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Making of the Simplest Interactive 3D Digital Globe as a Tool for the World Environmental Problems

Minoru Ueda
Dept. of Conputer Software
The University of Aizu
Ikkimachi, AizuWakamastu, Fukushima
Japan

Abstract:- To verify the world 's environmental issues, it is necessary to expand D. Meadows' theory of world system dynamics, within which, he first hypothesizes that nature, i.e. both in lithosphere and biosphere, is kept constant. Recent climatological studies suggest that everyday activities by man are conducive to serious climatological ramifications in the near future. Therefore, it is necessary to come up with some types of geographical tools that would help analyze possible deleterious effects, if any, of rapidly industrialized and economically growing nations, such as China and India.
By using JAVA3D language, the author has developed an interactive 3D computer graphics globe model that would help its users stay abreast of new developments in the world 's environmental issues. It does so by allowing the users to visualize environmental problems worldwide, and the users themselves can take part in updating a database over the Internet. In this literature, the author describes how he has come to create this 3D digital globe in its simplest form, verifies its current usability, and discusses how its functions can be expanded if need arises in the future.

Keywords:- system dynamics, climatic change,interactive 3D digital globe

1 Introduction

D. L. Meadows and his colleagues have been making great contribution to resolving the world ' s environmental problems for over 30 years[1][2][3]. Many researchers worldwide have followed in their footsteps. And after the Kyoto Protocol was adopted in 1997, even more research literatures have been published and numerous comments have been made not only by academics in this field but also by laymen and government agencies.
Environmental problems are randomly distributed on the globe in various conditions. And yet Meadows tries to approach these problems only unilaterally. He looks at his world system dynamics as a single unit, as " the world " or as " the system itself; " and does not take into account the fact that many geographical regions of the world are constantly interacting with one another.

At the same time, we know that climatologists have already implemented simulation software called Global Climatic Model, or GCM to be installed on supercomputers. GCM was first introduced by the Jet Propulsion Laboratory at California Institute of Technology in Pasadena, California in the 1960 's as incipient simulation software, which was known as " Mintz-Arakawa's GCM". Along with the advancement of the supercomputers, this software has also improved steadily in performance. Today, we have in Japan a supercomputer called " the Earth Simulator, " which was introduced in 2002, and had prided itself on being the world 's best performing computer up until the United Sates came up with a faster version in 2005.
With the help of the Earth Simulator, a team of

*†ueda@u-aizu.ac.jp

the Atmospheric and Oceanic Science Group has been analyzing data it has collected in order to predict future events that are likely results of global warming[4].

The Earth Simulator covers the surface of the earth by 20 Km x 20 Km mesh zones; in other words, the entire earth surface is divided into 2.25 million (1500 x 1500) regions. The cost in building the necessary hardware was some 40 billion Japanese Yen (ca.364 million US dollars,) and it takes a fulltime staff of more than fifty people dispatched from Japan Meteorological Agency to run the operation. The annual running cost turns out to be over 5 billion yen, or 45 million US Dollars. The latest findings by the Earth Simulator indicate that the United States will no longer be" the farmland of the world "by the year 2100 due to aridification. Europe also will be much drier if the proclivity for global warming continues to exist.

In 2005, the Bureau of Economics and Environment at the Japanese Ministry of Economy, Trade, and Industry launched a new project in order to take measures against the world 's environmental problems headed by a team of researchers. The author's responsibility was to provide a simple digital globe, which would allow anyone, who is interested in the world 's environmental issues, to easily obtain an access to it over the Internet and to participate in compiling and updating the database.

2 Requirements for the simplest interactive 3D digital globe

The interactive 3D digital globe is required to fulfill the following conditions:

A. The software must be functional with any standard personal computers connected to the Internet, furthermore anyone interested in the world 's environmental issues are allowed an easy access to look at the interactive 3D digital globe over the Internet, and to participate in compiling the database.

B. The software is to divide the surface of the earth into numerous geographical regions (mesh) that can interact with one another, and that it must be capable of increasing the number of regions, in preparation for corresponding with proliferating environmental problems in the future.

