Fast multipath generation method for underwater acoustic communications networking system simulation

Hyeong-Won Jeon, Jeong-Min Ryu, Heung-No Lee*
School of Information and Communications, GIST
{hyeongwon, jmryu, heungno}@gist.ac.kr*

Abstract

In underwater acoustic communications networks, channel modeling is one of important issues. In particular, distance calculation is an essential part. In this paper, we propose equations to calculate distance of the reflection path. Multipath generation via the proposed method shows exactly same result with the geographical ray tracing method with benefits of low complexity.

Keywords: underwater, multipath, channel modeling

1. Introduction

Among various research issues in underwater, reliable channel modeling is essential since underwater acoustic channel (UAC) is complex and difficult to predict [1][2]. Especially, the distance calculation of the reflection path is necessary to predict channel response. Thus, researchers have tried to calculate the distance of reflection path via geographical ray tracing method introduced in [3].

However, there is some limitation in such a method to be expandable to multiple sensor networks. As increasing the number of sensor nodes, the number of channels among sensor nodes increases geometrically.

In this paper, we aim to reduce the required steps and time in calculating the distances of reflections. To achieve such a goal, we propose a method.

2. Distance calculation

2.1. Channel response

The channel response of each reflected p-th path is represented as function of carrier frequency f, number of reflection times on surface n_{sp} and bottom n_{bp}, gazing angle θ_p and distance l_p [3] as follows.

$$\overline{H}_p(f) = \frac{\gamma_s^{n_{sp}} \gamma_b^{n_{bp}}(\theta_p)}{\sqrt{A(l_p, f)}}, \quad (1)$$

where γ_s and γ_b are reflection coefficients [3].

The impulse response of UAC can be modeled like

$$h(t) = \sum_p h_p(t - \tau_p), \quad (2)$$

where h_p is an inverse Fourier Transform of p-th path channel response and $\tau_p = (l_p - l_0) / c$ is an arrival time gap between direct path and the each reflection path.

2.2. Geographical ray tracing method

The geographical ray tracing method determines distance of the path by using simple triangular method. Assuming flat surface and bottom conditions in UAC as shown in Fig. 1, to calculate the distance, (*i*) find the a_1 and b_1, (*ii*) find the a_2 and b_2, (*iii*) calculate the distance between tx and a_1, i.e., d (tx, a_1), (*iv*) calculate the distance between b_2 and rx, (*v*) calculate the distance between a_1 and b_2 via multiplexing number of reflection n to distance between a_1 and b_1 and (*vi*) combine whole things like Eq. (3). Further, to calculate θ_P, we used the trigonometric function.

$$l_p = d(\text{tx}, a_1) + d(\text{rx}, b_2) + (n-1) \cdot d(a_1, b_1). \quad (3)$$

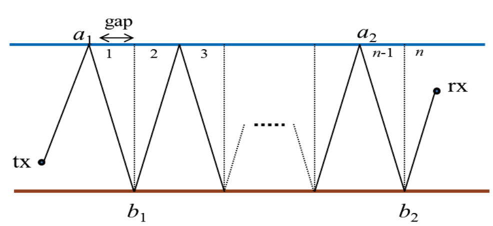

Figure 1: A reflection path between node and buoy

2.3. The proposed method

We start with an example to illustrate the proposed method. See Fig. 2. (a) for this example. To calculate the distance of reflection path from *A* to *B*, i.e., red dashed line, we (*i*) move *B* to *B'* against the sea surface, (*ii*) calculate the length of the base line, i.e., *d*, (*iii*) calculate the height of the triangle, i.e., $2h - a - b$ since the distance from surfact to point *A'* is $h - a$ and from surface to *B'* is $h - b$ and (*iv*) calculate the distance by using the Pythagorean Theorm, which is $l_p^2 = d^2 + (2h - a - b)^2$. It can be generalized but we omitted such procedure in this paper due to a limitaion of space.

We aimed at applying such an approach to more complex cases and obtained general equations about distance of reflection path as follows.

$$l_p = \sqrt{d^2 + (2h \cdot n_{sp} + \alpha a + \beta b)^2}\ , \tag{4}$$

where α and β are classification value according to first reflection position (surface or bottom) and total number of reflection (odd or even). As details, $(\alpha, \beta) = (-1, -1)$ is classification value for reflection path having first reflection on surface and total odd number of reflection like red dashed line in Fig. 2. (b). Other cases, i.e., $(\alpha, \beta) = (+1, +1)$, $(-1, +1)$ and $(+1, -1)$ are for reflection path like blue dashed line, i.e., having first reflection on bottom and odd number of reflection, violet dashed line, i.e., having first reflection on surface and even number of reflection and green dashed line, i.e., having first reflection on bottom and even number of reflection.

As input the parameter d, h, n_{sp}, a, b, α and β to these equations, the distances of all possible reflection path are calculable immediately.

3. Performance comparisons

We generated impulse response via two methods under the channel parameters; $h = 100$ m, $d = 1{,}000$ m, $a = 40$ m and $b = 80$ m. As shown in Fig. 3, both results are exactly same. However there is difference on calculation time like Table 1.

Table 1 shows that the proposed method based on distance equation, i.e., Eq.(4)-(7), is over 800 times quicker than ray tracing method.

4. Conclusions

We obtained general equation to calculate the distance of reflection path in UAC. Further we verified that our proposed scheme not only is exact but also benefits in terms of calculation time.

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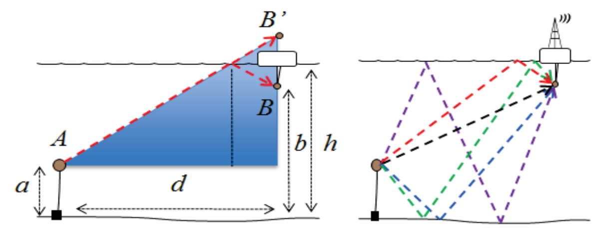

Figure 2: Simple example of reflection path

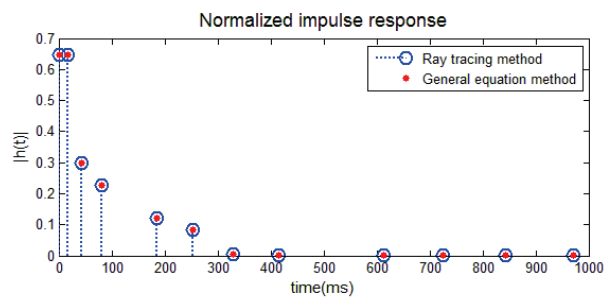

Figure 3: Impulse response comparison

Table 1: Average time comparison

Meth. / # of ch.	Ray tracing meth.	General eq. meth.	Speed rate
100	6.5 ms	7.8941 μs	1 : 823
1,000	6.4 ms	7.7770 μs	1 : 823
10,000	6.5 ms	7.6337 μs	1 : 851
100,000	6.5 ms	7.5132 μs	1 : 865