Visual Assessment of Landing-site Geography on Landing Feasibility

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Abstract. The primary problem and critical procedure that must be considered for landing operations is landing-site geographic environmental elements. Based on the impact of various geographical factors on landing, such as submarine slope, submarine characteristics, tides, tidal waves, this paper simultaneously applied the methods of mathematical description, quantitative evaluation, three-dimensional visualization, and integration analysis of multiple factors. Taking dynamic changes of geographical elements into consideration, a visual measurement for landing alternatives on account of geographic environment background was hypothesized, and the dynamic comprehensive evaluation was displayed. Experiments verify the effectiveness and superiority that mentioned, and can provide reference for the probability of landing.

1. Introduction

The primary problem and critical procedure that should be highly considered for landing operations is landing-site geographical elements. It impacts and restricts the embarkment of offshore workers and supplies, shipping, transfer and assault, but also air force, the firepower support of artillery and missile force. For picking up geographic environment elements of landing sites, submarine slope, submarine characteristics, tides, tidal waves need to be involved in major discussion. In the previous researches, the usage of mathematical description and three-dimensional visual expression of the landing area were less, and did not perform comprehensive dynamic changes of geographic environmental factors which is difficult to proceed quantitative assessment and lack of operability[1-3]. Therefore, there exist significant meanings in practically constructing a visual environment model and a digital evaluation model of landing-site, intuitively expressing the three-dimensional geographic environment of landing area, and scientifically serving the landing command decision.

In this paper, the geographic elements of landing-site were visual modeled and simulated respectively, the integrated visual simulation of the landing sites geographic environment were realized as well. Furthermore, analysis through the impact of each geographic environment elements on feasibility of landing has been proceeded. The visualization evaluation of the landing feasibility for each geographical factor was realized, integrate the display in implementing, estimated values of the submarine slope and submarine characteristics under influence of dynamic water level within a certain scope, and show dynamic comprehensive assessment.
2. Visual modeling of geographic features of landing-site

2.1 Visual modeling of seabed slope

2.1.1 Triangle-based calculation of submarine slope

This paper has fully utilized the characteristic of the triangular mesh of the TIN model, and adopted calculation method of submarine slope based on triangle[4]. Using the fitting place method, calculation method is: the triangle’s plane equation is determined by the coordinated of three vertices (x, y, z) of triangle. The elevation change rate in X and Y directions is calculated accordingly, and the slope of triangle \( f_x \) and \( f_y \) is calculated by applying a simplified difference formula. The specific formula is as follow:

\[
z = f(x, y) = \frac{A}{C}x - \frac{B}{C}y - \frac{D}{C}z
\]

\[
A = y_1(z_2 - z_3) + y_2(z_3 - z_1) + y_3(z_1 - z_2)
B = z_1(x_2 - x_3) + z_2(x_3 - x_1) + z_3(x_1 - x_2)
C = x_1(y_2 - y_3) + x_2(y_3 - y_1) + x_3(y_1 - y_2)
D = -Ax_1 - By_1 - Cz_1
\]

\[
f_x = \frac{A}{C}
\]

\[
f_y = \frac{B}{C}
\]

\[
slope = \arctan \left( \frac{f_x^2 + f_y^2}{\pi} \right) \times 180
\]

Based on the gradient of triangle, this paper further proposed a slope calculation model depends on triangular mesh points[4,5]. Taking Figure 1 as an example, the calculation principle is:

1. Find all the triangles around point \( O \);
2. Calculate the elevation change rate in X and Y directions of each triangle at point \( O \);
3. Average the elevation rate in X and Y directions of each triangle and point \( O \), and obtain the average value;
4. Calculate the slope of point \( O \) by using a simplified difference formula;
5. Calculate the slope of point \( O \) along the landing direction.

