The Study of Simulation Exercise System of Marine Oil Spill Crisis Response Based on GIS

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Abstract: The paper does researches and analysis on the process of marine oil spill crisis response (MOSCR), and develops the marine oil spill crisis response simulation exercise system. The system developed by this paper is composed of four subsystems, including the training system of MOSCR, the geographical information system of MOSCR, the marine oil spill control and cleanup decision-making expert system, and the computer simulation exercise system. The paper builds up the applied model system of MOSCR. The system takes the marine oil spill crisis response geographical information system as the platform, which integrates all aspects of MOSCR. This system can offer an oil spill scene to the trainees and simulate the whole process of MOSCR on the interface of GIS.
Key words: marine oil spill, simulation Exercise System, GIS, oil spill models

1 Introduction

Countless shipping oil spill accidents show that momentous marine oil spill pollution accidents have brought quite serious damages to the sea environment and human society. Oil spill pollution has recently become one of the environment pollution issues, which are recognized by all countries of the world. In order to deal with paroxysmal oil spill accidents and decrease their serious damages, International Maritime Organization (IMO) passed "International Oil Pollution Protection, Response and Cooperation Pact in 1990" (OPRC) in London in 1990. OPRC international pact definitely stipulates that every country, which has joined in OPRC, is under an obligation to constitute marine oil spill crisis response plan of its own country. China issued "Chinese Marine Shipping Oil Spill Crisis Response Plan" in April 2000. In the plan, it's necessary to establish a well-trained oil spill crisis response troop, which should be brought into a uniform oil spill crisis protection system. Training and exercise of the oil spill crisis response troop is on the important ground in the oil spill crisis protection system.

The marine oil spill crisis response simulation exercise system (MOSCR-SES) takes the marine oil spill crisis response geographical information system as the platform, which can offer a oil spill scene to the trainees and simulate the whole process of MOSCR. By the calculation of the dynamic prediction models, the system adopts graphics and images technologies to complete the monitoring and prediction of oil spill trends, the dispatching of all kinds of human and material resources under the different conditions of equipments, weather, hydrology, sensitive areas and damageable resources. According to the current weather influence, the system can select oil spill control, cleanup and recycling methods, and at the same time, evaluate the pollution damages. At last, the system combines fuzzy integration judging and expert system to evaluate the trainees 's operation during the simulation exercise.

2 Function and Structure Composition of MOSCR-SES

MOSR-SES is established based on the oil spill crisis response GIS, which takes the automatic generation of body-fitted coordinate grid, tide field prediction, oil spill behavior prediction, sensitive area protection priority finding, intelligence decision-making of oil spill control and cleanup, pollution damage evaluation, integration evaluation of simulation exercise as application models. The purpose is to simulate the whole process of marine oil spill crisis response and to provide trainees with exercises. MOSCR-SES is composed of four subsystems, such as the training system of MOSCR, GIS of MOSCR, the oil spill control and cleanup decision-making expert system and the computer simulation exercise system of MOSCR. Figure 1 is the function and structure diagram of MOSCR-SES.

