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Procedia Engineering 37 (2012) 79 – 84

Procedia Engineering

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The Second SREE Conference on Engineering Modelling and Simulation (CEMS 2012)

Matrixing network and distributed computing in the simulation of fishing nets

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Abstract

Matrixing network was developed in the simulation of fishing nets. We illustrated that it was a high efficient data structure in the engineering computation of such pelagic fishing gears as purse seine and trawl. Based on this matrixing network, distributed computing was employed in solving the huge mathematical models. The results indicated that distributed computing could logically and efficiently arrange the calculations, and the matrixing data gave great advantages in computations in computer. The results showed that knot model was easier and quicker to reach equilibrium state. More mass points with delicate distributions might be responsible for this phenomenon. The less stability for knotless purse seine in actual fishing at sea was also consistent with the simulations.

Keywords: Matrixing network; distributed computing; fishing net; purse seine; trawl; engineering simulation; engineering modeling.

1. Introduction

The dynamics of fishing net under the sea water are very complicated due to the external forces (gravitational force, buoyancy and hydrodynamic force) and internal force (linking force) acting on the net. It is still a challenge to appropriately model and simulate the dynamics of fishing net, especially for large scale pelagic fishing gears such as purse seine and middle water trawl. Fortunately, some studies on this subject have appeared in recent years. Lee et al. simulated the trawl [1-2]. Kim et al. developed a

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doi:10.1016/j.proeng.2012.04.206

simulation tool in C language to simulate the purse seine [3]. Zhang et al. modeled and visualized the part behavior of purse seine based on half-implicit algorithm and R language [4].

The engineering models of fishing gears are often complicated high-order differential equations. Some methods have been used to solve these equations recently. Zhang et al. used half-implicit Euler algorithm to have solved the purse seine models [4]. To obtain more stable solutions, Zhang et al. used whole-implicit method to simulate the dynamics of longline [5]. Newmark-β method was used in the hydrodynamic model of net in fishing simulator [6]. Non-linear finite element method was employed to determine the equilibrium configuration of a net in a uniform current [7]. Lumped masses method was used in simulating most of the fishing nets [8-9].

However, few people gave their computing processes in detail, especially for the data structure and distributed logic of computation, which may be the key in solving the complicated mathematical equations. In the present study, matrixing network was developed to virtualize the physical structure of fishing net. Based on this matrixing network, distributed computing was employed in programming and solving the mathematical models of purse seine and trawl.

2. Matrixing network

Purse seine and trawl are large scale fishing gears composed of nettings, ropes, floats and sinkers. But netting is their main component. Traditional fishing net made in polyester fibre is always characterized by obvious knots (Fig. 1 (a)). It may be called knot net. Some net factories have also manufactured knotless nettings using nylon (Fig. 1 (b)). Both of their mechanical characteristics (knot or knotless) have been investigated in experiments [10-11].

Most modeling and simulations of the fishing gears were based on the physical model of knot netting [1-3, 5]. Zhang et al. have modeled and simulated the part behavior of purse seine based on knotless net [4]. In the present study, both knot and knotless nettings were used to analyze the matrixing network and distributed computing in the simulations of trawl and purse seine, respectively.

Model designs of many fishing gears are based on a general principle, which is very famous with the name of Fridman Similarity Principle (Similarity rule) [12]. Here, two similar configurations in geometrical shape, corresponding to the physical models in Fig. 1, were introduced (Fig. 2). Knots were treated as solid spheres (Fig. 2 (a)). Each mesh was a diamond. A bar could be assumed as a cylinder with flexibility.

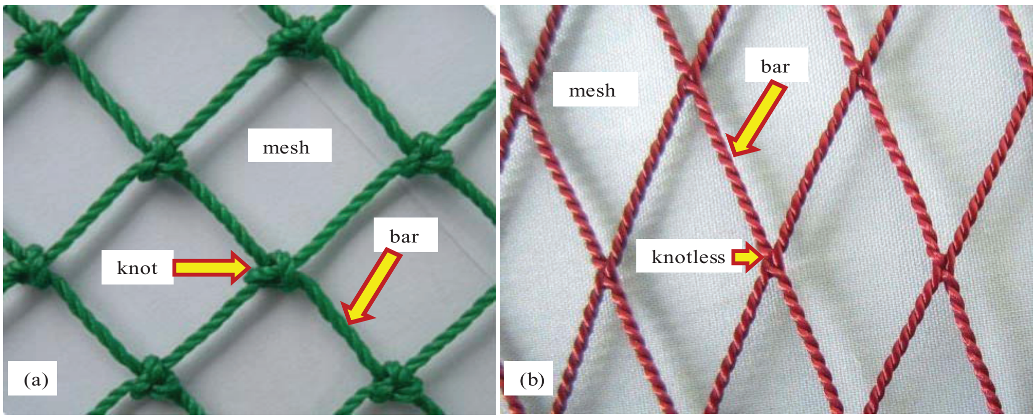

Fig. 1. (a) Net panel with big knots (knot netting); (b) Knotless netting.