According the the above method, the submarine slope of landing area could be visualized in three-dimensional version. Figure 2 is a three-dimensional display image of submarine slope based on the triangular mesh point, wherein the gray area is land. This method is unaffected by the number of triangles around the vertex, and error is relatively small.
Visual modeling of submarine bottom characteristics

The substrate Voronoi polygon is first generated, and then proceed boundary processing and combine with bottom material, so as to generate a bottom polygon. The steps to generate a bottom polygon from the set of discrete points are as follows:

1. Generation of substrate triangulation [6]
2. Generation of substrate Voronoi [7]
3. Boundary processing of substrate Delaunay Voronoi polygons

This paper used a triangular mesh convex shell to replace the above rectangular boundary. For a point on a non-convex shell beyond the boundary, the Voronoi polygon is clipped with triangular bulge. For the point on the convex shell, the midpoint of the line connecting the growth point of convex shell to adjacent convex growth point, which together with the convex center and circumscribed center of surrounding triangle to constitute a Voronoi polygon.

4. Merging of substrate Voronoi polygons

The variation of sediment distribution in the seafloor is usually continuous. During the generated process of Voronoi polygon, if properties of adjacent polygons are the same, merge adjacent Voronoi polygon elements of the same nature, until the surrounding polygons are no longer the same type of primitive polygons. In here, the merged simple polygon sequence is the primitive polygon.

5. Display of submarine bottom characteristics (SBC)

Read submarine bottom characteristics data and generate submarine bottom characteristics polygon, quickly construct the Delaunay triangulation, traverse triangles in the model, and calculate the normal vector value of each vertex. When calculation the normal vector of vertex, need to take the mean value of peripheral normal vector, and use corner method to determine the submarine bottom polygon. Make sure the nature of substrate, construct a three dimensional model and display. According to the above method, the three dimensional visual representation of the submarine bottom characteristics of landing area is shown, wherein the gray area is land like Figure 3.
2.3 Visual modeling and expression of tides and tidals

2.3.1 Visual modeling of tides

According to the regular of tidal changes, the future of tides is estimated, which is called tidal forecast. The basic principle of tidal forecasting is the inversion of tidal analysis. On the one hand, a known tidal harmonic constants is a necessary; on the other hand, astronomical parameters are needed as well, which is the commonly used harmonic forecasting method[8]. The expression of blending method is:

\[
\zeta(t) = A_0 + \sum_i f_i H_i \cos[\omega_i t + (V_0) + u_i - g_i] 
\]

\(i\) is the number of tidal waves; \(A_0\) is the average sea surface; \(f_i\) is intersection factor; \(\omega_i\) is tidal angle rate; \((V_0)\) represents the initial phase angle of Greenwich Astronomy (used to estimate the start date); \(t\) is time for the district; \(u_i - g_i\) is the angle of correction of astronomical angle. Dividend harmonic constant involves: \(H_i\) for the amplitude of the tide and \(g_i\) for the special retardation of the tide. Since the changes of \(f_i\), \(u_i - g_i\) are slow, therefore need to take their literal during a certain time period.

2.3.2 Visual modeling of tidals

This paper adopted the trend harmonic constant and used the harmonic method to forecast the trends. The principle is as follows: the description of the current is similar to that of the tide. At a certain point in the sea, it is necessary to superimpose the vibration in two mutually orthogonal directions, in the north and east. The component decomposes tidal currents, combines the given trend harmonic constant, calculates the flow velocity and flow direction of the tidal current to realize the forecast of tidal currents[6]. Its formula is as follows:

\[
\begin{align*}
\bar{u}(t) &= u_0 + \sum_i f_i U_i \cos[\omega_i t + (V_0) + u_i - \zeta_i] \\
\bar{v}(t) &= v_0 + \sum_i f_i V_i \cos[\omega_i t + (V_0) + u_i - \eta_i] \\
W &= \sqrt{u^2 + v^2} \\
\theta &= \arctan\frac{v}{u}
\end{align*}
\]

In the formula, \(u_0\), \(v_0\) means the average tidal currents, \(U_i\), \(V_i\) is the amplitude of each tidal current, \(\zeta_i\) is the specified lag angle of north component of tidal current, \(\eta_i\) represents the specified lag angle of east component, \(W\) indicated the magnitude of tidal current, \(\theta\) indicated the direction of tidal current.

