Simulation of coastal beach stability and coastal running based on embedded image system

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Abstract
Approximately 80% of the sandy beaches along the coastline have been eroded, resulting in the coarsening, narrowing of sandy beaches, steeper slopes, accelerated shoreline retreat, loss of a large amount of coastal land, and destruction of the ecological environment. Coastal beach stability assessment technology, through more than 1 year of field data observation, the stability analysis of the coastal beaches, from the observations of various data shows that the coastal beaches are in a dynamic and stable equilibrium state during the measurement period; around the beach, there is no large-scale erosion and accumulation. Moreover, because society is progressing, people’s concept of life is also constantly changing, and the requirements for health are also constantly improving. People have begun to advocate sports, and running has become people’s main sport due to its low economic cost and convenience. In this way, even many people who have no experience in running start to run. However, due to the constraints of the runners’ physical fitness and the surrounding sports environment and other objective conditions, coupled with the current running styles and even insufficient research on the prevention of injuries during the running process, they cannot meet the actual needs of people during the running process. People who experience sports are more likely to get injured. Using the embedded image system to conduct sustainable simulations of people running along the coast can fully analyze and investigate the injuries related to running, so that people can exercise more scientifically and promote running along the coast. At the same time, in order to improve the image display effect and algorithm efficiency of embedded image processing system in low resolution environment, Bresenham anti aliasing algorithm of region cloth is improved. The combination of linear scan conversion algorithm and region anti aliasing algorithm can effectively improve the drawing speed and operation efficiency of anti aliasing algorithm.

Keywords Embedded image · Coastal beach stability · Coastal running · Sustainable simulation

Introduction
Coastal erosion is a global problem. Most coastlines in the world are in a state of erosion. Coastal erosion in China is also quite common. Coastal erosion not only squeezes the land resources in the coastal zone, it directly harms the living environment of marine beings, and causes irreversible damage to the surrounding natural environment, and even threatens the lives of organisms in severe cases (Panagopoulos et al. 2006). This phenomenon has gradually changed from natural evolution to a disaster to the ocean. A province has a coastline of more than 3000 km, and its total length of coastline accounts for 1/6 of the total length of China’s mainland coastline. It is the second largest marine province in China. Moreover, there are highest quality beaches in this province of China (Pardo-Iguzquiza et al. 2013) (Perinçek et al. 2015). In 2016, China’s total coastal tourism revenue has exceeded 1 trillion, an increase of 9.9% compared to the same period last year, and it has become an important part of China’s marine industry (Qin et al. 2020). Tourism, leisure, and vacation activities based on coastal beaches are the main economic pillars that promote the development of coastal tourism industry and are also an important direction for China’s current marine industry growth. Only reasonable development, utilization, and protection of coastal...
resources can contribute to the healthy development of marine tourism economy (Ramirez-Davila et al. 2012). Based on this, protecting the stability of coastal beaches allows the coastal beaches to be protected to the greatest extent, showing great support in reducing engineering environmental disasters, and also having super high economic value. Moreover, because society is progressing, people’s concept of life is also constantly changing, and the requirements for health are also constantly improving (Saikia and Sarkar 2013). People have begun to advocate sports, and running has become people’s main sport due to its low economic cost and convenience. In this way, even many people who have no experience in running start to run. Based on the embedded image system, this article will investigate and study the stability of coastal beaches in a province, and discuss the significance of sustainable simulation of coastal beach running to people’s health (Şengüler 2013). Applying the embedded image system to the sustainable simulation of people’s coastal running can fully analyze and investigate the running-related injuries, so as to provide support for the extensive development of coastal running (Shahbeik et al. 2014). In addition, this article also summarizes the experimental data at different speeds, summarizes the angular movement and phase characteristics of the waist, knees, and ankles of people at different running speeds, as well as the regularity parameters, and then expands the regression analysis, and the regression model is based on the universal importance, established a mathematical model of the speed of hips, knees, and ankles (Shcherbakov et al. 2013) (Siddiqui et al. 2015). By exploring the inner connection between coastal running and simulation system, it can theoretically provide support and help for sports to improve people’s living environment, and also provide a practical basis for the healthy development of transportation and ecology in the later period of human society (Tercan and Karayigit 2001).

Materials and methods

Data collection and processing

The data collection equipment RTK (Real Time Kinematic Studio) can measure and monitor dynamic data. RTK positioning technology is a real-time dynamic positioning technology derived from carrier phase observations. Its advantage is that the coordinate values of specific coordinate systems such as plane coordinates and elevation coordinates can be transferred to the user at any time, and the accuracy is very high, reaching the centimeter level, which is deeply loved by people (Tercan et al. 2013). In the RTK operation mode, the data collection department transmits the position information and related data observed by the observation station to the mobile station through data link transmission. The mobile station has two methods of receiving data, one is to receive the data information provided by the reference station through the data link. The other needs to perform two observation data at the same time by collecting GPS observation data (Turkish Coal Enterprises 2018). Real-time processing is performed by forming differential observations in the system. The mobile station for data collection can be in a static state or a mobile state, and this flexible state is an important guarantee for ensuring data collection and processing (Uyan 2016).