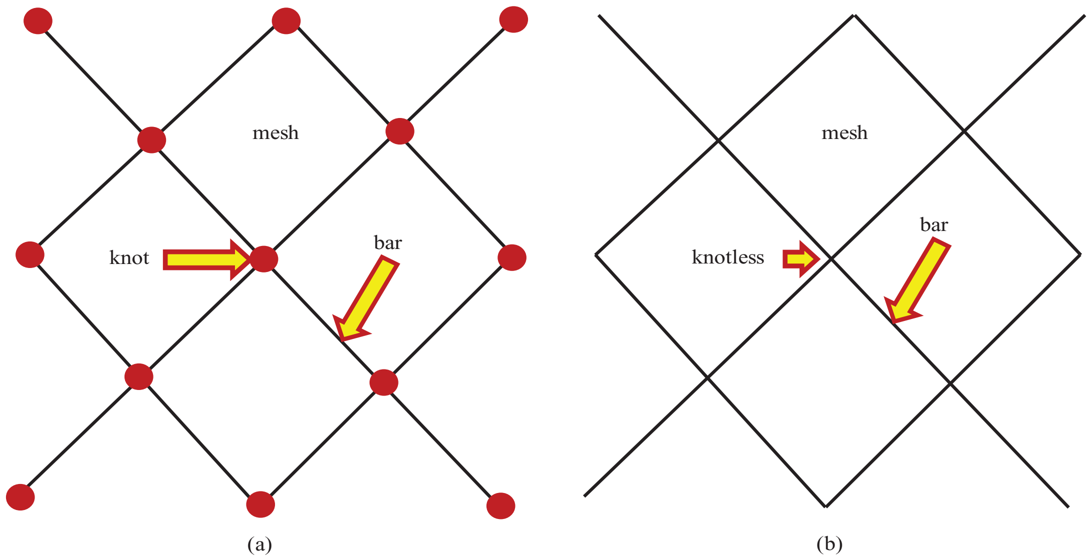

Fig. 2. (a) Virtual nettings with four meshes; (b) Knotless nettings with four meshes.

To simplify calculations, fishing net was assumed to be composed of lumped mass point which interconnected the massless cylinders (Fig. 3). We concentrated lumped point masses on each knot and on the center of mesh bar for knot netting, and knot was assumed to be spherical point where the fluid force coefficient was constant (Fig. 3(a)). For knotless netting, a mesh bar was divided into two parts at the center, and two parts of the connected bars constitute a cylinder. The mass was lumped at the center (Fig. 3(b)).

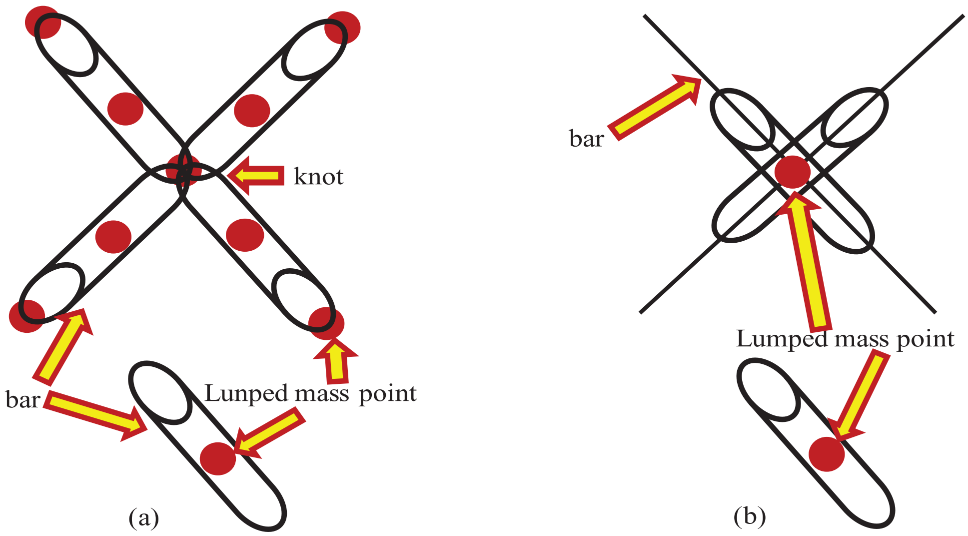

Fig. 3. (a) Decompositions of elements of netting with lumped mass distributions; (b) decompositions for knotless nettings.