2.3.3 Visual representation of tides and tidals

In landing site, the grid used in 21×15 horizontal direction, and grid size is 1000m×1000m, \(X\) axis is positive to west, \(Y\) axis is positive to north, and \(Z\) axis is positive to upward. The vertical direction indicates water depth direction, which is divided into 5 layers as: 0m, 2m, 5m, 10m, and 20, and the horizontal direction of grid is shown in Figure 4. calculate tidal level value of each grid point and flow direction and flow velocity of tidal current, then generate a log file, one record per grid point, record the outer loop from east to west, and record the inner loop from south to north.
Fig. 4. Grid diagram of tides and tidals

1) Visualization of tides

The visualization of tides data mainly includes visualization of single-point tidal and regional tides data[9]. The visualization of single-point tide data is mainly realized by reading tide process data, that is, tide level change with time, and then drawing tide curve. The visualization of regional tides data is majorly to read tide level data of the entire area at a certain moment, and then visualize by means of data filling or rendering. Figure 5 is a three-dimensional display of tides data in difference time zones.

(a)Time 1  (b)Time 2

Fig. 5. Visualization of tides

2) Visualization of tidals

The tidals is one of the elements of dynamic change. The visualization of tidals data is mainly the singly point tidals, regional tidals data, and dynamic demonstration of regional tidals[10]. This paper consider integrated display effect with other elements of geographical environment, then adopted vector expression method if the large surface flow field. The length of arrow indicated flow velocity and the direction of arrow indicated flow direction. This paper further combined reality of vertical tides stratification, and visualized the tidals of different depth layers like Figure 6.

(a)h=2m  (b)h=10m

Fig. 6. Visualization of tidals

2.4 Visual modeling of ocean waves

2.4.1 Directional spectrum model of ocean waves

(1) Wave spectrum

The random process of waves has stability and continuum of various status, and energy of the waves is mostly provided by a sine wave in a narrow frequency range.

\[
S(\omega) = \frac{1}{\Delta \omega} \sum_{\omega} \frac{1}{2} a_n^2
\]  

(8)
\( a_n, \omega_n \) is the amplitude of constituent wave and circular frequency respectively. \( S(\omega) \) represents average energy in the frequency interval \( \Delta \omega \), which is known as frequency spectrum as well.

(2) Wave direction spectrum

The actual sea surface is three-dimensional, and energy distribution is not only within a certain frequency range, but also in a wide rage of directions. The formula could be consisted with a number of amplitudes \( a_n \), frequencies \( \omega_n \), initial phases \( \varepsilon_n \), then add cosine waves propagating in an angular direction \( \theta_n \) with the axis \( x \) on \( x \), \( y \) horizontal plane[9]. As shown below:

\[
\eta(x,y,t) = \sum_{n=1}^{\infty} a_n \cos \left[ \omega_n t - k_n (x \cos \theta_n + y \sin \theta_n) + \varepsilon_n \right] (9)
\]

\( k_n \) represents the number of \( n \)th tidal constituent, \(-\pi \leq \theta_n \leq \pi\).

2.4.2 Three-dimensional visualization and integrated display of ocean waves

(1) Waves meshing and expression

The simulation of waves first constructs the mesh model of wave[11]. In this paper, wave front mesh of size \( m \times n \) is constructed by spatial point \((x, y, z)\), which is shown in Figure 7. In here, \((x, y)\) is horizontal position of spatial point, while \( z \) represents for the simulated value of all the wave amplitudes at a certain time \( t \). Let the array for storing each grid point \( z \) value be \( h[i, j] \), which is calculated as shown in the following equation:

\[
h[i,j] = \sum_{n=1}^{N} \sqrt{S(\omega_n, \theta_n)} \Delta \omega \Delta \theta \cos \left[ \omega_n t - \frac{\omega_n^2}{gh} (j \cos \theta_n + i \sin \theta_n) + \varepsilon_n \right] (10)
\]

Fig. 7. Grid diagram of waves

(2) Visualization of waves

For the simulation of waves in the text, the number of constituent waves has a limited amount. Too few simulation effects loses the sense of reality, too many wave fronts will appear beating phenomena. This paper has appropriately selects 32 waves sequences, and take wave simulation effect at a certain wind speed \( U \) and grid resolution, which as shown in Figure 8.