The beach coast is a coast formed mainly by wave action. The beach coastal zone includes the coast on the landward side of the coastline, and the beach between the washover and the low-water line. Because the composition of the beach coast is mainly sand and fine sand, it is also called sandy coast. China has more than 4000 km of sandy coastline (Uyan and Cay 2013). A good beach is a resort for coastal tourism and a place for people to yearn for leisure. The sandy coast is a wave dissipator, which can protect the coastal environment from the waves.

The beach is located between the coastline and the low tide line. It generally develops on the top of shallow arc bays on the original coast, or on the side facing the sea after the bay is blocked by sand dams and spouts (Vasquez and Nieto 2004). Most of the beaches are spread along the coast in a shallow arc, but its area is smaller than the original bay and slightly straight. The beach includes beach-ridge, backshore, foreshore, and inshore. The backshore includes the front edge of the ridge and the beach shoulder (Beach Berm), and the foreshore is roughly the same as the beach surface (Watson et al. 2001). Righteously, Neibin is equivalent to the underwater bank slope (see Fig. 1).

After RTK, the projection method of the instrument handbook is Gaussian customization, the central meridian in Yantai area is set to 121° 30’ 00", the central meridian in Weihai area is set to 123° 00’ 00", and the source ellipsoid is selected as WGS-84 ellipsoid. The target ellipsoid is set to CGCS2000 ellipsoid. The original data collected on site mainly includes the plane east coordinate E, the elevation Z (average sea level of the Yellow Sea), the year, month, and day of the measurement, and the time of the measurement. After obtaining the plane north coordinate N, the plane east coordinate E (i.e., the plane coordinate X, the plane coordinate Y) and the altitude Z, the different beach profiles cannot be put together for comparison. After processing by formula (1), the different the beach profile of is placed in the same coordinate system.

$$S = \begin{cases} \left[\left(\frac{(x-x_0)^2}{2} + \frac{(y-y_0)^2}{2}\right)^{0.5} \right]^{h \geq 0m} \\
\left[\left(\frac{(x-x_0)^2}{2} + \frac{(y-y_0)^2}{2}\right)^{0.5} \right]^{h < 0m} 
\end{cases}$$

After obtaining the sediment samples, they need to be sent to the laboratory to screen the sediment samples. The steps are as follows: manually pick out the stones with a particle size greater than 10 mm in the sand sample, divide the sample into
two parts, each not less than 300 g, put into the oven, set the
oven temperature to 105 °C ± 5 °C, wait for the sand sample
after drying to constant weight (see Fig. 2a), and take the
sample out of the oven and let it cool. Place the weighing
pan on the zero-cleared electronic balance and peel it, and then
put two 300 g dry sand samples into the weighing pan to
weigh the accurate mass. Pour the weighed 300 g sand test
into the uppermost layer of the test set of sieve (Webber et al.
2013). The test set of sieve consists of a bottom plate, a cover,
and six diameter round-hole sieves. Put the test set of sieve
with 300 g sand sample into the sieve shaker, and tighten the
disc-shaped button above the sieve shaker (Whalen et al.
1987) (Winchester and Floyd 1977). The working time of
the sieve shaker is set to ten minutes, waiting for the sieve
shaker to stop. When the shaker is finished, remove the set of
sieve and weigh the mass of each layer. Calculate the cumu-
lative sieving rate of each layer of sand, and draw the gradation
curve to get the gradation curve (see Fig. 2b).

Data analysis method

After each measurement, we will get the corresponding beach
profile curve (see Fig. 2). We integrate the corresponding part
of the curve. For each profile P_n-x (n represents the profile
number, x represents the xth measurement), we will select the
fixed length of the section for integration; the calculation for-
mula is:

\[ V_n = \int_{S_1}^{S_2} f(h) ds = \sum_{i=1}^{x} \frac{h_{i+1} + h_i}{2} \times (s_{i+1} - s_i) \]  

We regard the average sea level as the point where the
elevation is 0, and the elevation value will be negative during
the integration process. To avoid this, we will uniformly add
2 m to the measured altitude H value. The practical signifi-
cance of this approach is that we assume that the 2 m depth of
the beach at S1 is all covered by sediment. After integrating,
we have to wait for the area of each section, and then multiply it by one unit of length to get the sand volume \( V_n \) at the position of the section. Use formula (3) to calculate the volume of each profile and divide it by the fixed distance of the corresponding integration area. We call it the single-width sediment volume of the profile \( V_s \) (unit: \( m^3/m \)). After \( V_s \) is calculated, it can be compared. The increase and decrease of sediment volume in different numbered profiles, \( V_s \), the calculation method is as follows:

\[
\frac{V_s}{S_2-S_1} = \frac{\int_{S_1}^{S_2} f(h) \, ds}{S_2-S_1} = \sum_{i=1}^{\infty} \frac{h_{i+1} + h_i}{2} \times (s_{i+1} - s_i) \quad (3)
\]

For the entire coastal beach, there are roughly three types of secondary banks: natural dunes, artificial concrete seawalls, and artificial baths. The artificial concrete seawalls can be subdivided into artificial concrete seawalls with dry beaches and artificial concrete seawalls without dry beaches. The statistics of the secondary shores corresponding to the 20 profiles of the entire coastal beach are shown in Table 1.

