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Development of performance measures based on visibility for effective placement of aids to navigation

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ABSTRACT: *In order to develop the challenging process of placing Aids to Navigation (AtoN), we propose performance measures which quantifies the effect of such placement. The best placement of AtoNs is that from which the navigator can best recognize the information provided by an AtoN. The visibility of AtoNs depends mostly on light sources, the weather condition and the position of the navigator. Visual recognition is enabled by achieving adequate contrast between the AtoN light source and background light. Therefore, the performance measures can be formulated through the amount of differences between these two lights. For simplification, this approach is based on the values of the human factor suggested by International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA). Performance measures for AtoN placement can be evaluated through AtoN Simulator, which has been being developed by KIOST/KRISO in Korea and has been launched by Korea National Research Program. Simulations for evaluation are carried out at waterway in Busan port in Korea.*

KEY WORDS: Aids to navigation; Placement; Visibility; Performance measures; AtoN simulator.

INTRODUCTION

Aids to Navigation (AtoN) is an additive devices for navigation that inform navigators using human vision and can guide navigators to safe watercourse. The problem with placement of AtoN is to determine where to position AtoN after a waterway has been selected under the criteria set by a previous investigation for a safe voyage. Regulation and expert experience are only guidelines for placing AtoN. This paper describes an initial effort to investigate the effect of placement of AtoN. The greatest requirement for AtoN for navigators is visibility because AtoNs are additive devices through human vision. In this paper, we concentrate on visual AtoNs which make up the majority of AtoNs in use.

Visibility of AtoN depends on the light source, the weather condition, and the position of navigator on the sea. The visible range that the navigator can detect and identify AtoN within is increased according to the luminous intensity of the light source. The weather condition with clear air allows the visible range to be enlarged compared to the weather condition with fog. According to the position of navigator including the eye level, AtoN may be interfered with the background light or the other AtoNs beside the eye level affects the geographical range due to the curvature of the Earth.

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The light emitted from an AtoN is attenuated by dispersion and absorption during passage through air and the particulates within it. Thus these air conditions, and the distance, between AtoNs and the navigator set the actual level of attenuation. For estimation of visibility, the light arriving at the navigator is quantified as the luminous incidence or illuminance, and is termed the 'acquired illuminance' when perceived by the unaided eye.

Visual recognition is enabled by achieving adequate contrast between the target light and the background light (ITU-R, 2007; Waldman and Wootton, 1992). Therefore the differences in illuminance between the two lights allow the target light to be identified. Based on this fact, if the threshold of illuminance is determined so as to include the effect of the background light, it can be used as a criterion to be compared with the acquired illuminance. The threshold of illuminance can be defined by the minimum illuminance required for recognition, and is termed the 'required illuminance'. Consequently, the AtoN may be visually recognized by the navigator if the acquired illuminance is greater than the required illuminance.

The placement effect of AtoNs can be quantified by a performance measures for visibility, which has to contain the visibility for all AtoNs according to their placement. The amount of visibility can be described by an excess of acquired illuminance over required illuminance. Therefore the performance measures for visibility can be comprised of the total amount of illuminance differences for all AtoNs to be considered.

For the evaluation of the performance index for visibility, the simulation calculating the performance measures is carried out with the AtoN placement by AtoN Simulator (Kim et al., 2013), which has been developed by KIOST/KRISO in Korea and has launched by Korea National Research Program. For reasonable simulations, AtoNs are selected from the pre-installed AtoNs at Busan port in South Korea. The proposed method is evaluated by investing the results from simulation with example placement.

This paper is an expanded version of the previous studies (Fang, et al., 2013; 2014).

PREDICTION OF REQUIRED ILLUMINANCE

International Association of marine aids to navigation and Lighthouse Authorities (IALA) recommends the required illuminance which is needed to identify AtoN (IALA Recommendation, 2008). It does not mean the quantities for navigator to be able to figure out the existence of the AtoN, but the quantities for one to able to figure out the instruction of AtoN. Visibility of AtoN assumes that if the illuminance acquired on the eyes of the navigator is bigger than the required illuminance, the navigator can identify what the AtoN informs one of.

The required illuminance for visibility is given by 2×10^{-7} lux for night and given by 1×10^{-3} lux for day. One for night is based on the assumption of no background light. One for day is based on the assumption of meteorological conditions with bright cloud.

The required illuminance for night needs to be compensated by containing the effect of the background light since the visual recognition is carried out by getting the light contrast between the interested light source and the background light. The required illuminance has to be determined according to the status of the background light. The state of the background light is mainly changed with the existence of the background light, the distributed area, and the intensity of the light source.

While the required illuminance is given by 2×10^{-7} *lux* for no background light, the required illuminances are recommended by 2×10^{-6} *lux* for minor background light and by 2×10^{-5} *lux* for substantial background light, respectively (IALA Recommendation, 2008). Let E_t denote the required illumination in lux and p_{rb} denote the ratio of the background light. p_{rb} is defined to employ the effect of the background light and is in the range from 0 to 1. It is defined that no background light corresponds to $p_{rb}=0$; minor and substantial background lights correspond to $p_{rb}=0.5$ and $p_{rb}=1.0$, respectively. Based on the relationship which Fig. 1 shows and using a linear interpolation method, the logarithm of the required illuminance is formulated by employing the ratio of background light as follows

$$\log(E_t)=\log\left(2\times10^{-7}\right)+\left[\log\left(2\times10^{-5}\right)-\log\left(2\times10^{-7}\right)\right]p_{rb} \tag{1}$$