

Environmental Factors in a Realistic 3D Fishing-Net Simulation

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ABSTRACT

The mass-spring model has been typically employed in physical-based simulators for clothes or patches. The mass-spring model frequently utilizes equal mass and the gravity factor. The model structure of masses supports a shape applicable to fishing nets. Therefore, to create a simulation model of a fishing net, we consider the mass-spring model and adopt the tidal-current and buoyancy effects in underwater environments. These additional factors lead to a more realistic visualization of fishing-net simulations. In this paper, we propose a new mass-spring model for a fishing-net and a method to simplify the calculation equations for a real-time simulation of a fishing-net model. Our 3D mass-spring model presents a mesh-structure similar to a typical mass-spring model except that each intersection point can have different masses. The motion of each mass is calculated periodically considering additional dynamics. To reduce the calculation time, we attempt to simplify the mathematical equations that include the effect of the tidal-current and buoyancy. Through this research, we expect to achieve a real-time and realistic simulation for the fishing net.

Key words: 3D Simulation, Mass Spring Model, Fishing-Net, Tidal Current, Buoyancy.

1. INTRODUCTION

A 3D fishing-net simulation has been used to check the efficient spread of a net and also train a fisherman. The structure of a fishing-net is very similar with those of general mass spring models to show the motion of the cloth or patches. This similarity makes a 3D fishing-net simulation use a mass spring model [1]-[3], [9].

In general fishing-net simulation programs, the calculation speed is one of the critical issues for the real-time simulation [4] - [8]. There have been developed many researches to get the higher calculation speed. Ko proposed the method to reduce the integration time [5]. Lee simplified the equations to solve the motion of fishing-net using constant term [6]. These previous researches basically consider the only gravity factor to simulate the motion of mass-spring model. However, the fishing-net has to understand the undersea factors such as tidal-current and buoyancy to imitate its realistic motion [7], [11]. And also it needs to consider the non-uniform mass distribution of a fishing-net because a fishing-net can be formed with several netting twines with different weights [9] - [12]. These additional factors make the simulation system difficult to get

the real-time simulation because we have to create the model to consider the factors such as the density of fluid, the density of objects, the volume of objects, and the vector field of tidal current. Therefore, we try to implement a simulation system for the fishing-net whose motion also can be affected by the tidal-current, buoyancy, and the gravity factor [12] - [14]. In order to reduce the calculation time, we will simplify some equations to determine the motion of a fishing-net. The mass-spring model to imitate the motion of the fishing-net will be modified so that the mass at each vertex can have a different weight.

In this paper, we propose a practice system for 3D fishing-net simulation from general mass-spring background. We may obtain an accurate motion of fishing-net using a two-step approach: The first step is an *Input Data Control* based on actual fishing-net data with different masses. The second step is the *Physics Processor* which decides the motion of the fishing-net by a tidal-current factor, a buoyancy factor, and a gravity factor in an undersea environment.

Our approach has the following advantages. First, we may generate a realistic simulation in specific undersea environment. This is because *Physics Process* can generate better results than simple gravity. We also increase the calculation speed through the simplification of some equations.

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Manuscript received Jul. 18, 2014; revised Aug. 26, 2014;
accepted Sep.02, 2014

2. SYSTEM OVERVIEW

Our system consists of four steps as shown in Fig. 1. Because our net is suggested in a form with unequal mass, we first give an input directly for each mass point in *Input Data Control* step. In this step, the properties of masses or springs are also added into a structural fishing-net data. The second step, *Interactive User Interface*, determines the external force such as the lift force of tidal-current, the density of objects, the volume of objects. It also initializes a position vector of fishing-net by user's mouse control. The third step is the *Physics Processor* which calculates the motion of our fishing-net model using the environmental characteristics such as tidal-current and buoyancy. To obtain a real-time motion of fishing-net model, we will simplify several calculation equations to get the motion of our models.

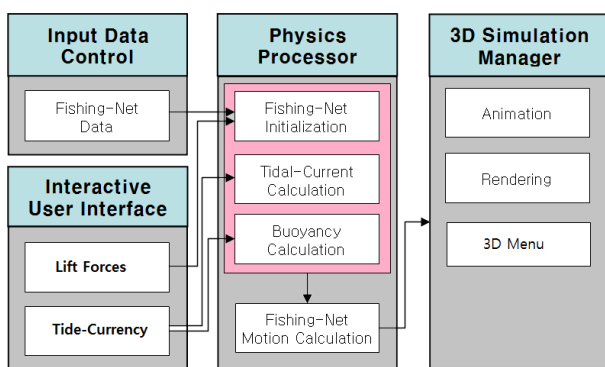


Fig. 1. System Overview

The last step, *3D Simulation Manager*, shows the natural motion on the display monitor using computed values.