The sand on the beach can move with the waves of the ocean under certain conditions. The particle size and the density of the sediment are different under the effect of different degrees of hydrodynamic transmission, and the result is the stratification of the sediment: first the sediment is screened by the ocean wave, which has a selective effect, and the beach the particle size of sediment is generally related to the energy of ocean waves. The energy of ocean waves is greater. The remaining sediment has a coarser particle size, and the particles will be removed. The particle size of the deposit is usually expressed in \( mm \). Sediments can be classified according to their particle size and classification standards applicable to China’s coastal projects (see Table 2). Obtain the quality of each sieve layer from the sediment samples after screening in the laboratory, draw the cumulative curve of the sediment particle size, and read the median particle size \( D_{50} \) of the sediment.

### Assessment of beach system stability

Generally speaking, the balanced profile of the coast means that under certain sea environment (waves, tides, topography, etc.), the sand on any beach will not move, and the profile of the beach will not change. Coastal beach profile is also the main evaluation parameter for studying beach erosion/siltation, and it is also an important parameter for artificial beach conservation design. It is still quite difficult to accurately predict the beach balance profile based on the dynamic condition on the beach, so the current research results are still semi-empirical (Wang et al. 2019). A large number of scholars at home and abroad have carried out a lot of research work on the coastal beach profile. The geometric model and the dynamic model are represented by the Bruun-Dean balanced profile model. Dean (1991) assumes that the wave energy dissipation per unit volume is constant and linearity is applied. Wave theory and wave breaking criterion standards derive the following model.

\[
h = ax^{2/3} \quad (4)
\]

where \( a \) is a coefficient and a function of particle size, but formula (4) does not include the wave breaking zone, especially the beach profile above the wave upwash zone. Komar and Jaenicke (1994) perfected formula (4) as:

\[
h = h_0 (1 - e^{-kc}) = \frac{m_0}{k} (1 - e^{-kc}) \quad (5)
\]

Beach closure depth is another important parameter in beach conservation design. The closure depth is defined as a critical water depth at which the surface sediment elevation of the seabed remains constant and does not change with time. Hallermeier’s closing depth formula is the most commonly

### Table 1 Statistics on the types of secondary shores of coastal beaches \( P_1 \sim P_{20} \)

| Profile | Distance | Type of secondary bank | Distance | Type of secondary bank | Distance |
|---------|----------|------------------------|----------|------------------------|----------|
| P1      | 0.00     | Dry beach seawall      | 0.31     | Dry beach seawall      | 0.53     |
| P2      | 0.31     | Dry beach seawall      | 0.53     | No dry beach seawall   | 0.78     |
| P3      | 0.53     | No dry beach seawall   | 0.78     | No dry beach seawall   | 1.02     |
| P4      | 0.78     | No dry beach seawall   | 1.02     | Natural dunes          |          |
| P5      | 1.02     | Natural dunes          |          |                        |          |
used in beach conservation design. Hallermeier (1977) uses the conversion of two dimensionless parameters:

$$\phi = \frac{u_0^2}{(s-1)gd} \Rightarrow \psi = \frac{u_0^2}{e(s-1)gd} = 1.0$$

(6)

And using the linear wave theory, derive the beach closure depth as:

$$h = 2.28H_e - 68.5 \frac{H_e^2}{gT_e^2} \Rightarrow H_e + 5.6\sigma_S$$

(7)

Based on the field data of the Duck test station in the USA, Birkemeier re-evaluated Hallermeier’s closed depth model and modified the equation to:

$$h = 1.75H_e - 57.9 \frac{H_e^2}{gT_e^2} \Rightarrow H_e \approx 1.57H_e$$

(8)

### Embedded image system design

The hardware of the whole system consists of DM642 processing chip, memory unit, video input unit, video output unit, peripheral communication unit (network port, serial port), and power supply unit. DM642 is a high-end, dedicated video processing chip released by TI in 2002. Due to its powerful single-core processing performance, it is expected to be more widely used in the video field in the next few years. The characteristics of the DM642 processing chip are as follows: (1) the core processing frequency up to 720 MHz, and there is a secondary cache inside. Multiple data operations can be connected to SD, SDM, 64-bit EMIF (peripheral data memory interface), SDRAM, Flash, and other storage devices seamlessly. The 64-bit data line is convenient for moving multiple data. (2) 10/100 M Ethernet port, and provide convenient communication. The analog video signal collected by the 4-channel camera is converted into a digital signal by TVP5150 and sent to DM642. The output terminal is connected to a Philips encoding chip SAA7105 for local video playback. DM642 collects the video data encoded by MPEG4 standard and sends it to the remote upper-level computer through EMAC. The upper computer is the server forming a monitoring system. According to a system, extended information is provided, so that the transmission of picture information and the purpose of detecting the system can be achieved.

