Geographical Relations Dynamics (1) on an Interactive 3D CG Digital Globe

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Abstract:- Traditionally geography was the collection of topography of explorers. Its descriptive nature has been inherited by GIS (computer assisted mapping system) who displays the static distributions of various map objects or phenomena rather than analyzes causality. In the early 1970's, D. L. Meadows and his colleagues created the "World Dynamics" model as a tool to simulate the future of mankind. This tool treated the whole Earth as a single entity, and we could not implement simulations with different regional parameters. As the continuation of the previous study presented at EEED'06 in Venice, the author attempts to present "Geographical Relations Dynamics (GRD)" to study how various regions on the Earth interact each other in time series, to verify individual survival strategies. This primary version system segmentalizes the surface of the Earth into 90 regions, 65 ocean and 25 land meshes (or cells). Each of land mesh consists of four layers, namely, a layer of the underground non-renewable natural resources (represented by energy in Kcal unit), that of the biosphere-atmosphere-ocean system (by food production in Kcal), that of the man-made material production (represented by green house gas emission), and that of the man-made value system (information) such as world wide financial activities. It is expected that, when completed, GRD would allow simulations of horizontal regional interaction (transportation) as well as vertical simulations, for instance, rates of efficiencies reflecting combination of different value system, different way of life, and different resource management methods. *Keywords:-*
World Dynamics, Global Climatic model Geographical Relations Dynamics, interactive 3D CG digital globe, GHG (green house gas),international trade

1 Introduction : Point Model vs. Geographical Model

1.1 Meadow's model

D. L. Meadows's team has selected pupulation, food, natural resources, and environment as the parameters to run their "the World Dynamics". However, the world dynamics is not suitable for analysis of the individual regions of the world. It was a "point" model that has made the analysis of the whole world[1].

In 2005, Katrina, the largest hurricane ever, hit the Mississippi Delta and inflicted heavy damage on that region. And yet, if we were to take the entire Uinted State as an individual entity, or a "point", it had sufficient food supplies and a variety of logistics measures. Only when we examine this disaster using the geographical model, we could appreciate how this climatic phenomenon had escalated into a national disaster because the food supplies and aid did not reach the lower Mississippi regions from other parts of the United States.

1.2 DEARS model by Purdue University

This is a multi-regions and multi-layers model to analysis the world trade originated by prof. T.W. Heertel, at Purdue University,USA , in the mid-1980s. This model divides the earth surface into 18 regions the following. North America, Latin America, West Europa,MidEast and North Africa, South South Africa, Eastern Europa and Russia, Central

Pacific East Asia, Other Asia, Oceania (Figure 1). The world industry consists of 18 sub-groups. Among them, the energy group is further divided into 11 subsections.
It original purpose is to analyze the world trade on regional basis. In Japan, a Japanese team granted by Ministry of Economic, Industry, and Trade has been studying the future energy problem especially on China and India. (Institute of Innovative Technology for the Earth)[2]

1.3 Earth Simulator, Japan

Today, there are several super computers in the world. One of them, working in Japan is called the "Earth Simulator". Its major project is to study the global warming as a successor of "Global Climatic Model". Its cell size is 10 Km x 10 Km. The Earth surface is divided by 4000 x 4000 meshes. It deals mostly natural phenomena such as atomosphere and ocean interaction[3]

Figure 1: Regions used in DEARS model

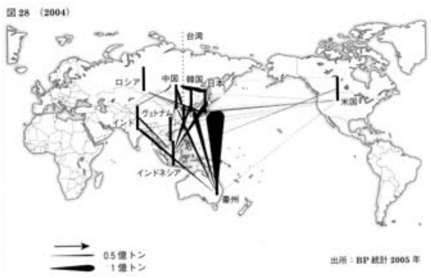

Figure 2: Diagram used in "East Asia Community" study

1.4 Network Analysis of an East Asian Community

Professor K.Mouri et al, Japan, have studied "Designing an East Asian Community" as a special grant research of Ministry of Education and Science, Japan. Based on economic data of Asian countries, they blend multi-variable analysis for numerical analysis and network analysis how Asian countries are interrelated (Figure 2). [4] Their field is restricted to the western Pacific belt.

2 Geographical Relations Dynamics

2.1 basic requirement

Geographical Relations Dynamics is required to fulfill the following conditions:

A. It is a software system able to study the interaction among regions in the world through an interactive 3D CG digital globe. The software must be functional with any standard personal computers connected to the Internet.

