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Web-based Geovisualization System of Oceanographic Information using Dynamic particles and HTML5

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ABSTRACT

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A web-based geovisualization system of oceanographic information using dynamic particles and HTML5 has been established to address the limitations of the existing Web-GIS based oceanographic information system. The limitations include systematic scalability, slow service speed, a non-standard internet web environment, poor user accessibility and interactivity, and spatial and temporal variability visualization. Importantly, spatial observation data through remote sensing and 3D numerical modeling data are oceanographic data having spatial and temporal variability. Such data are heterogeneous, large capacity, and multidimensional and are based on geographic information. In order to understand intuitively and analyze effectively, dynamic particles were applied to visualize the spatial and temporal variability. This paper introduces the oceanographic information geovisualization system, in which the information inquiry and analysis functions are implemented using open libraries such as HTML5, WebGL, Canvas, D3, and Leaflet map, which are next generation Web platform standards for multimedia service and map with location service.

ADDITIONAL INDEX WORDS: *Geovisualization, Oceanographic Information System, Spatial and Temporal Variability, Dynamic Particles, HTML5.*

INTRODUCTION

The awareness of and demand for oceanographic information have been increasing recently. Oceanographic information is important for safe ocean marine tourism and leisure activities (fishing, yacht, and surfing), as well as maritime transportation, shipping industry, fishery industry, and marine development. Especially, the importance of acquiring oceanographic information is now even greater considering that the information is used for systematic response and management by predicting ocean-related disasters such as floods due to typhoons and tsunamis, marine accidents, and marine ecosystem pollution caused by oil spills, red tides, and green tides.

Oceanographic data are produced by calculations using a numerical model and site observation. Two types of observations are used: (i) observation at a specific point and (ii) spatial observation through X-band or high frequency radars and remote sensing using satellites. Numerical models are mainly used to reproduce past phenomena (reanalysis) and to predict future ocean conditions, which produces massive multidimensional spatio-temporal datasets. The oceanographic data include geographical information of latitude and longitude as well as time information as common attributes.

To effectively explore large multidimensional heterogeneous spatio-temporal oceanographic data, it is necessary to provide an information visualization system through appropriate geovisualization (Dykes *et al.*, 2005) in accordance with data attributes and information characteristics.

The existing web-based oceanographic information systems can be categorized into two types depending on whether or not the geographic information system (GIS; Chang, 2006) is used. Figures 1(a) and 1(b) show the web-based oceanographic information systems of the Korea Meteorological Administration (KMA; www.kma.go.kr) and the Korea Hydraulic Oceanographic Administration (KHOA; www.khoa.go.kr) without using a GIS engine. Although spatial observation data and numerical model data have spatial and temporal continuity, the information provider gives users information in only one direction, in the form of images, text, and symbols indicating certain predefined fixed regions. However, nowadays users are familiar with utilizing the GIS-based map environment where they analyze information through interaction with maps by mapping multiple information to layers on the map service of commercial portals. Therefore, considering the characteristics of oceanographic information, a system is needed that provides map-linked information through the GIS engine to explore and capture information intuitively.

Figure 2 shows an example of the Web-GIS based oceanographic information system (Fu, and Jiulin, 2010) using the ArcGIS Server Development Toolkit (SDK), which allows users to interact spatially with location information on the map. Figure 2(a) shows a GIS-based real-time integrated oceanographic information portal site, nowCOAST

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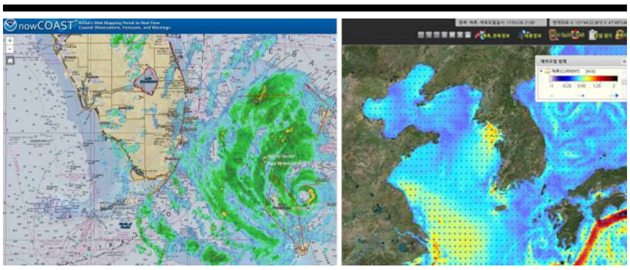
(https://nowcoast.noaa.gov), which is an oceanographic information visualization system (Allard, 2006) using the ArcGIS engine (Eric, 2005) of the National Oceanographic Atmospheric Administration (NOAA). Figure 2(b) shows the marine forecasting information system (Jinah *et al.*, 2011) developed by the Korea Institute of Ocean Science & Technology (KIOST).