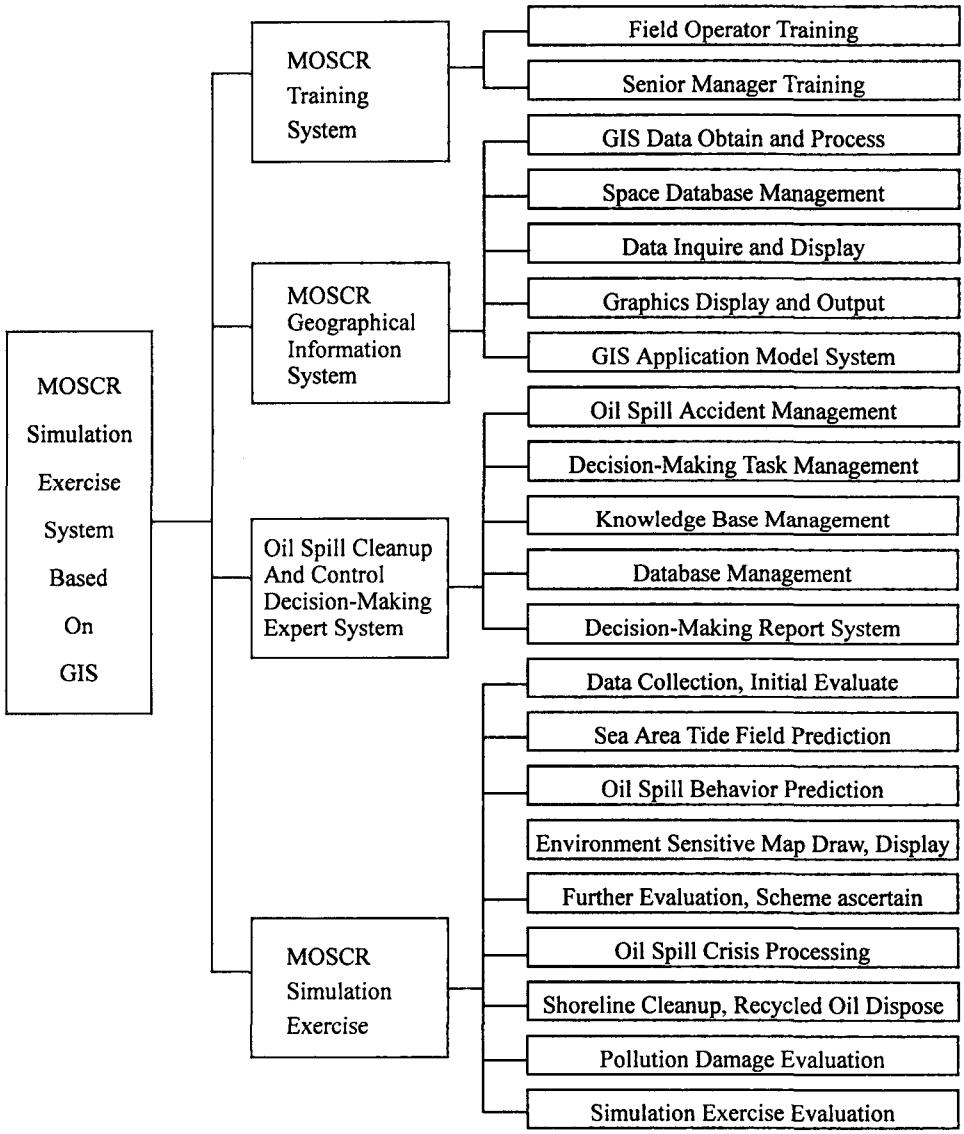

Figure 1 The function and structure diagram of MOSR-SES

The training system of MOSCR trains the trainees by CAI courseware. The trainees include two kinds: the secondary and advanced managers and the field operators.

3 Marine Oil Spill Crisis Response GIS [1]

Aiming at the actual feature of marine oil spill crisis response system, this paper researches and develops MOSCR-GIS, which applies the theory and technology of GIS to the marine oil spill crisis response system. The MOSCR-GIS is also the platform of MOSCR-SES. All the system application models of MOSCR are realized on the MOSCR-GIS platform.

The MOSR-GIS is composed of the basic function of GIS and the unique function of marine oil spill crisis response system. The basic function includes: data obtaining, data processing, data storage, data query, graphics display and alternation; the unique function of marine oil spill crisis response system includes: the automatic generation of body-fitted coordinate grid, tide field numeric calculation, marine oil spill spreading and transport prediction, sensitive area and damageable resources protection priority finding, marine oil spill control and cleanup decision-making expert system, pollution damage evaluation. Data obtaining and processing and space database buildup of MOSCR-GIS are the most important contents during the research.