B. The software is to divide the Earth surface into numerous geographical regions (mesh or cell) who interact with one another in time series. It allows for future region number expansion. In preparation for corresponding with proliferating environmental problems , each mesh contains several layers representing different human and natural geographical phenomena.

2.2 Programing requirement

We adopted JAVA 3D language for visualization, and ACCESS by Microsoft Corp. for compiling its database (Figure 3). When a user obtains an access to this program, a picture of the globe, which is divided up into 90 geographical regions, appears on the display, and the user is able to specify a region of his/her choice at the click of a mouse. A user can perform various simulation based on its database and retrieve and visualize the simulation result.

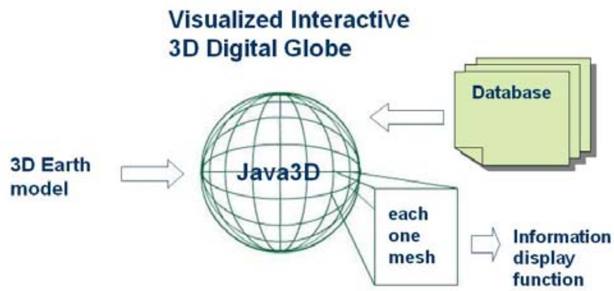

Figure 3: Schematic System Diagram of Geographical Relations Dynamics

3 Tesselation of the Earth Surface

3.1 Basic requirement

As is well known, the accuracy of figures calculated by using the finite element method is directly dependent upon how skillfully the surface of the target 3D object is segmented. When expanding

Meadows ' world dynamics model into a geographical model, it is preferable to minimize the number of tessellated zones. While the calculations of the finite element method are only required to simulate interactions between a target cell and its neighbor eight cells for a 2-dimensional world; the global scale geographical model, however, has to be capable of calculating interactions between regions that are far removed from one another. For instance, shipping crude oil from a Middle-East country to the Far East, or exporting automobiles manufactured in Japan to the United States. Our criteria for tessellating the surface of the earth are as follows:

1. The United States and the southernmost part of Canada put together is placed under an independent mesh (region), because this part of the world is considered to be the most influential region for every point of the world.
2. China and India, both of which have become rapidly industrialized, are considered to exert a great deal of impact on the environment through the consumption of natural resources, and therefore are also placed under an individual mesh of its own.
3. Oil and natural gas producing nations in the Middle East and those bordering the Caspian Sea are altogether placed under an independent mesh.
4. The Suez Canal, the Panama Canal, and the Strait of Malacca, who are the most important critical point in the world trade, should be expressed on this mesh system clearly.
5. Meshes covering land areas and those covering seas are allocated over the globe in mutually exclusive manner as much as possible.

After several attempts to satisfy all of the criteria listed above, the author has proposed the following conditions for tessellating the surface of the globe:

- The latitudinal length of the globe, from the North Pole to the South Pole, is separated into nine segments, each corresponding to the climatic zones, namely (1) the Arctic (2) the northern polar front zone (3) the westerlies belt (4) the northern trade wind zone (5) the equatorial doldrums (6) the southern trade wind zone (7) the westerlies belt (8) the southern polar front (9) the Antarctic.
- The longitudinal length of the globe along the equator, which is 40,075 Km in length, is divided by ten, thereby making a side of each segment 4,000 Km in length alomh the equator.
- That is to say, each mesh along the equator will have an area of 4,000 Km x 4,000 Km in the first version model.
- When the globe is segmented into one tenth of the longitudinal length and one ninth of the latitudinal length, most of the North American region mentioned in criteria No.1 above can fit under a mesh placed at longitude 80 degrees west to 120 degrees west, and at latitude 30 degrees north to 50 degrees north, thereby making it possible to handle this most significant region of the globe as a single mesh.
- Figure 4 shows the tessellation of the surface of the globe while fully satisfying all of the criteria 1, 2, 3, and 4.

Here, we get 10 x 9 meshes.
Let define $M_{i,j}$ as a single mesh: where i = 1 - 10 around the equator and j = 1 - 9 around meridian.