(a) (b)

Figure 1. Real-time oceanographic information system of (a) KMA and (b) KHOA without using a GIS engine.

The information provider supplies oceanographic data maps based on geographical information, and users can navigate the desired area of data by interacting with the map. In addition, the displayed information is not an image or a symbol, but is a rendered value in real time; it is therefore possible to inquire about the value of an arbitrary location rather than only the representative value of the fixed location. It is also possible to utilize user-oriented information by calculating distance and area, multivariate geospatial and statistical analysis, and animation for a random period to determine the spatial and temporal variability. Both systems use a commercial GIS engine, ArcGIS SDK, to realize map services as well as dynamic user-interactive map navigation to allow users to make spatial and temporal inquiries for marine prediction information. The systems also provide the retrieval of data time series of arbitrary locations, and image reproduction of space-time prediction information through multi-layer map service reiteration.



(a) (b)

Figure 2. Web-GIS based real-time oceanographic information system of (a) NOAA and (b) KIOST.

However, the development of a web-based geovisualization system using a GIS engine has a number of practical issues. First, the system scalability is low since various processes (such as data acquisition and geospatial database construction, generation of raster image through spatial interpolation and correction, issuance of map services, and application of multimedia services) are developed under the ArcGIS SDK. Inevitably, this reduces the speed of the information service due to the issuance of the map service and the map cache. Lastly, restrictions exist on the use of multi-devices such as web browsers and mobile system. In addition, non-standard internet web environments are needed that require installation of additional plug-ins such as ActiveX, Flash, and Silverlight as well as a dedicated library for displaying information using charts.

This paper introduces the oceanographic information system using HTML 5, the next generation web platform standard (Anthes, 2012) to overcome low system scalability, service delivery speed vulnerabilities, and low accessibility due to the non-standard internet web environment.

Furthermore, the purpose of the system is to visually and effectively geovisualize oceanographic information, which is spatially and temporally volatile, using dynamic particles.

OCEANOGRAPHIC DATA

The main basic oceanographic information includes sea-level pressure, sea-surface wind, waves, tide, tidal currents, ocean currents, water temperature, and salinity. Application information, which is calculated from basic information in the case of coastal disasters and marine accidents, includes inundation and flooding of tsunamis and typhoons as well as migration pathways and regions of oil spillage, red tides, green tides, and suspended sediment.

Oceanographic data commonly include geographical information of longitude and latitude as well time. In particular, heterogeneous multidimensional spatial and temporal data are produced through spatial observations using satellites and radar, as well as 3D numerical modeling, which are volumetric meshed gridded datasets. In order to understand these data, appropriate geovisualization is necessary to describe the spatial and temporal variability.

For such oceanographic data, the Global Ocean Observing System (GOOS), the NOAA, and the European Center for Medium-Range Weather Forecasts (ECMWF) provide reanalyzed data and forecasts calculated from global observations and numerical models in real-time or in near real-time. High-resolution oceanographic data obtained from the oceanic waters around Korea are provided by the KMA's weather data release portal (https://data.kma.go.kr), KHOA's public data development portal (www.khoa.go.kr/kcom/cnt), the National Institute of Fisheries Science (NIFS), and the KIOST. They produce and provide predictive numerical model data by using observation platforms such as ocean observation towers, coastal observatories, marine vessels, survey vessels, observation equipment mooring, HF Radar, and satellites. The Public Data Portal (www.data.go.kr) also gives data in the form of a source file or OpenAPI in accordance with Korea's public data open policy.

METHODS

Geovisualization of oceanographic information using dynamic particles

Two types of oceanographic information are used: scalar and vector. Scalar information has magnitude only data (*e.g.* water temperature, salinity, wave height, tide level, *etc.*), while vector information has magnitude and direction data, such as u and v components (*e.g.* sea-surface wind speed and direction, tidal current speed and direction, wave height and direction, *etc.*) according to the variable attributes, except location and time.