### Design of the running motion model of human lower limbs

By using the SimMechanics toolbox provided by Matlab for modeling and simulation analysis of mechanical devices, there is no need to derive the analytical formula of the kinematics model of the mechanical device, but the structural parameters of the mechanical device and the connection actions between the components can be known. The general simulation analysis method is difficult to establish an accurate analysis model of the human body due to the complex structure of the human body. The conclusion of this paper, the SimMechanics toolbox is used to simulate human body mechanisms. Because human walking is symmetrical, the phase difference of walking is 50%. According to this characteristic, only one lower limb is simulated. The modeling, simulation, programming, and calculation of this paper are all based on AMATLAB version 2014 software. The modeling method is as follows:

1. Use the Bodies and Joints module provided by SimMechanics to build a human lower limb mechanism model. First, the Ground module of the body module group is used to represent a fixed frame defined as a part of the human body. Then, select the Revolute Joints module that builds the first rotation defined by the hip joint rotation. Again select the Body module defined as the thigh from the Bodies group module. Three Revolute modules are required. Then they are defined as the rotation of the hip, knee, and ankle joints, the three rigid bodies of the thigh, foot, and foot, the drive module, the connecting joint and joint detection module, and the rigidity detection module (Xu and Yang 2018).

2. To connect to the machine environment of the environment variable setting module, select the [Display machine environment] check box. The parameters of the environmental variable module, rotating pair module, and rigid module of the mechanism are set with point H as the origin. Here, the gravitational acceleration vector is [0, −9.81, 0], and the gravitational acceleration of the axis is 0, which means that the acceleration of the y-axis is −9.81 m/s². The length, mass, moment of inertia matrix, and the position of the center of gravity of the bar...
can be calculated according to the regression equation of the human lower limbs in Chapter 2 (Zhang et al. 2018).

(3) Determine the input module and output module, and select SimMechanics as the driver corresponding to the rotation of the hip joint, knee joint, and ankle joint of the human mechanical device model. Select the oscilloscope module and the XY mediator module from the corresponding modules of Simulink. Start as output. Set the SIMULINK simulation environment parameters, and show the motion model of the lower limb of a human being as shown in Fig. 3.

Results

Changes in beach slope

It can be seen from Fig. 4 that the inclination of the coast is proportional to the particle size D and period T of the deposits, inversely proportional to the breaking wave height Hb, and finally close to a constant.

It can be seen from Fig. 5 that the above-water part of the seawall profile with dry beaches has an obvious change outside the P1 and P11 profiles during the measurement on September 23, 2018. Let us take the P16 profile with the most obvious change to briefly explain: The change in the profile slope indicates that the profile shape has changed. Figure 5 shows the profile shape measured on June 23, 2018, before the change in the slope of the P16 profile and on September 23, 2018, when the change was greatest, and on November 20, 2018, after the change.

It can be seen from Fig. 6 that in the beach profile of the Wugantan seawall, only the water slope of the P13 profile is in an unstable state. According to the actual situation of the site, the elevation of the front foot of the seawall at the P13 profile is only about 0.5 m above the average sea level. At high tide, the seawater floods the foot of the embankment, and the waves begin to break at the breaking point and collide with the upright wall, causing sediment transport in front of the embankment, and the shape of the beach profile prone to change.

It can be seen from Fig. 7 that in the natural bank section, the slope of the P10 profile above the water surface in the early period of the measurement is relatively small, around 0.0125, but in the later period of the measurement, the slope becomes larger. We find the two profile data graphs before and after the slope change (see Fig. 8), it is found that in the survey on July 27, 2018, the profile type belongs to the storm profile type, and there is no beach shoulder. In the survey on January 21, 2019, the storm profile has become a constant wave profile. A beach shoulder develops, so the slope of the water part of the profile changes obviously. In the early stage of the measurement, the slope above the water surface of the P10 section of the natural bank section is much smaller than
the slope above the water surface of the other natural bank sections. The reason is that the P10 section is located near the estuary, supplemented by river sediment, and the development is very wide shore beach.

It can be seen from Fig. 9 that the underwater slope of the profile with dry beach seawall only has obvious changes in the P14 profile during the measurement period (Fig. 10). We found the profile on March 18, 2018, and the profile on August 17, 2018. Measuring the profile, firstly, it is found that the two profile lines intersect about 0.1 m above the mean sea level. The amount of sand measured in March below the intersection point is more than that in August, and the amount of sand measured in August above the intersection point is higher than that in March. There are many surveys. The reason for the above changes is that the summer wind and waves reshape the beach. The profile measured in August has gradually developed beach shoulders, making the slope steeper.