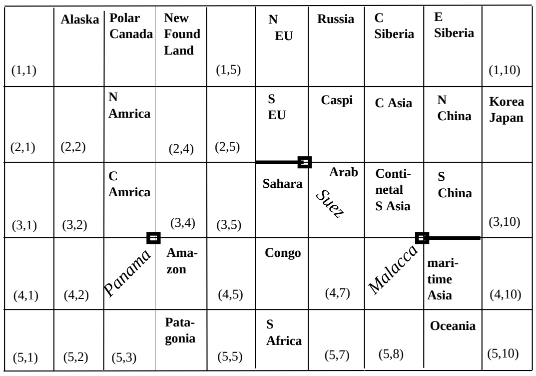

Figure 4: 24 Land meshes with singular points

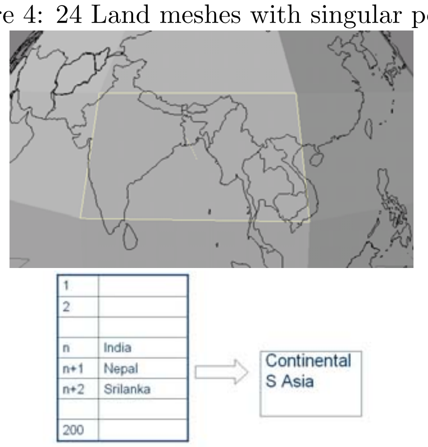

Figure 5: Sri Lanka and Continetal South Asia Mesh

3.2 Adjustment of land mesh vs. countries

Fortunately, selected land meshes include neigboring continental shelves well and do not include deep sea regions. Next, what we have to do is which country should belong to which land mesh. There are almost 200 countries and some minor compromizing adjustment is necessary. For example, as shown in Figur 3, Sri Lanka belongs to Indian Ocean sea mesh in fact. We compromize that Sri Lanka belongs to the Contineta l South Asian mesh where India and the Southeast Asia Peninsula countries are.

4 Interaction among Meshes

Different from finite element analysis, in "Geographical Relations Dynamics" case, we have to deal with any interaction betweem far apart meshes such as when Arabia mesh exports her oil to Japan and Korea mesh. Usually, this has been studied as international trade marix analysis[5].

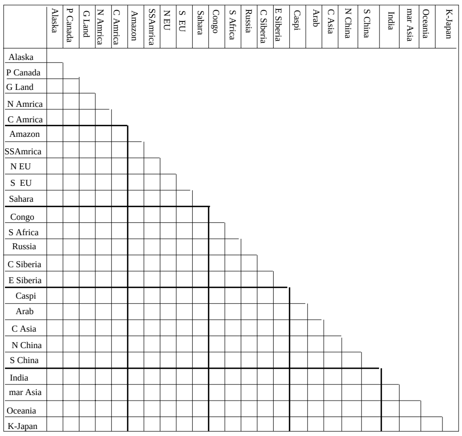

Figure 6: the World Export and Import Matrix

Figure 6 shows the feasible combination of world trade among 24 regions.

4.1 Route Finding Algorithm

4.1.1 Route Finding Algorithm

As for shortest path finding problem on two dimensional plane map, there have been many resurches, starting from Dijkstra's algorithm[7]. However, in the case of finding navigation routes on 3D sphere there are some different nature from the conventional shortest path argorithm. They are;

- the target field is seamless sphere surface, not a 2 D plane with boundary edges.
- there are important point where a navigator must pass such as important canals and straits.
- selection of vehicle, i.e., by see, by land, and by air. we have consider the cost(money and energy consumption) and the time.

To deal with problems above, we put some limitations.

- not cross the Arctic Ocean and the Antarctic Ocean, so that the target field becomes cylinder-like.
- usually not naviagte around the Strait of Magellan and Cape of Good Hope. Mostly navigate through the Panama Canal, the Suez Canal, and the Strait of Mallaca, so that any route tends to be east-west direction.
- prefer by ship as much as possible, because of cheaper cost.

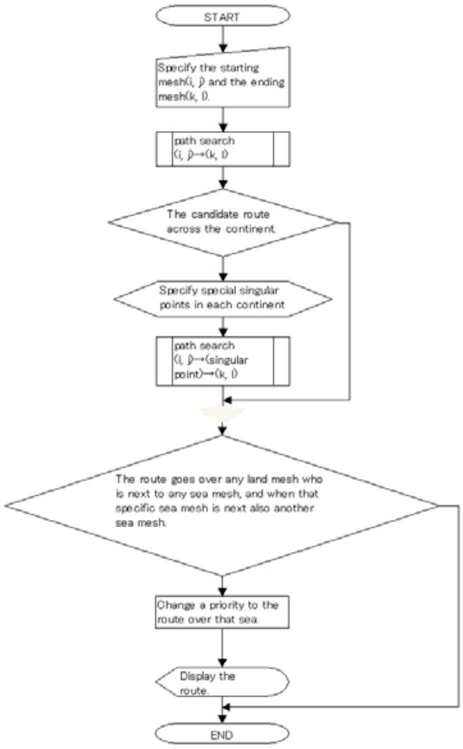

Figure 7: A flow chart finding a route

Fig 7 is the flow chart of the basic algorithm finding a route.

