Using image processing to improve semaphore communication

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Abstract: Currently, the training of semaphore communication of younger signalmen on ships has been canceled due to a lack of hours for training. However, according to statistics, a quarter of accidents at sea occur due to a lack of coordination between vessels. They are due to the complexity of using radio links in close interaction, when a ship can get into the “dead zone”. An alternative may be optical communication. At the same time, signal floodlights are not always visible in bright sunshine. An alternative is semaphore communication. This article discusses the possibility of replacing the signalman with technical means using digital image processing. The main issue under consideration is the use of RGB color histograms to determine the transmitted signal.

1. Introduction
The issue of emergency communications in the interaction of vessels remains relevant at the present time. Along with radio communications on ships, signal lights and searchlights, color flags and similar traffic and communication systems are still used.

The semaphore communication is one of the most important systems for close ship interaction in emergency cases. However, due to the reduction in training time for junior signalmen, the training of relevant specialists has been canceled. As a replacement, a spotlight connection in Morse code is used. But this is not enough. For example, semaphore communication is necessary in case of sun brightening. [1]

According to the statistics, about half of the incidents at sea occur due to navigational reasons, half of which is the lack of information interaction between ships located close to each other. [2]

With close ship interaction, communication in the infrared (IR) range is not acceptable, since a sufficiently powerful radiation source should be used for transmission, which will negatively affect the health of people in the direction of its action. In the case of radio communications, smaller vessels may be in the dead zone. Thus, the optical range can provide information security in this case. [3,4]

To improve the safety of navigation and increase the reliability of the transmission of information, it is proposed to automate this type of communication, with minimal human involvement.

2. Semaphore device
Since the transmitting system must transmit data in such a way that the signal is decrypted not only by the receiving system, but by the signalman, the semaphore must have a form that is distinguishable and adequately perceived by a person. As a coloring of the transmitter, the following view is proposed in figure 1.
The transmitting device itself, such as a semaphore, should have two wide rotating shoulders, like the hands of an equal size, painted at the end in red, creating the appearance of signal flags. [5,6]

To transmit the signal, the shoulders are brought to the position corresponding to the transmitted symbol. In figure 1, this is a symbol - letter "N".

3. Signal processing at the receiving site

As a receiving device, a digital camera can be used, the data from which will be subjected to digital image processing.

This article will not discuss how to aim and focus the camera on the transmitter. Therefore, a description will now be made of digital image processing at the receiving side.

Since the device is supposed to be used at sea, where factors that complicate signal reception, such as fog, twilight time and so on, are possible, methods sensitive to changes in color and brightness of the image should be used for image processing. The color processing methods RGB correspond to these parameters.

The main methods of digital processing of histograms are: chi-square method, correlation method, histogram intersection method, Bhattacharya distance. However, the evaluation of image histograms is not the main direction of their application, although they can be used in this sphere [7-9].

In this regard, a method for estimating histograms by the average angle of the histogram was proposed. [10,11]

When finding the angle of the histogram, the gradation of brightness and the number of pixels corresponding to it are taken by the sides of the right triangle, then the average value for all the angles of inclination of the histogram is found (figure 2)

$$\bar{\alpha} = \frac{1}{N} \sum_{j=1}^{N} \alpha \cos \left( \frac{x_j}{\sqrt{x_j^2 + y_j^2}} \right) \frac{180}{\pi}$$

where $x_j$ - the value of the level of gradation of brightness; $y_j$ - the value of the number of pixels for a given gradation of brightness; $j = 5 ... 69$. $N = 64$. The range of values was chosen experimentally.

Figure 1. The coloring of the transmitter, the shoulders show the signal - letter "N".

Figure 2. An example of R range histogram.
The angle values will change when the position of the shoulders of the transmitter changes.

4. The methodology of the experiment
The experiment was carried out in the following sequence:

1. The images of the semaphore were compiled and the values of the histogram angles for them were found (figure 3, table 1). Values of $j$ for formula (*) are from 188 to 252.

2. Similarly, the values of the angles of the histograms for the image of a person with signal flags were found.

3. The image of a passenger cabin was taken (side view), which was considered as a calibration (figure 4a).

4. The image of the semaphore was applied to the calibration image (figure 4b, approximate).

5. Calibration was subtracted pixel by pixel from the obtained images.

6. The method of image estimation by the slope angle of the RGB histograms was applied to the result.

7. The images of the signalman were applied to the calibration image (figure 4c, approximate), and steps 6-7 were repeated.

For points 6 and 7, 6 images were taken, each including the “Delimiter” signal and the balanced signals “H” - “Z”, “B” - “F”. Since, after subtraction, the histogram values were shifted to the origin, the value of $j$ for formula (*) was chosen from 5 to 69.

![Figure 3](image3.png)

**Figure 3.** Measurement results: - a) codes obtained from images with a semaphore; - b) codes obtained from images with a signalman.