4 Marine Oil Spill Crisis Response Simulation Exercise System (MOSCR-SES)

4.1 Data collection and initial evaluation on oil spill accident

The instructor sets up a marine oil spill accident before starting simulation exercise. After that, the trainees come into the simulation exercise system to exercise and evaluate the oil spill accident on the interface of oil spill accident initial evaluation.

During the simulation exercise, the trainees need to make initial evaluation on the oil spill accident according to oil spill reports and monitoring system's data. The results of initial evaluation are recorded in the simulation exercise database as the basis of evaluating the trainees' integrative abilities.

4.2 Marine oil spill behavior prediction based on GIS

In the process of the oil spill crisis response, oil spill spreading and transport behavior is the main aspect that should be considered. It is one of the most concerned problems when the trainees take emergency measures. It is also the basis and key to make oil spill crisis decision. Tide of sea area is one of the main factors that influence the oil spill transport besides wind tide.

4.2.1 Tide field numeric simulation

Marine oil spill accidents mostly happen in shallow sea area and marine petroleum exploitations are also concentrated in this area. Thus, there is important practicality value to build up a tide prediction model, which applies to shallow sea area.

Three dimensions control equation of sea area tide process is as follows [2]: (basic movement equation of offing tide)

Regarding seawater as homogenous liquid, namely, the density, the temperature and the salinity of seawater are all constants.

Continuous equation: $$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0$$

Momentum equation:

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}-fv=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\frac{\partial}{\partial z}\left(\mu\frac{\partial u}{\partial z}\right)+\lambda\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}+fu=-\frac{1}{\rho}\frac{\partial p}{\partial y}+\frac{\partial}{\partial z}\left(\mu\frac{\partial v}{\partial z}\right)+\lambda\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)$$

Static pressure assumption: $$\frac{\partial p}{\partial z}=-\rho g$$

In above equations, ***(x, y, z)*** is the right-angle coordinate of three dimensions, the ***xoy*** plane is putted on the unperturbed static sea surface, the ***z*** axis is in the vertical direction, ***u, v, w*** are the velocity of the directions of ***x, y, z*** axes, ***t*** is time, ***f*** is Coriolis parameter, ρ is the density of sea water, ***g*** is acceleration of gravity, μ is vertical viscosity coefficient, λ is horizontal viscosity coefficient, ***p*** is pressure.

By running the tide field model, the dynamic situation of tide field can be calculated and showed on the GIS platform. The calculation results of tide field will be used as the basic data of oil spill spreading and transport prediction. Figure 2 is the tide field numeric simulation result some time a day in Bohai sea area, which is dynamically showed on GIS platform.