1. First, specify the starting mesh(i, j) and the ending mesh(k, l). Usually, we can identify several possible candidates at first. We give a priority to any route navigating over sea meshes, because transportation cost is far cheaper navigating on sea than on land.
2. Next, when the candidate route is across the continent, we specify special singular points where the route must pass. Those singular points are the Suez Canal, the Panama Canal, and the Strait of Malacca.
3. As the last criteria, when the route goes over any land mesh who is next to any sea mesh, and when that specific sea mesh is next also another sea mesh, we give a priority to the route over that sea mesh, because of the cost. By this means, we can find the cheapest route.

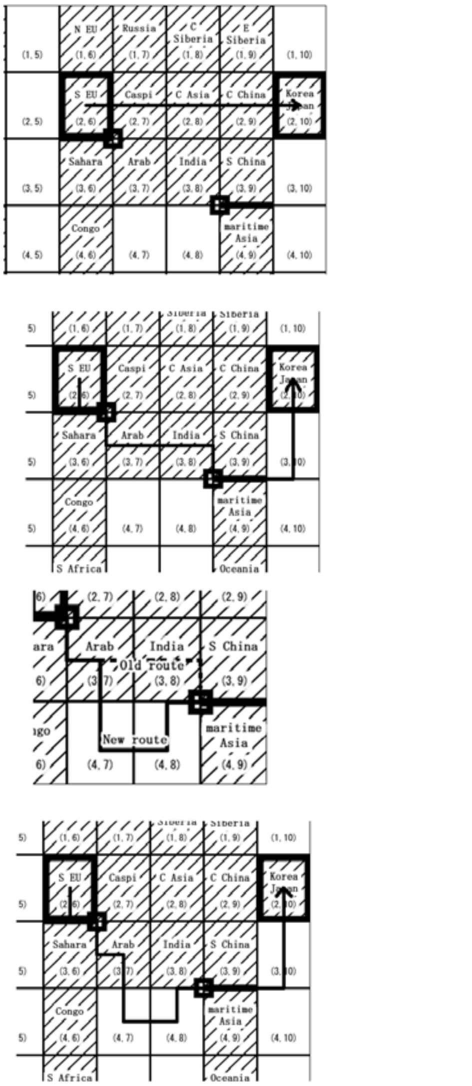

Figure 8: finding a route: step 1, step 2, step 3, step4

4.1.2 An example: South Europe to Japan

As an application of this algorithm, we calculate the route from South Europe mesh to Korea and Japan mesh (see Fig 8) First, find the shortest route between two mesh, drawing a straight line between them (step 1: left upper).

As this route goes cross over the entire Eurasia continent, we designate the Suez Canal and the Strait of Malacca as the special points to find the next shortest route. (step 2 :left below)
However, this route travel over land meshes such as Arab mesh and Indian mesh. between the Suez Canal to the Strait of Malacca. Both the neighbor mesh (4,7) who is next to Arab mesh, and another neighboring mesh(4,8) are next to sea meshes. (step 3 : right upper)

So we modify the route to go over these sea meshes. modifying the former route, show the new candidate route in comparison to the former route. Like this, we can obtain the final route between South Europe to Korea and Japan. (step 4 : right lower)

