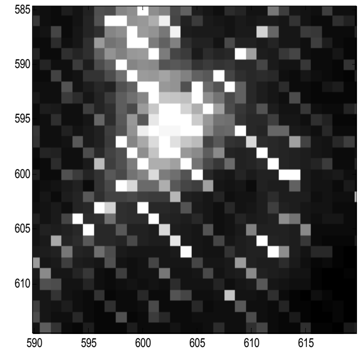


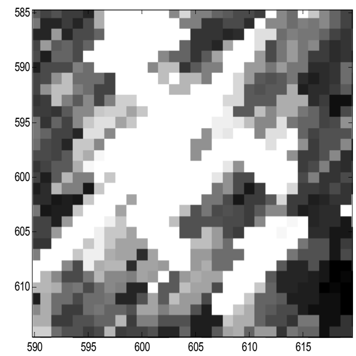
Fig. 7. Sample sonar image obtained by:
averaging (a), duplication algorithm (b), polar interpolation (c), marked regions are magnified in Fig. 8

Rys. 7. Obraz sonarowy oraz jego powiększony fragment uzyskany poprzez:
uśrednianie (a), duplikację (b), interpolację biegunową (c), zaznaczone fragmenty powiększono i przedstawiono na rys. 8

a)



b)



c)

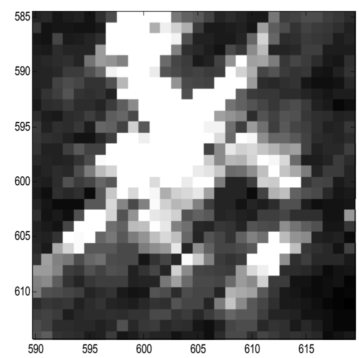


Fig. 8. Magnified fragments of the images of Fig. 7,
averaging (a), duplication algorithm (b), polar interpolation (c)

Rys. 8. Powiększone fragmenty obrazów z rys. 7,
uśrednianie (a), duplikacja (b), interpolacja biegunowa (c)

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