C. Within each unit of the mesh (region), the basic algorithm proposed by Meadows ' world system dynamics is applied to calculate the interactive relationships between nature and mankind.

3 Creating the Simplest Digital Globe (Materialization)

3.1 On Requiremen A

We adopted JAVA 3D language for visualization, and ACCESS by Microsoft Corp. for compiling its database. 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 screen, and the user is able to specify a region of his/her choice at the click of a mouse (Figure 1 and 2).

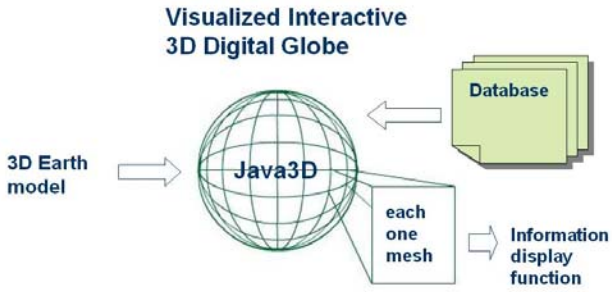

Figure 1: Schematic System Diagram

3.2 On Requirement B (Zoning)

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 onject is segmented. When expanding Meadows ' world model, which is comparable to a point model, into a geographical model, which is comparable to a plane model consisting of a tessellation of zones, 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 central region and the eight regions (for a 2-dimensional world) directly surrounding it; the geographical (plane) model, however, has to be capable of calculating interactions between regions that are far removed from one another. This geographical model is required, for instance, to simulate very likely scenarios, such as shipping crude oil from a Middle-East country to Japan, 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, 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. 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 4,000Km x 4,000 Km.

- 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 2 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.

Alaska	Polar Canada	New Found land	Green land	N EU	Russia	C Siberia	E Siberia	Kamch aka
	N America			S EU	Caspian	C Asia	N China E Asia	
	C America			Sahara	Arab	Contine ntal S Asia	S China	
		Amazon		Congo			maritime S Asia	
		Patagon ia		S Africa			Oceania	

Figure 2: 26 Land meshes

3.3 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 Continetal South Asian mesh where India and the Southeast Asia Peninsula countries are.

3.4 Four layers structure

D. Meadow's world system dynamics deals with 4 elements. i.e., natural resources, food, population, and environment. Global Climatic model has multilayer structure of air masses just above the same Earth surface, because they have to deal with vertical air masses interaction above the same land mesh as well as horizontal interactions. For the visualization sake, our digital glove consists of 4 concentric balls. They represent the following;

1 st layer: underground natural resources. i.e., lithosphere. this layer include not only gas and oil, minerals, but also fossil underground water. We assume those resouces are non-renewable resources.

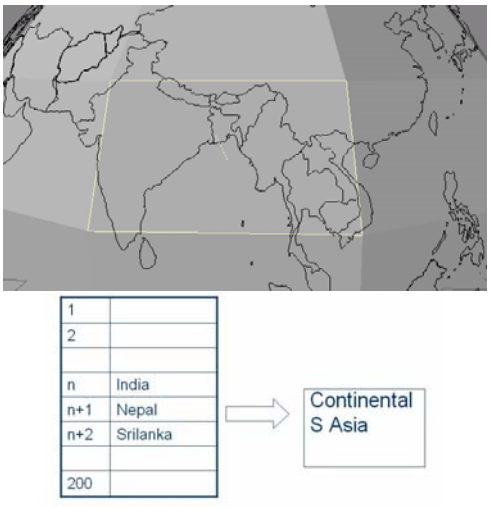

Figure 3: Sri Lanka and continetal South Asia Mesh

2 nd layer: so-called biosphere, including land and ocean, and atomosphere which are conneted by water circulation drived by solar energy.

3 rd layer: man's economic activity mostly materials (atom) which we regards as main contaminants producer.

4 th layer: man's non-material activity i.e., information in a broad sense (bit) such as religion, political and social activities technologies. We create this category after N. P. Negroponte of Media Laboratory, MIT[5].