It is well known that matrix operation is easy to be executed in computer. To establish high efficient data structures, matrixing method was applied to the virtual netting models. By adding virtual mass points (hollow circles in Fig. 4) to Figs. 2 and 3, all the mass points (actual or virtual) constituted two matrixes: 9×9 matrix for knot netting and 5×5 matrix for knotless netting (Fig. 4). A matrix with the mesh bars constituted a matrixing network. In such matrixing network, actual mass points interacted with each other through the mesh bars. Virtual mass points braced only the matrix and never interacted with either actual mass point or virtual mass point.

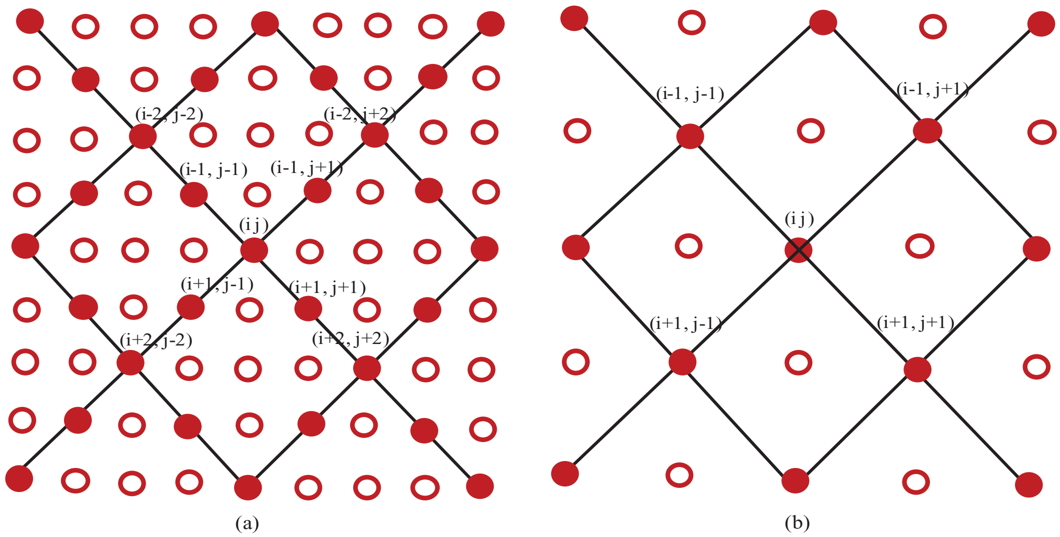

Fig. 4. (a) Matrixing network for knot netting; (b) matrixing network for knotless netting. Solid points are mass points, and hollow circles are virtual mass points, which are missing values in calculation.

3. Distributed computing

According to the Newton second law, the basic mechanical model of the mass point of (*ij*) is:

$$M_{ij}a = \vec{T}_{ij} - \vec{F}_{ij} + \vec{W}_{ij} \tag{1}$$

Where M_{ij} is the mass of mass point (*ij*). a is acceleration, T_{ij} is elastic force. F_{ij} is hydrodynamic force. W_{ij} is the weight of mass point (*ij*) in the water. Mathematical model of mass point (*ij*) can be obtained by differentiating equation (1) two times along three dimensions x, y and z.

$$\begin{aligned} x''_{ij} &= f_1(x_{ij}, y_{ij}, z_{ij}, x'_{ij}, x_{mn}, y_{mn}, z_{mn}) \\ y''_{ij} &= g_1(x_{ij}, y_{ij}, z_{ij}, x'_{ij}, x_{mn}, y_{mn}, z_{mn}) \\ z''_{ij} &= h_1(x_{ij}, y_{ij}, z_{ij}, x'_{ij}, x_{mn}, y_{mn}, z_{mn}) \end{aligned} \tag{2}$$

Where x_{ij}, y_{ij} and z_{ij} are the coordinates of mass point (*ij*), (*mn*) is the neighboring mass point of (*ij*).

For large scale fishing gears (such as purse seine and trawl), there will be thousands of mass points. The mathematical models and computations will be huge. Distributed computing, which studies distributed systems, is a field of computer science. A distributed system consists of multiple autonomous computers which communicate through a computer network. Distributed computing also refers to the use of distributed systems to solve huge computational problems. Similarly, multiple mass points that communicate through a matrixing network constitute a distributed system (Fig. 4), the data calculations and the results of computing were all distributed on each actual mass point. The actual mass points interacted with each other in the process of computing. The connected logics for the mass point (*ij*) and neighboring mass points were shown in Fig. 4. We called this method a kind of distributed computing. Matrixing network and distributed method were all used in programming and computation.