From Fig. 11 to Fig. 12, we can see that the slope of the section of the dry beach seawall and the artificial bathing beach section, as well as the natural bank section, is relatively stable during the measurement time span. The underwater slope of the section of the dry beach seawall is at between 0.0075 and 0.03; individual profiles will have small fluctuations in the later stage of the measurement; the underwater slope of the artificial bath profile is between 0.005 and 0.01; the underwater slope of the natural bank section is between 0.01 and 0.04.
0.0225; the slope of the natural bank section in the underwater part is between 0.075 and 0.0225.

The relationship between beach sediment particle size and profile slope

We selected the sediment data D50 of the wave erosion area of the six sections of P4, P6, P7, P11, P15, and P19 and the corresponding slope of the underwater part of the slope (−1 m ~ 0 m) for the surface sediment particle size D50 and slope. The relationship diagram of tanα is drawn. There are five sets of slope and particle size data for each profile:

It can be seen from Fig. 13 that the five tilt data of the same beach profile are different from each other, but the tilt of the beach has a positive correlation with the particle size of the deposits. The coast slope data in Fig. 3.29(a) is the instantaneous coast slope during the collection period, and will also be affected by waves during that period.

Stability analysis of dune-beach system

We also conducted field data collection on this beach. The collection method is the same as the on-site data collection method of the coastal beach, and the dune-beach system stability assessment technology was verified. It can be seen from
Fig. 14 that the maximum elevation of local waves (Fig. 14a) does not exceed 1.55 m, and the elevation of the sand dunes (Fig. 14b) must be greater than 1.55 m, so the local beaches are relatively stable.

In Fig. 15, H2 represents the elevation point where the slope line above the mean sea level of section 17 intersects with the slope line of the supra-tidal zone; V is the volume we predict that the coastal beach section 17 may lose in the future.

**Analysis of coastal sports represented by running**

Activity time refers to the total time (unit: minutes) of athletes participating in physical activities. According to the statistical analysis of the description of various activities sample data of SPSS, as shown in Table 3, the average time of people’s running, walking, and cycling activities is 53 min, 66 min, and 71 min, respectively. Cycling has the longest average time, followed by walking and running.

The movement distance is the length of a person’s movement in km. As shown in Tables 2, 3, and 4, SPSS statistically analyzes the movement distance data of various activities. The average travel distances for running, walking, and cycling are 7.54 km, 5.78 km, and 14.23 km, respectively. Comparing the average distances of the three activities, cycling is the longest distance, followed by running, and walking is the shortest average distance. The maximum driving distance is...
42.82 km, the minimum distance is 0.10 km, the span is large, the skewness is 1.898, and the sharpness is 7.683. The value of the driving distance is very different. It can be seen that the distribution of the value to the right is a steep slope. The maximum distance for walking activities is 20.90 km, and the minimum distance is 0.68 km. Skewness and sharpness are both positive, and the distribution of values is still right skewness, but it shows that it is not as urgent as the activity in progress. The maximum distance for cycling activities is 48.10 km, the minimum distance is 2.86 km, the numerical span is the largest, the distortion is 1.436, and the sharpness is 1.749. The numerical distribution shows obvious left distortion. This shows that running and walking are generally short-distance and medium-distance sports, while bicycles are long-distance sports. Please refer to Table 4 for specific values.

Activity speed refers to the distance of various activities per unit time; the unit is km/h. It can be seen from Table 2, 3, and 4 that the average speed of bicycles is the fastest, followed by running and walking. The average speeds of the three activities were 13.25 km/h, 8.79 km/h, and 5.65 km/h. From the extreme point of view, the maximum cycling speed of cycling is 45.10 km/h, and the minimum cycling speed is 3.61 km/h. For running, the maximum travel speed is 20.00 km/h, and the minimum travel speed is 1.93 km/h. If it is walking, the maximum walking speed is 17.14 km/h, and the minimum walking speed is 1.41 km/h. Please refer to Table 5 for specific values.
Analysis of simulation results of human lower limbs running

According to people’s movement, the use speed of legs and joints is more than 12 km, and then the simulation analysis of the model is carried out, so that the way of movement can be analyzed, as shown in Fig. 16.