Table 1. Algorithm for drawing and moving particles of vector.

```
var draw = function (context, mapInfo, ptclInfo, configs) {
        var prevCtx = context.globalCompositeOperation;
        context.globalCompositeOperation = "destination-in";
        context.fillRect(mapInfo.x0, mapInfo.y0,
         mapInfo.width, mapInfo.height);
        context.globalCompositeOperation = prevCtx;
        // Draw new particle trails.
        context.beginPath();
        context.strokeStyle = configs.strokeStyle;
        ptclInfo.data.forEach(function (ptcl, i) {
            context.moveTo(ptcl.x, ptcl.y);
            context.lineTo(ptcl.xt, ptcl.yt);
            ptcl.x = ptcl.xt;
            ptcl.y = ptcl.yt;  });
context.stroke();      };
```

```
var move = function (ageMax, mapInfo, dataInfo, ptclInfo) {
        for (var i = 0; i < ptclInfo.data.length; i++) {
            if (ptclInfo.data[i].age > ageMax) {
            var x = ptclInfo.data[i].x;
            var y = ptclInfo.data[i].y;
            var v = pick(x, y, dataInfo);
            if  (UTIL.isNullEmpty(v[0]) ||
                UTIL.isNullEmpty(v[1])) {
                ptclInfo.data[i].age = ageMax; } else {
            // renew on next loop
               var xt = x + v[0];
               var yt = y + v[1];
               var vt = pick(xt, yt, dataInfo);
               ptclInfo.data[i].xt = xt;
               ptclInfo.data[i].yt = yt;
            }  ptclInfo.data[i].age += 1;     }     };
```

In order to visualize the scalar type information, an appropriate thematic map is determined among a range including choropleth map, proportional map, isarithmic map, dot distribution map, and dasymetric map according to the characteristics of information (Jinah and Jinah, 2012). In the case of expressing directions, it is important to visualize in the same way as that for the spatial variability in the sequence of time. In the Web-GIS system, the direction is shown using symbols such as arrows. However, this is not effective for capturing the spatial variability in the series of time and it can also cause service speed degradation. To improve these limitations, dynamic particles are applied to visualize the vector field's spatial variability according to the sequence of time. Major algorithms for drawing and moving/updating particles of vectors are described in Table 1. Figure 3 shows examples of global oceanographic information visualization systems using dynamic particles in EarthWindMap (earth.nullschool.net), MeteoEarth (meteoearth.com), and Windy (wind and weather forecast, windy.com).

In order to map the oceanographic data represented by the dynamic particles to the map service on the web, the information system was implemented using HTML5 Canvas (Mira *et al.*, 2011) and Leaflet map (http://leafletjs.com), which is an open-source JavaScript library that configures the browser to display the map as a standard map service. Leaflet places an image on a map so that it can be used similar to a map layer.

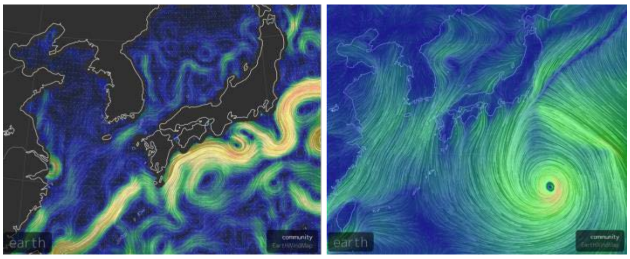


Figure 3. Example of geovisualization of ocean currents and sea-surface wind in EarthWindMap using dynamic particles.

Web-based geovisualization system of Oceanographic information using HTML5

Figure 4 shows the entire process of the web-based geovisualization system of oceanographic information using dynamic particles and HTML5. For the system scalability, the data acquisition and standardization process are implemented independently regardless of the GIS engine. This causes an increase in the utilization of the high-level data analysis such as the geostatistical analysis.

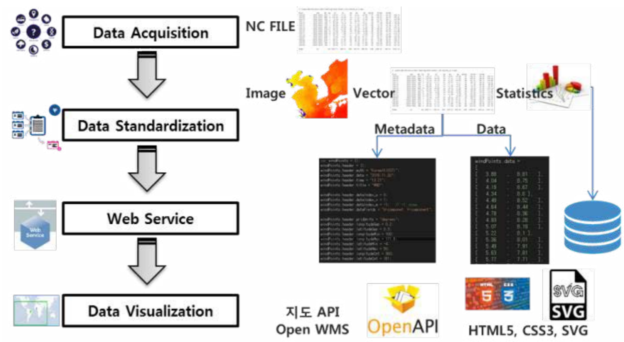


Figure 4. Flow chart of web-based geovisualization system of oceanographic information using dynamic particles and HTML5.