Fig. 8. Visualization of waves
3. Integrated display
Based on layered display technology and fusion technology to integrated display of submarine topography, tides and tidals; and the integrated display of submarine topography, tides and waves are realized [12, 13, 14]. For analyzing influence of different elements of geographical environment on the feasibility of landing and providing visual assessment of the feasibility of landing, integrated analysis of multiple factors provide aid decision making.

3.1 The integrated display of submarine topography, tides and tidals
In actual conditions, the water level is not static. As time goes by, water level will change, the flow rate and flow direction will change as well. Through integrated display of seabed topography, that tides and currents at different times, the dynamic changes of marine environment could be reflected from a certain angle[15]. Figure 9 is a three-dimensional integrated display of seabed topography which set tides and tidals at different times.

![Fig. 9. The submarine topography, tides and tidals](image)

3.2 The integrated display of submarine topography, tides and waves
Waves are different from tides. Even though they are all dividend grids, the data of tides does not exist beyond the surface of water and waves are displayed throughout the grid (including land). For the integration of waves and topography, the part below the sea shows waves, while the part above the sea is replaced by land[16]. Figure 10 shows the integrated display of submarine topography, tides and waves at high and low tides.

![Fig.10. The submarine topography, tides and waves](image)

4. Experiment and analysis
This paper conducted experiments on a landing site, analyzed the affect of submarine topography, submarine characteristic, tides, tidals and waves on the feasibility of landing and could be partitioned into three classifications as available, accessible and unaccessible which corresponding levels set for different colors. Integrated analysis and display are required in order to judge comprehensive effects of each element. In the cases of integrate analysis of various factors, the algorithm is applied to lower level. The three-dimensional visualization static and dynamic evaluation of feasibility of landing is carried out separately, and landing level and color correspondence condition is shown in Table 1.

| Table 1 | Landing level and color correspondence table |
|---------|-----------------------------------------------|
| Landing level | Tidal(Knot) | Color setting |
| Available     | <1          | ![green]     |
| Accessible    | >1; <2      | ![yellow]    |
| Unaccessible  | >2          | ![red]       |
4.1 Assessment of landing feasibility in a static environment

The best time for a warship landing is high tide moment[17]. When static assessment is carried out to visually evaluate the feasibility of landing conditions under various geography elements, usually select high tide moment and conduct experiments on landing site. During the integration process, firstly need to estimate landing level for each grid of submarine sloop and submarine bottom characteristic to obtain a proper landing level assessment by the above criteria. Then, integrate with tidal and receive integrated landing feasibility figure. The experiment is shown in Figure11.

![Fig.11. In static environment](image)

It could be captured from the figure that the analysis of local areas meets the requirement of landing, and obtain landing feasibility strip map that influence by tidal in a static environment.

4.2 Assessment of landing feasibility in dynamic water level

Actual landing operations are generally initiated 2-3 hours before high-tide, and it is not possible to perform at only one time[17]. During the period, water level could not be static. The difference of water level will cause a change of 0-5m depth interval, and corresponding tidal will change as well. Therefore, it is necessary to visually evaluate the landing feasibility based on dynamic water level studies.

In traditional studies of submarine slopes, a sciatic approach without considering the change of water level. In practice, submarine slopes in different locations are different. With the fluctuation of water level, the area near instantaneous water side line of landing is changing constantly, while the slope of seabed at landing site will have a probability to change greatly. The surrounding quality will change, since the change of water level affects landing site. This paper chose two moments of high tide and mean sea level so that a dynamic visualization analysis could be achieved. As shown in Figure 12, it is the result of the feasibility comparison between high-tide moment and mean sea level moment.

![Fig. 12. In dynamic water level](image)

It could be drawn from the figure that tidals and waves could have an overall impact on the landing feasibility.

5. Conclusions

This paper studied a three-dimensional visual assessment methods of landing site feasibility towards landing-site geographic environment and realized visual expression of submarine topography, submarine characteristic, tides, tidals and waves on landing feasibility. Moreover, this paper proceeded integrated display, estimated and comprehensive expressed landing feasibility conditions under both static and dynamic environments. Experiments show that the proposed method increases three-dimensional display effects, and the expression for terrain information is intuitive and abundant, compared with traditional method. It is superiority and provides an accurate and scientific reference.
for the feasibility of selecting landing-site.

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