Here let define $M_{i,j,l}$ as a specific layer on coordinate (i,j). where l = 1 - 4 corresponding to layers 1 to 4. When we want to specify the population of $M_{i,j}$, we use a symbol $M_{i,j,3,pop}$ for a sub-layer. We define the population of mesh(i,j) in the specific year t as $M_{i,j,3,pop}(t)$. Thus, the world population in 2050 expresses as

$$\sum_{i=1}^{10}\sum_{j=1}^{9} M_{i,j,3,pop}(2050)$$

. We use a symbol $M_{i,j,3,food-prod}(t)$ for a food production at the mesh (i,j) in the year t.

atom and bit: D. Meadows' world system deals with only materials, mostly non-renewable natural resources, food, industrial products, and contaminated soils, water and moleculers in the air. They are **atoms** in Negroponte's context. To solve foreseeable world catastophe, they have been preaching on the urgent necessity that man has to change his way of thinking. Assume a man is a robot which

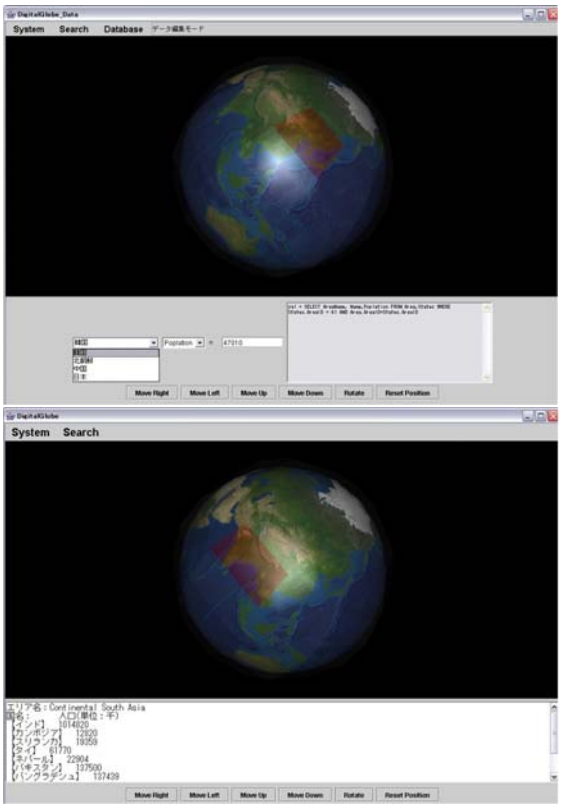

Figure 4: Database manipulation, showing the Continetal South Asia mesh above: data input, below: display query result

specific software is installed. Change of our way of thinking means that we have to adopt another information system i.e., **bit**. When *The Limits to Growth* was published in 1972, there were only mainframe computers and PC had just appeared.

We can group man's activities into two major categories. First, production of food and industrial goods, as results of natural resources consumption occur in the **atom** world. Secondly, behaving after one's religion or faith, political activity, technologies belong to information **bit**. Man as a being in atom world collects atom, eats and use atom, discharge atom into biosphere. Man as a being in bit world behaves following his already acquired knowledge (bit) and think of something new idea (bit).

4 Visualization by 3D digital globe

Based on database, the digital globe visualizes statistcal data as thematic maps and displays simulation output.

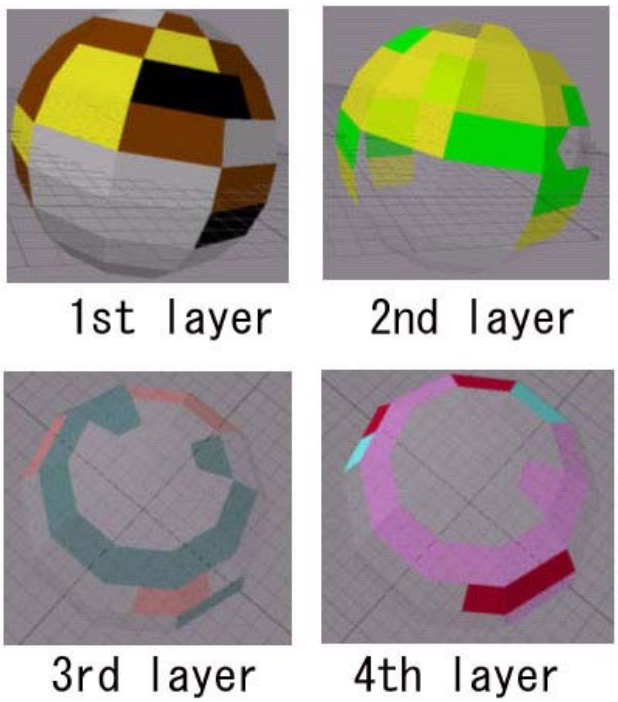

Figure 5: Thematic maps display of todays world

Figure 5 shows how contents of 4 layers display themselves.