In addition, the use of HTML5 greatly improved the users' access speed of the graphical information visualization and showed good speed performance. Besides, using WebGL enabled smooth particle animating (Feng *et al.*, 2011). If WebGL is not used, the browser engine itself handles the graphics. However, since the graphics are handled by using a user's graphic resource if WebGL is used, the service loading speed is determined by a user's graphics card specifications. In addition, the HTML5 Scalable Vector Graphic (SVG), is the Web standard for drawing two-dimensional vector images, and is used for seamless visualization in various screen resolutions. D3(Data-Driven Documents, https://d3js.org).js is well-known as a data visualization framework and is a JavaScript library that visualizes data using web standard technologies. It is used in conjunction with HTML, SVG, and Cascading Style Sheets (CSS) to create dynamic graphs and charts bound with data and images. This renders it simple and effective to visualize using the D3 library without the use of ActiveX or dedicated graphics libraries which previously were used to draw charts on existing systems. In addition, in order to catch the spatial variability of the sequence of time, a playback function such as animation was implemented using HTML5 multimedia technology. It was possible to solve the disadvantages of discontinuous and delayed playback for the cache function when visualizing using a GIS engine.

In particular, for geostatistical visual analytics, a UV radar chart was designed and applied to easily determine the cumulative dominant direction during the inquiry period. In order to display the directions, the summed value was calculated as the direction value, again using the trigonometric function, and this was also visualized.

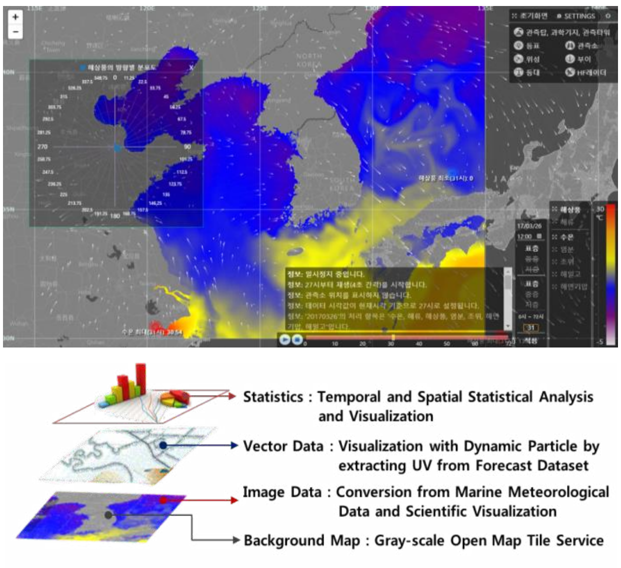


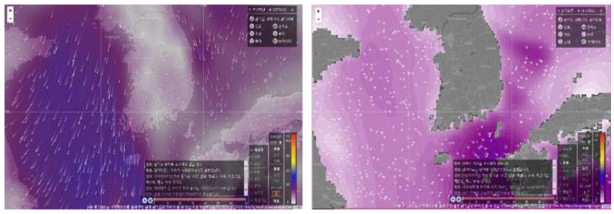
Figure 5. Implementation of web-based visualization system of oceanographic and meteorological information using dynamic particles, HTML5, and multiple layers according to the order of contents for a scene.

RESULTS

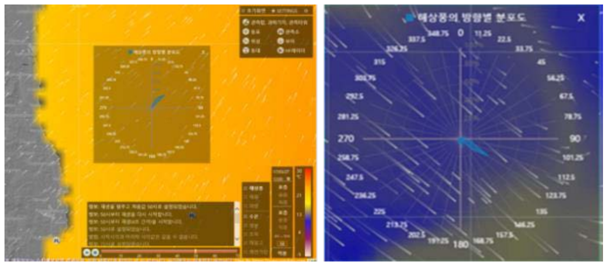
Figure 5 shows the implemented oceanographic information visualization system using dynamic particles and open libraries such as HTML5, D3, and Leaflet.

Figure 6(a) shows an example of applying the dynamic particles to visualize sea-surface wind and waves. Figure 6(b) shows the dominant wave direction of accumulated particles using a UV chart on a specific location on the map.

Figure 7 shows a comparison of the procedure for map visualization using HTML5 (Figure 7(b)) and the existing method using the ArcGIS engine (Figure 7(a)). The map visualization using the ArcGIS involves one transaction from data preprocessing to map service generation depend on the ArcGIS SDK. The ArcGIS renders it difficult to read the dynamic flow of data, as it generates the layer internally and transmits the final image to the client when displaying the map.