To illustrate the distributed arithmetic, two pieces of screenshots of matrixing data in the computing process in R language (http://www.r-project.org/) were given (Fig. 5). Here, the actual numbers were the calculations for mass points, "NA" meant missing values for virtual mass points, i.e. virtual mass points never participated in computations. Taking advantages of the matrixing data, the results were easy to work out and to plot (Fig. 6). Knot model was used in trawl and knotless model in purse seine. The results showed that the former was easier and quicker to reach equilibrium. More mass points with delicate distributions for knot model might be responsible for this phenomenon. The less stability for knotless purse seine in actual fishing at sea was also consistent with the present study.

(a)

-1.086718	NA	NA	NA	-1.086602
NA	-1.108645	NA	-1.108251	NA
NA	NA	-1.129924	NA	NA
NA	-1.151240	NA	-1.151609	NA
-1.173221	NA	NA	NA	-1.173205
NA	-1.195229	NA	-1.194805	NA
NA	NA	-1.216514	NA	NA
NA	-1.237839	NA	-1.238209	NA
-1.259822	NA	NA	NA	-1.259805

(b)

-0.01481118	NA	-0.01481118	NA	-0.01481118
NA	-0.021881176	NA	-0.021881176	NA
-0.02895118	NA	-0.02895118	NA	-0.02895118
NA	-0.036021176	NA	-0.036021176	NA
-0.04309118	NA	-0.04309118	NA	-0.04309118
NA	-0.050161696	NA	-0.050161587	NA
-0.06657295	NA	-0.06388941	NA	-0.06388941

Fig. 5. (a) Part of screenshot of calculation in computing process for knot netting; (b) part of screenshot of calculation in computing process for knotless netting. The frameworks of data matrixes were the same to the matrixes in Fig. 4.

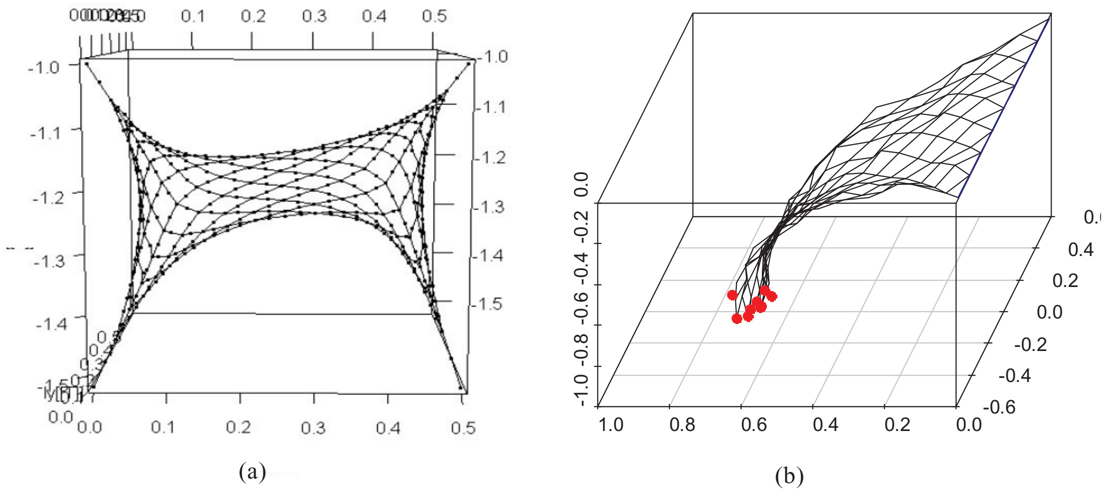

Fig. 6. (a) Simulated steady state of knot net under the sea water; (b) simulated dynamics of knotless fishing net under the sea water. Uniform flows were assumed.

4. Conclusions

Matrixing network was a high efficient data structure in simulating the fishing net. Distributed computing had notable advantages in solving huge calculations in modeling the dynamics of purse seine and trawl. Knot model was easier and quicker to reach equilibrium state. More mass points with delicate distributions might be the reason. The fact of less stability, for knotless purse seine in actual fishing at sea, indicated that: the use of matrixing network and distributed computing in the simulation of fishing net was effective and reasonable.

Acknowledgements

This work was supported by: 1) Specialized research fund for the doctoral program of higher education (No. 20103104120006); 2) Shanghai municipal education commission innovation project (No. 12ZZ168; 11YZ156); 3) Key technology in Oceanic tuna purse seine fishing and deep freezing preservation of catch (No. SS2012AA091802); 4) Key technology in high efficient utilization of Chilean jack mackerel resources (No. SS2012AA091801); 5) Technical development in fishing and processing of squid resources (No. SS2012AA091803); 6) Shanghai leading academic discipline project (No. S30702); 7) National natural sciences fund (No. NSFC31001138).

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