3. INPUT DATA CONTROL FOR FISHING-NET DATA

Since our fishing-net model considers the various environmental effects, this model has to define the various types of mass. We will collect the actual data of real fishing-net in order to define the mass types for our fishing-net model. After the tuning of these actual data, we use the tuning data as input data of our fishing-net model. To express the fishing-net simulation with unequal masses, we consider the following data structure.

Table 1. Input Data of Fishing-Net

Symbol	Definition
id	ID of each mass point(=object)
x, y, z	Position of x, y, z for each mass point
volume	Volume of each mass point(=object)
density	Density of each mass point(=object)
mass	Mass = volume * density
surface	Projected area
part_type	Type of point(=object)
link_count	Count of link between neighboring points

link_id[]	ID array of links
l	Length of each link
k	Tension of each link

As shown in Table 1, each mass point has its mass properties, 3D position, and link attributes implying its connectivity structures. Through investigation of actual fishing-nets, we designed our mass-spring model for fishing-net as expressed in Fig. 2. Most of mass points have link connections of a diamond shape among its neighboring mass points. Periodically, vertical links are added to the link connection of a diamond shape.

A fishing-net model consists of a finite number of mass points and its mass points are connected with several spring links. As depicted in Fig. 2, each point can have different densities, and it divide into three regions. For example, the buoys, the sinker, and the general points are located at the top-line, the bottom line, the middle region, respectively.

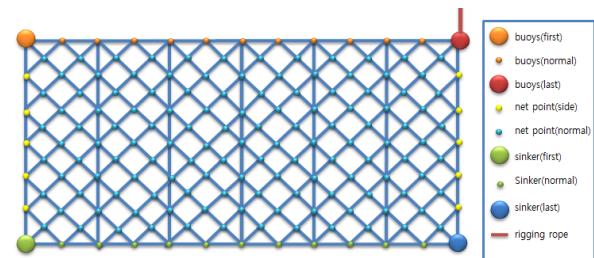


Fig. 2. Mass-Spring Model of Fishing-Net

4. PHYSICS PROCESSOR

4.1 Initialization of Fishing-Net

In the second process of Fig. 1, the initial fishing-net model can be structured by input step come from both actual net information of *Input Data Control*, and a position of fishing-net through *Interactive User Interface*. In general, for each mass point, we calculate the initial position using mathematical equations. Mass and link connection between mass points are chosen among the user-defined basic forms which are derived from real fishing-net structures. For special masses around the top line and bottom line of a fishing-net, we input different masses and properties through the *Interactive User Interface* dialog box. In *Interactive User Interface*, it is possible that we directly move each point after picking vertex.

A fishing-net has a lot of intersection points which correspond to the mass point. If we use all intersection points in fishing-net, this simulation system is not possible to get a real-time fishing-net simulation system. So, we have chosen some representative intersection points that is enough to show the simulation of fishing-net. The selected points are shown as large circle points in Fig. 3. To express the net structure with unselected points, we use the texture mapping technique with diamond shapes. This texture is given in a checked pattern with black color in Fig. 3.

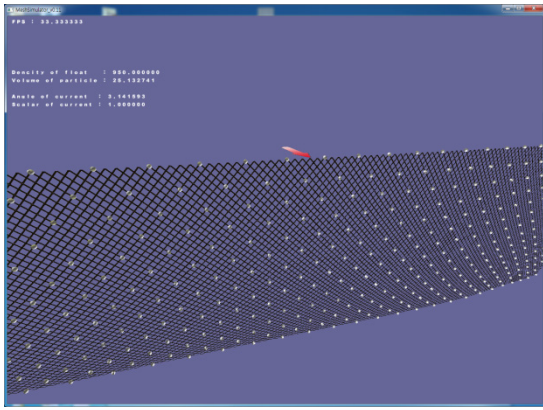


Fig. 3. Initial Positions of Mass Points for a Fishing-Net and its Textures

4.2 Motion Equation

The mesh structure in an actual fishing-net should be approximated with a small number of mass points to get a rapid calculation. We will try to add the environmental forces to a fishing-net simulation and then consider the environmental forces such as buoyancy and tidal current force. So, at each mass point of the fishing-net, its motion equation includes the gravity, tidal-current force, and buoyancy as follow:

$$F_{(t)} = F_g + (F_c + F_{cd} + F_{cl}) + (F_b + F_{bd}) \dots\dots\dots (1)$$

where F_g is a gravity force, $(F_c+F_{cd}+F_{cl})$ is a tidal-current force, and (F_b+F_{bd}) is a buoyancy force. Although our method will show the mesh-structure similar with the other mass-spring model based on gravitation, it also has characteristics of tidal-current and buoyancy as well as each point can have different mass.

4.3 Tidal-Current Equation

The Tidal-current force is subdivided into F_c, F_{cd}, F_{cl} forces in the motion equation (1). F_c means the magnitude and direction vector of the tidal-current, and F_{cd} is the drag force that the tidal-current affects on the object. F_{cd} is generally calculated as follows:

$$F_{cd} = S \times normal(F_c - v) \times (1 - (N \cdot normal(F_c - v))^2) \dots\dots\dots (2)$$

where S is the projected area of the object, V is the velocity of the object, and N is the normal vector of the object. Vector $(F_c - v)$ is normalized by $normal()$ function.

F_{cl} is the lift force that the tidal-current makes the object afloat. F_{cl} can be defined as follows as:

$$F_{cl} = S \times V_L \times K_L \dots\dots\dots (3)$$

where S is the projected area of the object, V_L is the vector of the lift force, K_L is the coefficient of the lift force. V_L and K_L are given as follows:

$$V_L = N - normal(F_c - v) \times (N \cdot normal(F_c - v)) \dots\dots\dots (4)$$

where N is the normal vector of the object, V is the velocity of the object, and F_c is the vector of the tidal-current. From equation (4), we obtain the vector of the lift force as V_L .

$$K_L = L_{func}(1 - 2(N \cdot normal(F_c - v))) \dots\dots\dots (5)$$

where K_L is a very important factor because it determines the scale of lift force. In order to choose the adequate K_L value, we utilize a lift function $L_{func}()$. These values are depended on the N, F_c , and V factors. The N is the normal vector of the object, F_c is the vector of the tidal-current, and V is the velocity of the object.

In several experimental observations of fishing-net, we can obtain the experimental coefficients for $L_{func}()$ as given in Table 2.

Table 2. Experimental Coefficients of the Lift Force

No	Angle	Lift force	No	Angle	Lift force
1	0.00	0.020675	13	51.00	0.504986
2	5.00	0.029830	14	55.00	0.517126
3	6.00	0.028353	15	56.00	0.521239
4	10.00	0.052438	16	60.00	0.496089
5	11.00	0.049820	17	61.00	0.500870
6	20.00	0.138550	18	65.00	0.427470
7	21.00	0.136940	19	66.00	0.435763
8	30.00	0.265190	20	72.00	0.238003
9	31.00	0.265750	21	73.00	0.235445
10	43.00	0.438975	22	85.00	0.088935
11	44.00	0.441512	23	86.00	0.092204
12	50.00	0.501985	24	90.00	0.057054

Using data in Table 2, $L_{func}()$ can be represented as curvature graph as shown in Fig. 4. This graph for the coefficients of lift forces is skewed slightly in right direction.

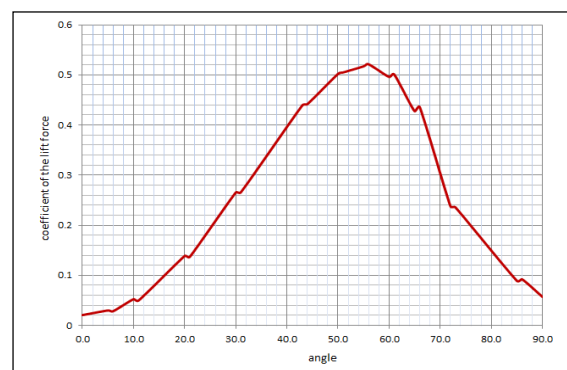


Fig. 4. Graph of Lift Function, $L_{func}()$

We can recognize that this coefficient graph is very similar with a cosine function. Fig. 5 shows the difference between the graph of $L_{func}()$ and general $\cos()$.