- 1st layer (underground non-renewable resouces in lithosphere) : In the upper left image, oil and gas location is displayed in yellow color and black color indicates coal rich areas..

- 2nd layer (so called ecosystem including land, ocean, and atomosphere) : In the upper right image, meshes in yellow are dry and semi-dry area and meshes in green color are humid regions.

- 3rd layer (agriculture, forestry, fishing, stock farming, manifacturing, and transportation) : In the lower left image, industrialized contries such as USA, Europa, Japan and other countries are shown in thin pink color.

- 4th layer (political, religious, social, reseacrh activities, information network) : In the lower right image, meshs in light blue color show the contries who signed on Kyoto Protocol. We assume that there are more people caring the world environmental problem than other areas. Meshes where countries are against Kyoto Protocol are shown in red color.

aaa

5 Verification of 4 layers model

The most important difference of our system against finite element simulation model is that, as shown in Figure 6, we have to calculate the interaction between far aprt cells, e.g., Japan Sea mesh imports oil and gas from Middle East mesh and export automobile to North America mesh. On the other hand, in the case of finite element simulation, we calculate the interactions meshes (cells) only neighboring each other.

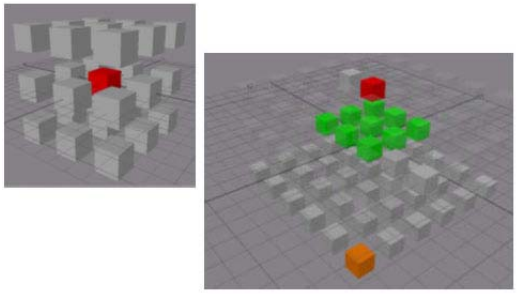

Figure 6: Finite elements model vs. our model

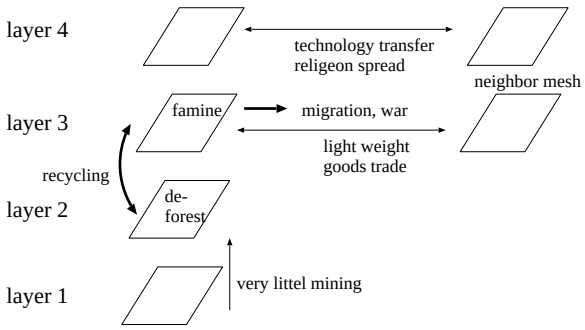

Figure 7: Interaction of meshes in historical time

5.1 Interaction in the past

Figure 7 shows interaction among meshes since the agricultural revolution about 7,000 years ago till the industrial revolution about 1800. Man did not bring out underground natural resouces from the 1 st layer to the 3 rd layer to produce food and other goods. On the 3rd layer, man got necessary energy

only from the sun and recycle system existed between the 3rd layer and the 2nd layer (ecosystem). Between meshes on 3rd layer, there were a few trades of light weight valuable goods such as rare metal, silk and so on, due to transportation measure over meshes. On 4th layer, there were some technology transfer (how to make gun powder or paper) and spread of religion. Historians find out that decline and extinction of specific civilizations in the past occured after man exploited surrounding forest for making farm land and timber use. At first cutting trees brought benefits but later deforestration caused desertification and quick reduction of food production.
In that case, man had three options the following:

- decline and exitinction: no inhabitation eventually after.
- migration and war: man migrates or invades into another mesh.
- new way of living based on new technology: man invents a new technology to overcome the economic desaster. Man adopted a new living style and have continued to live in the same mesh.