In Fig. 16, Figure (a) as the beginning of the walking cycle time, Figure (b) as the maximum ankle angle moment, and figure (d) as the toe starts from the ground. Finally, in order to support Figure (d), Figure (c) on the left is the minimum knee joint angle, Figure (e) is the femoral joint angle at the minimum time, Figure (f) is the minimum ankle angle time, Figure (g) is the right moment support action, and Figure (H) is the figure supporting the end of the knee joint period. The maximum angle in table (I), the maximum torque angle during entering the suspension as the femoral

Fig. 12 The slope of the natural shore section of the bathing beach section underwater (−1 m ~ 0 m) changes with time

Fig. 13 The relationship between the sand size of the coastal beach and the slope of the scour area

Fig. 14 The maximum climb height of waves on the east beach of Jiahe Bridge, Fushan District, Yantai (a) and the foot elevation of dunes (b)
joint in Figure (j), and Figure (k) is the end of the walking cycle; and then next cycle begins to enter. Due to limited space, this article does not configure the output speed simulation model of the simulation curve of the hip, knee, ankle joint angle and angular velocity together with the contrast of the experimental measurement data. The visiting speed is only 4km/h, 6km/h, 8km/h, 10km/h and 12km/h. The angle and angular velocity of the experimental curves of hip circumference, knee and ankle as well as the simulation model are established based on the contrast of the output simulation curve of SimMechanics shown in the figure. The dotted line represents the experimental curve, and the solid line represents the simulated curve.

It can be seen from Fig. 17 and Fig. 18 that the experimental curves of the rotation angles and angular velocities of the hip joints, knee joints, and ankle joints are almost the same as the simulated curves at various speeds. Therefore, the speed-based mathematical model and simulation model of the rotation of the hip, knee, and ankle joints are correct, and can be used to describe the motion characteristics of the lower limb joints of the human body at various driving speeds. At a speed of 4–12 km/h, the mathematical model of the rotation angle of the hip joint, knee joint, and ankle joint is used as the kinematic model derived from the DH method. The theoretical motion track of the knee, ankle, and ankle (toe) is calculated. As shown in Fig. 19, the motion trajectories drawn at 9 speeds are in the same coordinate system.

### Table 3: Descriptive statistics of the activity duration of the three types of activity samples

|       | Sample size | Full range | Minimum | Maximum | Average value | Standard deviation | Skewness | Kurtosis |
|-------|-------------|------------|---------|---------|---------------|--------------------|----------|----------|
| Run   | 680         | 437        | 3       | 440     | 52.82         | 33.863             | 3.935    | 31.442   |
| walk  | 213         | 289        | 8       | 297     | 65.61         | 42.181             | 2.034    | 6.666    |
| Cycling | 51         | 288        | 16      | 304     | 73.29         | 61.492             | 1.571    | 2.652    |

### Discussion

#### Analysis of beach conservation methods

Hard engineering methods for coastal beach protection include seawalls, spurs, offshore dikes, offshore submerged dikes, artificial capes and artificial shallow reefs, and other coastal auxiliary structures. Although seawall protection can effectively prevent shoreline erosion, seawalls will accelerate beach erosion or even disappear. At present, western developed countries have not adopted such beach protection projects. The spur dam mainly intercepts the sediment transported along the coast and resists and dissipates the coastal currents. However, while intercepting the upstream sediment transport, it also causes the erosion and retreat of the downstream coast. The spur dike group can better protect the coastal erosion caused by sand transportation along the coast, but it cannot prevent the coastal erosion disasters induced by lateral sediment transportation. The offshore submerged dike is the most used scene at this stage. The function of the submerged dike is to break the waves from the open sea in advance, so that the interaction between waves and the beach is reduced, and it will not affect the landscape of the coast. The dike can consume wave energy. The protection of submerged dike works is mainly suitable for beach erosion caused by lateral sediment transport, but the effect of coastal beach protection is not good. If there is a lack of a clear understanding of artificial banks, artificial structures will not achieve the expected results, but will increase the degree of coastal erosion and ultimately lead to engineering environmental disasters.

The soft engineering method of beach conservation is Beach Nourishment, which is to periodically add new sand sources to the eroded beach system, so that the amount of sand lost in the eroded beach system and the amount of new sand added to the eroded beach system reach a dynamic equilibrium state. There are two types of beach maintenance design: super sand filling method and balanced profile design method. The overfilling method needs to determine an overfilling coefficient RA, taking into account the amount of sand compensation required under the conditions of different fill diameters. The improved overfilling method now needs to determine two design parameters: the overfilling coefficient RA and the repeated sand filling coefficient R1. The super sand filling method does not care about the specific sand filling position and the
design shape of the cross section. This method is often used in the early beach maintenance projects in the Netherlands and other European countries. The second soft engineering beach maintenance method is the balanced profile method, which is a relatively general engineering design method for beach maintenance. The main design parameters include dune elevation, top width and slope, beach shoulder width, height and slope, and beach shoulder balanced profile shape design. At present, the most commonly used design software is BMAP (Beach Morphology Analysis Package), which determines the beach shoulder width and elevation of artificial beaches; X-Beach software can also be used for the design of artificial beach profiles to determine the beach shoulder width and elevation under the action of storm surge; the Bruun-Dean balanced profile model is also commonly used in the engineering design of beach conservation. Compared with the hard engineering beach protection method, the soft engineering beach maintenance method is not only cost-effective, but also has fewer environmental disasters (Table 6).