Figure 9: non fixed-length records table of travel

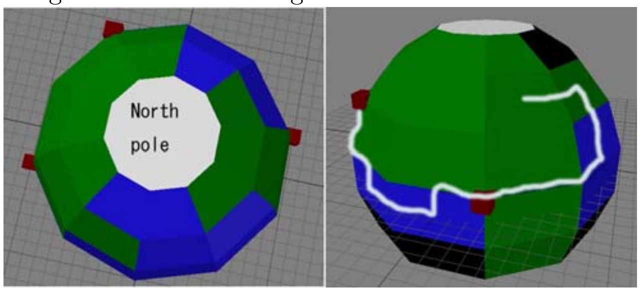

Figure 10: Calculated route

5 Conclusion and Discussion

5.1 Conclusion

The author obtains a set of meshes inbetween from the starting mesh(i,j) to the ending mesh (k,l). The total combination is 264. The calculated results are stored into database consiting of the starting mesh ID, the ending mesh ID, and all meshes ID inbetween. Obviously, the number of inbetween meshes are not same so that this database members are non-fixed length records. The shortest is zero (tarvel to the just next mesh) and the longest is to travel almost half around the globe.(Figure 9)

In this case, the total number of combination is only 264 so that the algorithm stated above worked. When the number of meshes increases, we have to develop a better algorithm. As for the the current algorithm, there are a few problems. First, if the target mesh is a land mesh surrounding by other land meshes, the transportation cost might become more expensive depending on the kind of cargo. We have to study specific transportation cost by good bais. Secondly, if there are only land meshes between the starting and the ending meshes, sometimes transporting cost by land and by air might become cheaper than those by sea. It depends on kind of cargo Thirdly, we ignore the locations of ports, canal, river and so on existing within land meshes. The last problem is the fact that we have to deal with a closed sphere (the Earth surface) not a opeen 2 dimensional plane. Due to this condition, we can not adopt the conventional route finding method.

5.2 Absolute distance between meshes

As the Earth surface is infite, we can pre-calculate the navigation distance between any two land meshes, regardless by ship, by land (car or train), and by air. Our meshes becomes smaller as its latitude becomes higher toward either the North pole or the South pole.
The absolute distance from the center of an individual mesh toward its edge can be calculated in advance. In the previous subsection, we calculate the routes between any two meshes. Our mesh system consists of 9 x 10 meshes and there are 24 land meshes so that the whole matching for the world trade becomes 264 (shown in Fig. 444).

5.3 Automatic visualization of Trades

Mr. Nakayama, Tokyo Custom, Japan provides various logistics data as to the world trade[7].

- By Ship from LA, USA to Shnaghai, China transport ca. 10,000 ton grain by Container ship (5600 TUE, 25 knot)
  9 days and 10 hours, fuel 2000 ton oil

- By ship transport ca. 10,000 ton grain by bulk cargo ship (50,000 ton, 12 knot)
  19 days and 18 hours, fule 500 ton oil

- on land (non-higways) 1 ton grain, by 4 ton truck
  2days fuel 200 -250

- on land (highway)
  1 ton grain, by 4 ton truck
  12-13 hours, 170

Combining the data above with the distance table data, we can calculate how many hours and how much energy are necessary to transport any cargo such as energy, food and so on between two land meshes. Figure 11 is the table showing how many days whould take from any exporter to importers. To visualize any route on the 3D CG globe, we create a JAVA program which read the distance table and the trade database table (e.g., how muc crude oil is exported from Arabia mesh to Korea and Japan mesh) and draw the navigation pass on the 3D CG globe between two meshes by JAVA3D language. (Figure 12)

larger exporter ↔ smaller

larger importer ↔ smaller

food export / import	N Amrica	Amazon	SS America	India SEAsia	Oceania	Caspian	Russia	maritime Asia
S China	24	52	75	23	15	30	33	15
N China	24	56	75	25	23	25	25	23
C Asia	32	60	80	28	31	17	17	30
Korea Japan	20	48	70	38	30	35	30	23
Congo	30	15	22	25	30	38	34	23
Arab	24	38	37	8	30	8	17	23
S EU	20	30	38	23	45	8	14	37
C America	8	8	23	56	60	38	45	38
N EU	20	30	38	25	48	15	8	42

Figure 11: Food exporter and importer matrix as of navigation days

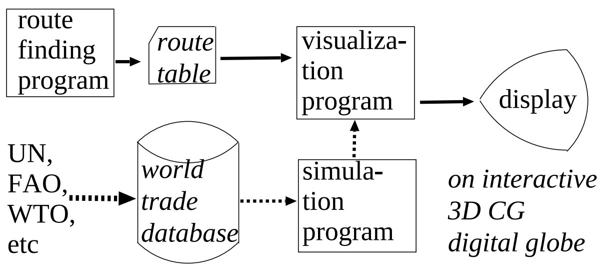

Figure 12: Flow chart of visualization and simulation of the world trade

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