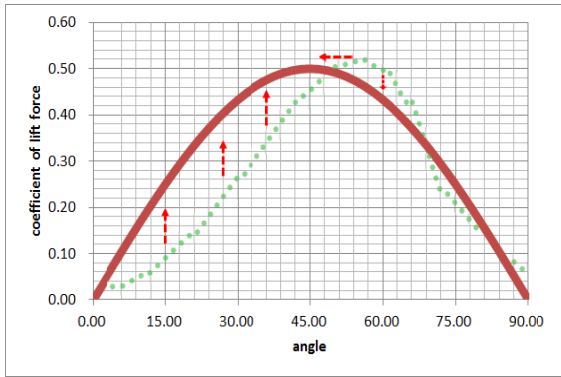


Fig. 5. Comparison of the $L_{func}()$ with $\text{Cos}()$ Graph

Since the coefficients shows a small gap between two curves, it is possible to approximate the K_L value with a general cosine function. Therefore, we can simplify the K_L value as follows:

$$K_L = \cos(1 - 2(N \bullet \text{normal}(F_c - v))) \dots\dots\dots (6)$$

In order to reduce the computational calculation time of $\cos()$, we compensate the cosine value using Taylor series function $\text{Taylor}()$. Therefore, K_L can be converted as follow as:

$$K_L = \text{Taylor}(1 - 2(N \bullet \text{normal}(F_c - v))) \dots\dots\dots (7)$$

Tidal-current force make mass points move to adequate position according to the tidal-current force.

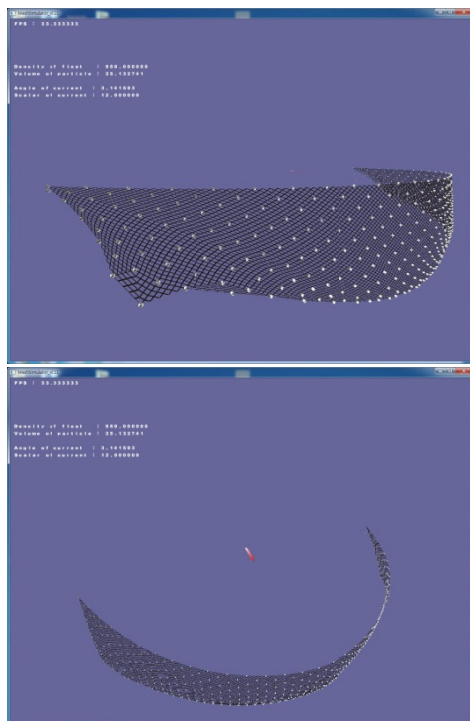


Fig. 6. Net Deformations by a Tidal-current

If the tidal current force is adapted in a perpendicular direction with fishing-net, the fishing-net are moved into the curved shape as shown in Fig. 6 because two or more end

points are attached to the fixed position such as a ship. According to the magnitude of tidal current force, the curvature of fishing-net will be smaller.

4.4 Buoyancy Equations

Buoyancy force is defined as combination of F_b and F_{bd} in the motion equation (1). If F_b is the buoyancy force, D_o is the density of the object, D_f is the density of the fluid, D_t is the density by the temperature, D_p is the density by the pressure, V is the volume of the object, and W is the weight of the object, the buoyancy force can be defined as

$$F_b = (D_o - (D_f + D_t + D_p)) \times V \times W \dots\dots\dots (8)$$

Since D_f , D_t , and D_p are relatively expensive to compute, Eq. (8) should be simplified. Through the various experiments, we can observe that two density factors, D_t and D_p , do not show the great graphical effects in the simulation of a fishing-net. So, we decide to eliminate two factors in the equation (8) and then the equation to calculate the effect of buoyancy can be simplified in one term as follows:

$$F_b = (D_o - D_f) \times V \times W \dots\dots\dots (9)$$

The drag force occurred by the buoyancy force is define as follows:

$$F_{bd} = D_f \times S \times K_b \dots\dots\dots (10)$$

where D_f is the density of the fluid, S is the projected area of the object, and K_b is the coefficient of the drag force.