### Analysis of running system mode in coastal area

Because running sports have high requirements on the shape of the road network, the second layer needs to build a road network with high ring formation rate and good connectivity as much as possible. To build a small-scale, high-density road network above the road interval, it is necessary to use about 200m. It is not only necessary to ensure access to the road network in the community level, but also to meet the connection with the park. Because the average distance of running activities is longer than the walking time, people choose to run in open spaces such as roads or parks. Therefore, the second layer is mainly used to perform activities. According to the streets built in the road network, the network form must be adopted as much as possible, because the connection with the park is more convenient, so running activities can choose the streets with better environment and higher green level for activities. However, in order to carry out the activity, it is also possible to enter the green area simply and quickly.

### Recommendations for optimization of running systems in coastal areas

#### Building a walk-oriented community

From the point of view of constructing an active and healthy human living environment, it is necessary to focus on constructing a physical environment suitable for a slowly walkable community outside. It is necessary to build a community with the goal of walking with parks and green spaces as the core. The community road network must be based on grids as much as possible. It is recommended to use a road interval of about 200 m to create a small, highly connected road network to create a useful space environment for communication.

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**Table 4** Descriptive statistics of activity distance of three types of activity samples

| Sample size | Full range | Minimum | Maximum | Average value | Standard deviation | Skewness | Kurtosis |
|-------------|------------|---------|---------|---------------|--------------------|----------|----------|
| Run         | 680        | 42.71   | 0.10    | 42.80         | 7.52               | 4.361    | 1.90     | 7.68     |
| Walk        | 213        | 20.21   | 0.66    | 20.92         | 5.77               | 3.197    | 1.33     | 2.63     |
| Cycling     | 51         | 45.25   | 2.87    | 48.11         | 14.25              | 11.132   | 1.45     | 1.74     |

**Table 5** Descriptive statistics of activity speed of three types of activity samples

| Sample size | Full range | Minimum | Maximum | Average value | Standard deviation | Skewness | Kurtosis |
|-------------|------------|---------|---------|---------------|--------------------|----------|----------|
| Run         | 680        | 21.06   | 1.92    | 23.01         | 8.78               | 2.12     | 0.392    | 4.704    |
| Walk        | 213        | 15.74   | 1.42    | 17.15         | 5.66               | 1.93     | 1.645    | 6.488    |
| Cycling     | 51         | 41.48   | 3.62    | 45.11         | 13.23              | 5.96     | 3.134    | 15.922   |

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![Simulation process interface](image-url)
Fig. 17  Experimental curve and simulation curve of hip, knee, and ankle joint angles at multiple speeds
Fig. 18  The simulation curve and experimental curve of the angular velocity of the hip, knee, and ankle joints at multiple speeds.
between neighbors. Combined with the road network, in order to strengthen the connection between the area and the park and green space, improve the low-speed operation facilities, enrich the street form, and create an outdoor space suitable for physical activities, a continuous and networked low-speed operation system has been set up. Ensure the effective development of sports themes, as well as slow outdoor physical activities. Low-speed lanes connecting urban highways generally have simple routes and strong purposes. On the premise of ensuring convenience and safety, more attention should be paid to the landscape of the event space and the comfort of the event itself. The space design should take the human scale as the starting point, and provide people with comfortable physical activity space to walk slowly. Combine the supporting facilities of independent low-speed roads such as parks and rivers to improve decoration, leisure, and comfort. In addition, by appropriately improving the mixed use of land in nearby areas, it is an important way to promote active participation in outdoor activities and help build a positive health intervention living environment.

**Improve the network of urban boulevards.**

In the planning of the new city, attention should be paid to optimizing the structure of the road network, improving the connectivity of the road network, and making use of a small-scale network as much as possible to construct an urban road network. In the rejuvenation of the old urban area, the road network cannot be adjusted significantly due to the constraints of the current situation. Therefore, the density of branch roads and auxiliary roads can be appropriately improved, and road connectivity can be improved. The road can be avoided as much as possible, and the network road network can choose to set the road to continue as far as possible. Based on the preference for outdoor activities, in the open space with better green environment, the avenue should connect the important ecological patches of the city as much as possible, improve the convenience of the outdoor space, and strengthen the design of comfortable public space.