5.2 After the industrial revolution

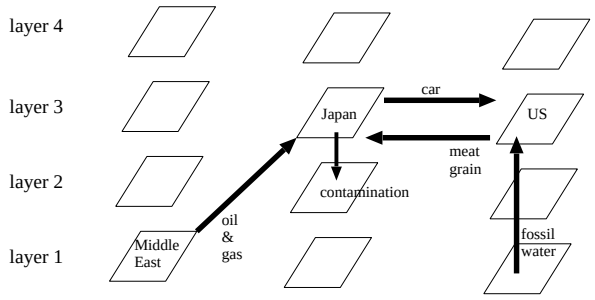

Figure 8: Interaction of meshes since the 1800

Since the industrial revoluton, man has been digging underground non-renewable resoouces and bringing them into the 3rd layer and producing food and goods. The residuals of material (atom) production are dumpted into the 2nd layer (ecosystem) and causes environmetal pollution. Goods and food are exported over meshes. For example, Japan and Korea import oil and gas from Middle East mesh and produce industrial goods and export them to North America mesh.
In 1972, for the first time, Meadows and his colleages warned that this way of interaction among layers would not last long time. They called the change of life style but people have not listened to their warning.
Recently, quick economic development of China (1.3 billion population) and India (1.0 billion population) will cause serious environmental contamination over meshes and foreseeable shortage of resources both in the 1st layer (energy and minerals) and renewable resouceses in the 2nd layer such as surface water. In addition, scientists predict that under ground fossil water in North America mesh and oil and gas in Middle East mesh will peak out around 2020.

5.3 Preferable interaction in future

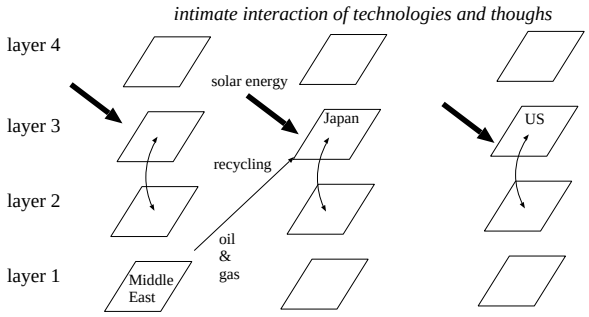

Figure 9: Sustainable world in the future

Many people have adovocated how to avoid the foreseeable catastophe as a result of man's abuse of the Earth resources and environment.

1. energy: develop solar energy use in every feasible forms. less interaction in 1 st layer and mobilize solar energy in 2nd layer.
2. population and food: birth control. less activity in 3rd layer.
3. material use: advancement of recycling better interaction bewteen 2nd layer and 3rd layer.
4. change of life style i.e., thrift.

Among them, the most difficult measure is how to change the current life style. This is categorized as the matter belonging to the 4th later (bit, information). In the past, great religions changed man's way of thinking and created specific life styles in various meshes. For exmaple, traditional Indian life suits to Monsoon Asia environment and Islamic life style suits to semi-arid environment.
The very life style after the industrial revolution asumes that there is no constraints from the nature

Table 1: Comparison

Meadows' system dynamics	our digital globe	Global Climatic Model
point model	mesh model	mesh model
1 mesh	90 x 4 meshes	2 million
resources	1st layer	-
environ-ment	2nd layer	atmospehric circulation
food	3rd layer	-
population	3rd layer	-
-	4th layer	-

thanks to technology advancement so that we can persue more affluent life after North American way of life. Today, we gradually understand that no matter how technology would advance we somehow have to refrain from materials (atoms) affluent life.

6 Conclusion and Future Study

The interactive 3D digital globe is the very first step forward to expand from a point model to a geographic model. Table 1 is the comparison of elements dealt by three models discussed.

For future study, we have to create simulation software soon. The population of advanced nations is decreasing. But Chinese and Indians begin to eat more proteins so that the consumption of energy and resources snowballs. They can not support themselves within their mesh. We will create a cross table showing how mush energy a mesh exports or imports to-from which mesh. Around 2020, oil and gas might have its peak-out and agricultural production in USA begins to be stagnant. The world could not have an adequate stock of energy and food. If global warming would cause chaotic occurrence of large scale weather disasters, man might face serious difficulties.

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