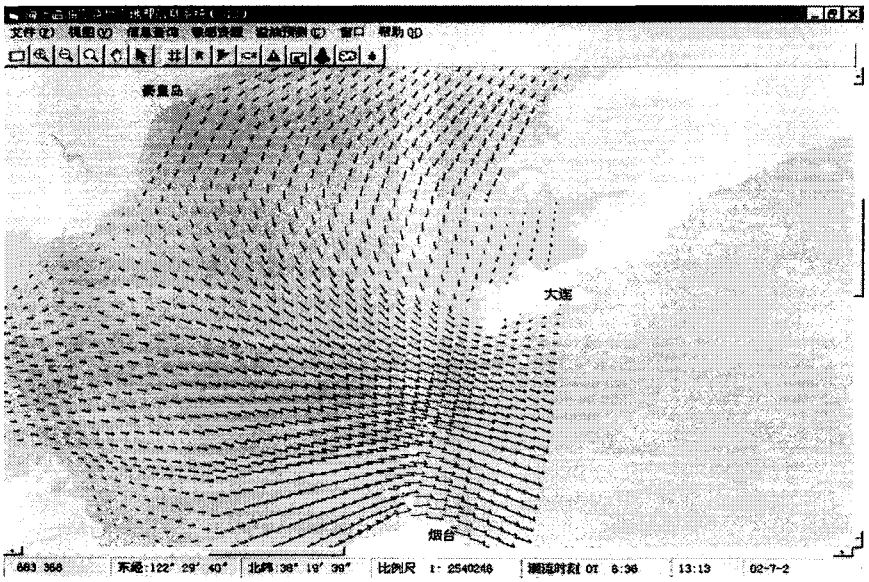

Figure 2 Bohai tide field numeric simulation result

4.2.2 Marine oil spill spreading and transport prediction

The paper adopts oil particle model to simulate the marine oil spill behavior. The oil particle model is to disperse the oil spill into a mass of oil particles; every oil particle represents a certain amount of oil and is drifting under the surface tide. The distribution of oil particle's size and the process of shearing

flow and inflow control the oil spreading. The oil film spreads by the oil particle's random movement. The process of oil's evaporation and dissipation is incarnated by the quality loss of oil particle. The thickness of oil film is obtained by calculating the oil particle's quantity, volume and quality within a certain area of sea surface.

On the precondition of having known the oil particle's position of previous step, after a Δt interval, the oil particle's space position can be showed:

$$X_i^* = X_i^n + (U_i^n + U_i^{n+1})\Delta t / 2$$
$$X_i^{n+1} = X_i^* + \Delta X_i^{'}$$

Vector X_i^n represent the number I oil particle's space position at the time of $n\Delta t$; vector U_i^n represent the total velocity at the point X_i^n at the time of $n\Delta t$; including the velocity of oil particle's transport and floating. random vector $\Delta X_i^{'}$ represent the i th oil particle's random movement distance which taking the point X_i^* as jumping-off point.

The calculation results will be the reference basis for the trainees to do further evaluation to the oil spill accident and make the crisis response decision.

4.3 Sensitive map drawing of environment sensitive area

It is necessary to investigate and plot the environment sensitive area on the sea and the seacoast before further evaluation on oil spill accident. Sensitive maps are created on GIS platform; and the corresponding sensitive resource information is input into database. The trainees can complete above all tasks by the function menu "sensitive resource". Sensitive maps are the important basis of the evaluation and the crisis processing of the oil spill accident. All of the operating contents will be stored in the simulation exercise database.

4.4 Expert decision-making of marine oil spill control and cleanup

On the basis of the oil spill spreading and transport prediction, environment sensitive areas and sensitive maps, continuous reports and supplement reports of oil spill accident, reports of watching and monitoring systems, database information etc., the trainees should take a farther evaluation to the oil spill accident and make the crisis response decision. In the MOSCR-SES, the trainees can transfer the oil spill control and cleanup expert decision-making model to get the decisions on marine oil spill control and cleanup, coastline protection and cleanup, processing of recycled oil and oil-polluted garbage by inputting correlative data and information. The marine oil spill control and cleanup expert decision-making system will be expatiated in another paper.

4.5 Marine oil spill crisis processing

The oil spill crisis processing measures should be taken immediately after the oil spill crisis decision-making schemes have been made. The simulation exercise system takes the marine oil spill crisis response GIS as the operating platform, which can train the trainees all kinds of abilities of processing marine oil spill. The trainees should confirm the concrete operation methods to process the oil spill according to the information of oil spill's type, scale, category, spreading direction and environment etc.

The results of the trainees processing operation on the marine oil spill will be recorded in the integrative evaluation database as the basis of evaluating their simulation exercises.

5 Conclusion

Marine oil spill crisis response computer simulation exercise is the most effective training measure against the marine oil spill accident disaster. It can greatly improve the decision-making and operation abilities of the decision-makers and operators. The paper does researches and analysis on the whole process of marine oil spill crisis response systematically, and develops the marine oil spill crisis response simulation exercise system to train the trainees and operators. The system can be used as marine oil spill crisis response decision-making support information system if it is combined with the remote sensing system (RS) and the global position system (GPS).

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