**Building a continuous cycling corridor**

Around the street, the strong continuity of the main road is combined with the construction of the auxiliary road of the bicycle corridor. In the case of cycling, the road is the main place for activities. Not only must a bicycle pass be provided, but also a safe, convenient, and non-impeding place for sports. Therefore, the main road must be equipped with different bicycle lanes as much as possible and auxiliary roads and fork roads can be mixed with sidewalks and bicycle lanes. In response to the needs of athletes, bicycle corridors should be connected to parks and green spaces, and the construction of bicycle corridors along mountains, seas, rivers, lakes, and other places with good natural and artificial environments and

### Table 6

| Type of protection engineering | Advantage                                                                 | Disadvantage                                                                                           |
|-------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| Seawall                       | Easy construction, moisture-proof and wave-proof                          | The reflection in front of the embankment makes the beach easy to disappear and high cost             |
| Spur                          | Intercept coastal drift sand                                               | Causes downstream erosion and only prevents sand transport along the coast                              |
| Offshore embankment           | Sha Tsui and sand banks are formed behind the embankment                  | Only prevent offshore sand transportation and damage the landscape                                    |
| Offshore submerged dike        | Reduce wave energy in front of the embankment                             | Only prevent offshore sand transportation and safety hazards                                          |
| Artificial cape bay           | The bay forms a static equilibrium                                         | Storms cause coastal erosion and high cost                                                            |
good environmental quality should be strengthened, in order to create a good leisure environment and promote the development of outdoor physical activities, to walk leisurely.

**Strategic choices and countermeasures for the development of leisure sports in coastal areas**

**Develop leisure sports and enrich the types of leisure sports**

According to the data analysis of the questionnaire survey, the number of people who did not participate in sports activities only accounted for 8.63%, which fully proves that the holding of sports activities is the best way to attract leisure and sports tourists. Recreational sports started in the coastal areas. In the same industry, fierce competition, rational use of resources, and development of new projects with characteristics are particularly important. The development of sports tourism products in various cities in China also has the same problem. Coastal areas need to actively develop new projects to improve brand competitiveness. At present, most of the sports activities being held in the coastal areas of the country are international marathons, bicycle riding competitions, beach volleyball, etc., but there are relatively few sports tourism projects in the air. Taking into account the late start of leisure activities and sports tourism in coastal areas, and insufficient talents and equipment, there is a lot of room for development of paragliding and other projects. In addition, there are relatively few water sports in coastal areas. Sailing is gradually integrated into people’s lives, and high-end projects such as sailing, motorboats, and sea fishing are all restricted by factors such as high costs and crowd gathering. Therefore, it is difficult to promote as a distinctive brand.

**Improve the laws and regulations of coastal running and other outdoor sports**

According to the analysis of the questionnaire statistics, the development of outdoor sports in coastal cities is relatively good, and it is necessary to strengthen the mutual exchanges between outdoor sports in surrounding coastal cities and other provinces and cities to promote the development of outdoor sports in surrounding cities. Running is the most popular folk sport in outdoor sports. From an operational point of view, the major need is to provide public services. The mature development of outdoor sports organization and management in coastal cities is very important for the development of outdoor sports in surrounding areas and the deepening of the entire industry. Coastal city managers have set up a separate outdoor sports department, which is responsible for the organization of outdoor sports and related policies, regulations, and safety management of outdoor sports to promote the safety awareness of outdoor sports participants in coastal cities. And because the outdoor sports operation system gradually matures with the improvement of the city’s infrastructure, outdoor sports in coastal cities are also developing in the direction of centralized standardization. However, the management of outdoor sports, especially the legal system for outdoor sports, is necessary. In order to make up for the gaps or conditions in the relevant legal system, the development characteristics of coastal cities can be combined with their own outdoor sports to formulate relevant laws and regulations. The development of coastal cities will improve the environment, create an outdoor sports market in coastal cities, and solve some important problems, such as doubts and difficulties.

**The introduction and training of professional events, and the popularization of safety knowledge**

Introduce and train professional talents to ensure the sustainable development of the sports tourism industry. The introduction, deployment, and employment of retired professional athletes and retired soldiers should proceed smoothly. Continuous education and reform training must be implemented according to the professional advantages of athletes and retired soldiers, injecting professional knowledge into the implementation and promotion of running sports. For example, a retired soldier turns into an outdoor development coach, using the knowledge and experience of outdoor development to guide and train customers. Retired athletes can organize and provide concentrated technical training for participants before the competition, and provide recovery and relaxation services for participants after the competition. Through the experience and methods of professional athletes, the work efficiency of athletes can be greatly improved.

**Conclusion**

The society is progressing, people’s concept of life is also constantly changing, and the requirements for health are constantly improving. People have begun to advocate sports, and running has become people’s main way of exercise due to its low economic cost and convenient exercise. Even many people who have no experience in running started to run. Using the embedded image system to conduct sustainable simulations of people running along the coast can fully analyze and investigate the injuries related to running, so that people can exercise more scientifically and promote running along the coast. From the perspective of leisure sports, the author has a comprehensive understanding of the current development of leisure sports tourism at home and abroad, and conducted data research using the research results of domestic and foreign scholars. Through the use of documentary, expert interviews, questionnaire surveys, and coastal leisure sports tourism development mathematical statistical methods to analyze the
current leisure sports, find shortcomings, and give suggestions for coastal leisure sports tourism development strategies.

Declarations

Conflict of interest The authors declare that they have no competing interests.

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