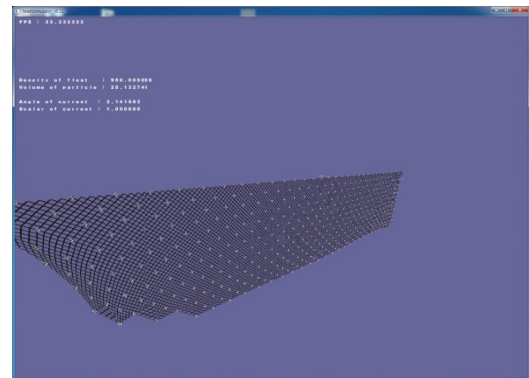


Fig. 7. Fishing-Net shape by Buoyancy Effect

Finally, fishing-net motion is generated using *implicit Euler integration* as follows:

$$\Delta v = F_{(t+1)} \times m^{-1} \times T \dots\dots\dots (11)$$

where m is mass of particle, T is a time-step of simulation. The fishing-net in trawler should be positioned in an adequate height in undersea and also can be opened in a vertical form. This buoyancy factor make the fishing-net form a vertical shape. Fig. 7 shows the fishing-net opened vertically.

5. EXPERIMENTAL RESULTS

We implemented the 3D fishing-net simulator using simplified equations that are described in section 4. We make a test the net shape according to the buoyancy force and tidal-current force. At this time, both ends of the fishing-net are always fixed similar with real fishing-nets. Fig. 8(a) shows the fishing-net without buoyancy and tidal-current forces. The middle point of this net are drooped under the weight of fishing-net. The buoyancy mitigates the drooping of fishing-net because the mass points get the upward force. Fig. 8(b) represents the effects of buoyancy force. Buoys attached along the above line of fishing-net cause the different buoyancy force between the above line and the bottom line. These differences give the good opened shape of a net. It is similar with the shape of a net in real world. Fig. 8(c) shows the effects for only tidal-current force and so the net have moved along the direction of tidal-current. Fig. 8(d), 8(e), and 8(f) is net shapes considering the buoyancy and tidal-current. The top line of fishing-net is floating on the sea while its bottom line goes under by sinker attachments. They present the shapes from various camera views in the fishing-net simulation employing buoyancy and tidal-current force.

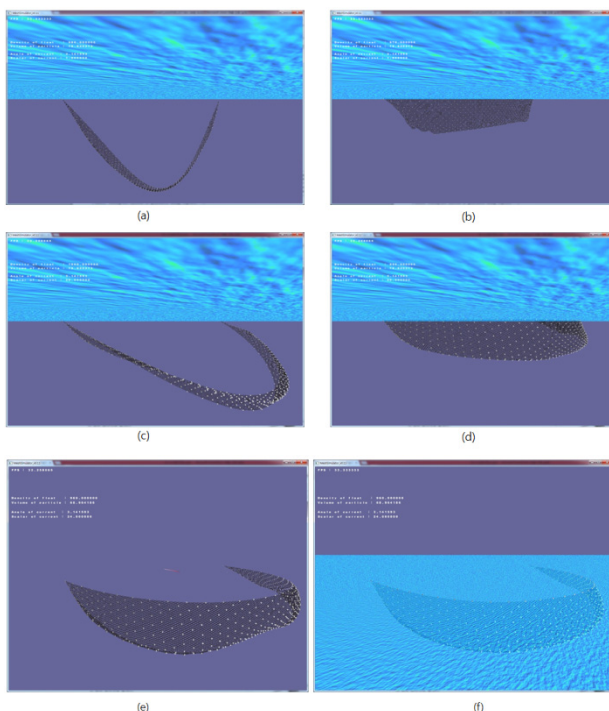


Fig. 8. Simulation Results

From these simulation results, we can observe that our simulation system employing buoyancy and tidal-current forces is very similar with the real fishing-net.

6. CONCLUSION

In this paper, we have developed a 3D fishing-net simulation system considering a tidal-current force and buoyancy. In order to get a real-time simulation, we have

chosen the physics model and then simplified the equations to describe the physical effects of the tidal-current force and buoyancy. This simplification makes the real-time simulation possible. In particular, the cosine function for coefficient value K_L gave very similar visual results and also caused a huge cut-off in an execution time. In case of buoyancy, we considered only the density of fluid because the other factors do not provide big differences. Through such simplifications, we achieved the real-time simulation and also upgraded the visual effects in the 3D simulation of the fishing-net.

ACKNOWLEDGEMENT

This work was supported by Research Grant of Pukyong National University (2013 year).

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