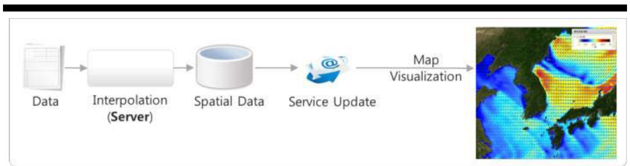
(a)



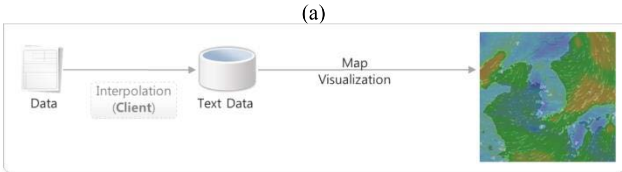
(b)

Figure 6. (a) Visualization of sea-surface wind and wave using dynamic particle and (b) UV radar chart for wave direction.

On the other hand, map visualization using HTML5 reduces the risk of errors and processing time to make map service by dividing the transactions according to units. Since the user draws the layer for the map at the time of map display, it decreases error in the multiple layers configuration and reduces processing time. In addition, the dynamic flow or trace of data can be understood through the animation playback through HTML5 Canvas.



(a)



(b)

Figure 7. Comparison of visualization process using (a) commercial ArcGIS engine and (b) HTML5.

Moreover, to show the improvement of performance quantitatively, the processing time required for map visualization using the same raw data produced by numerical models is compared in Table 2 between that when using the existing method of ArcGIS SDK and that when using the proposed method of HTML5. Except for the sea-surface wind, the oceanographic information shows a reduction of processing time by almost 10 times and the sea-surface wind is reduced by 5 times. The reduction of map visualization time enables the user to receive the latest ocean prediction information through the web without time delay.

Table 2. Comparison of processing time for map visualization with existing method using the ArcGIS SDK and the proposed method using HTML5.

Oceanographic Information	Data Size		Map Visualization	
	Raw data (NetCDF)	Output file (PNG/ CSV/JS)	ArcGIS SDK	HTML5
Water level	376 MB	48.9 MB	20 min.	≤ 2 min.
Salinity	2,260 MB	123 MB	≃60 min.	≤ 4 min.
Sea-surface temp.	2,260 MB	201 MB	≃ 60 min.	≤ 5 min.
Water currents	2,260 MB	309 MB	≃60 min.	≤ 7 min.
Sea-surface wind	753 MB	449 MB	≃40 min.	≤ 8 min.
Waves	753 MB	135 MB	≃40 min.	≤ 3 min.
SUM	≃10GB	≤ 1.5GB	5~6 hr.	≤ 35 min.

CONCLUSIONS

An oceanographic information system through web-based geovisualization was constructed using dynamic particles and HTML5. The purpose of the oceanographic information system is to enable general users to intuitively and easily explore and recognize oceanographic data that have spatial and temporal variability, that are heterogeneous, large capacity, and multidimensional, and based on the geographic information. Especially, the visualization effect of the spatial and temporal variability was maximized by using dynamic particles to represent vector-type information such as the direction of sea-surface wind, ocean currents, and waves.

Further, in order to address the limitations of low system scalability and accessibility, various factors were considered such as the service speed vulnerability, non-standard internet web environment, HTML5 with open libraries such as WebGL, Canvas, D3, and Leaflet map (which are next generation Web platform standards). In addition, by constructing various multimedia techniques, map service, location information service, *etc*. through open libraries such as those mentioned above, the proposed oceanographic information system will help users as it was possible to solve the problem of existing systems implemented using ArcGIS SDK and to construct the oceanographic information system with various information inquiry and multidimensional geostatistical analysis functions.

It is therefore expected that the improved information visibility, service delivery speed, and high system scalability will help users improve their information perception ability and increase the system utilization.

Furthermore, with the basic ocean forecast information provided through this scalable system, it is possible to predict migration pathways and search rescue areas during coastal disasters such as flooding caused by typhoons, tsunamis, red tides, and green tides or in marine accidents such as ship accidents and oil spillage. By combining the proposed system with other disaster response systems, the proposed system can be easily expanded to an effective decision support system. With its various spatial analysis functions and effective visualization functions, it is expected that the proposed system can be used as an integrated marine disaster management system.

ACKNOWLEDGEMENTS

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