![Figure 4](image4.png)

**Figure 4.** Experimental images: - a) calibration; - b) deckhouse with a semaphore, transmitting a signal “H”; - c) deckhouse with a signalman, transmission of the Delimiter signal.
Table 1. The values of the slope angles of the RGB histogram for semaphore images and for images with a signalman.

| Symbols for international semaphore alphabet | Semaphor R | Semaphor G | Semaphor B | Semaphor RGB | Signalman R | Signalman G | Signalman B | Signalman RGB |
|---------------------------------------------|------------|------------|------------|--------------|-------------|-------------|-------------|---------------|
| Delimiter                                   | 6.46       | 6.46       | 6.46       | 6.46         | 42.44       | 42.44       | 42.44       | 42.44         |
| A                                           | 8.46       | 8.46       | 8.46       | 8.46         | 38.45       | 38.45       | 38.45       | 38.45         |
| B                                           | 8.96       | 8.96       | 8.96       | 8.96         | 40.91       | 40.91       | 40.91       | 40.91         |
| C                                           | 9.32       | 9.32       | 9.32       | 9.32         | 47.56       | 47.56       | 47.56       | 47.56         |
| D                                           | 9.11       | 9.11       | 9.11       | 9.11         | 41.97       | 41.97       | 41.97       | 41.97         |
| E                                           | 9.82       | 9.82       | 9.82       | 9.82         | 44.42       | 44.42       | 44.42       | 44.42         |
| F                                           | 9.08       | 9.08       | 9.08       | 9.08         | 43.4        | 43.4        | 43.4        | 43.4          |
| G                                           | 10.09      | 10.09      | 10.09      | 10.09        | 42.18       | 42.18       | 42.18       | 42.18         |
| H                                           | 8.14       | 8.14       | 8.14       | 8.14         | 43.15       | 43.15       | 43.15       | 43.15         |
| I                                           | 10.93      | 10.93      | 10.93      | 10.93        | 48.87       | 48.87       | 48.87       | 48.87         |
| J                                           | 10.58      | 10.58      | 10.58      | 10.58        | 47.34       | 47.34       | 47.34       | 47.34         |
| K                                           | 10.42      | 10.42      | 10.42      | 10.42        | 47.66       | 47.66       | 47.66       | 47.66         |
| L                                           | 10.83      | 10.83      | 10.83      | 10.83        | 47.16       | 47.16       | 47.16       | 47.16         |
| M                                           | 10.85      | 10.85      | 10.85      | 10.85        | 45.2        | 45.2        | 45.2        | 45.2          |
| N                                           | 9.28       | 9.28       | 9.28       | 9.28         | 48.99       | 48.99       | 48.99       | 48.99         |
| O                                           | 10.46      | 10.46      | 10.46      | 10.46        | 44.61       | 44.61       | 44.61       | 44.61         |
| P                                           | 10.69      | 10.69      | 10.69      | 10.69        | 46.94       | 46.94       | 46.94       | 46.94         |
| Q                                           | 10.21      | 10.21      | 10.21      | 10.21        | 47.7        | 47.7        | 47.7        | 47.7          |
| R                                           | 11.1       | 11.1       | 11.1       | 11.1         | 43.86       | 43.86       | 43.86       | 43.86         |
| S                                           | 10.97      | 10.97      | 10.97      | 10.97        | 47.72       | 47.72       | 47.72       | 47.72         |
| T                                           | 10.57      | 10.57      | 10.57      | 10.57        | 52.49       | 52.49       | 52.49       | 52.49         |
| U                                           | 11.5       | 11.5       | 11.5       | 11.5         | 53.27       | 53.27       | 53.27       | 53.27         |
| V                                           | 10.2       | 10.2       | 10.2       | 10.2         | 47.46       | 47.46       | 47.46       | 47.46         |
| W                                           | 11.11      | 11.11      | 11.11      | 11.11        | 44.73       | 44.73       | 44.73       | 44.73         |
According to the results, the following graphs were obtained (figure 5):

![Graphs](image)

**Figure 5.** Measurement results: - a) codes obtained from images with a semaphore; - b) codes obtained from images with a signalman.

5. Conclusions

It can be seen from figure 3a and figure 5a that the signals received from the semaphore are similar to each other, both in individual measurements and in measurements on the model. That is, individual dimensions can be used to create a table of the relationship of code and value.

It should be noted that for signals received from changing the position of the signalman’s flags, the angles of inclination of the histograms also change. Part of the repeated values of the angles, when transmitting signals by a person, will be regarded as two signals. But they will not affect the general information during the signal transmission, since the number of such repetitions is small relative to all signals. Moreover, as can be seen from figure 3b and figure 5b, the values in different ranges will vary slightly, which makes it possible to separate similar signals.

Thus, the proposed method can be used in cases where it is impossible or difficult to use other ranges than optical. It allows to evaluate the signal transmitted both from the semaphore and from the person, which increases the reliability of communication during the transmission of information.

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