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Survey on geographic visual display techniques in epidemiology: Taxonomy and characterization

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ABSTRACT

Many works have been done on the topic of Geographic Visual Display with different objectives and approaches. There are studies to compare the traditional cartography techniques (the traditional term of Geographic Visual Display (GVD) without Human-Computer Interaction (HCI)) to Modern GIS which are also known as Geo-visualization, some literature differentiates and highlight the commonalities of features and architectures of different Geographic Visual Display tools (from layers and clusters to dot and color and more). Furthermore, with the existence of more advanced tools which support data exploration, few tasks are done to evaluate how those tools are used to handle complex and multivariate spatial-temporal data. Several test on usability and interactivity of tools toward user's needs or preferences, some even develop frameworks that address user's concern in a wide array of tasks, and others prove how these tools are able to stimulate the visual thought process and help in decision making or event prediction amongst decision-makers. This paper surveyed and categorized these research articles into 2 categories: Traditional Cartography (TC) and Geo-visualization (G). This paper will classify each category by their techniques and tasks that contribute to the significance of data representation in Geographic Visual Display and develop perspectives of each area and evaluating trends of Geographic Visual Display Techniques. Suggestions and ideas on what mechanisms can be used to improve and diversify Geographic Visual Display Techniques are provided at the end of this survey.

1. Introduction

In the past 40 years, the integration of the Internet and Geographic Information Services (GIS) technology has produced an expanding area of research referred to as Web-based GIS, Internet GIS, On-line GIS, Quality of Geographic Information Services (QoGIS) and Internet-distributed GIServices [34]. Today, these efforts have emerged as an innovative and important component of many Geographic Visual Display tools in public health and epidemiology. Primitive development focused only on static maps, interactive maps with pan-identify-zoom features that support client and server designs. Change in technology has changed cartography, the current GIS programs produce high-quality, detailed, dynamic, animated, multi-view, two to three-dimensional maps and have more to offer to health sciences.

However, issues and questions arise when these tools are able to solve the problems in the aspects of cognition, adaptability and usability. Then again, like any other tools equipped with business intention, Geographic Visual Display techniques can appear to be more complex and may cause split attention amongst users, thus lead to misunderstanding and incorrect interpretation from data presented. There are many Geographic Visual Display techniques available in the literature. However, there is no survey done to investigate the performance and consequence of these techniques for solving epidemiology issues. There is no guidance to help researchers in comparing or

Abbreviation. GVD, Geographic Visual Display; HCI, Human Computer Interaction; ICA, International Cartography Association; SMR, A ratio or percentage quantifying the increase or decrease in mortality of a study cohort with respect to the general population; MCDCDs, Multi-component dynamic cartographic displays; ESTAT, Exploratory Spatial-Temporal Analysis Toolkits; STIS™, A Space Time Information System has been developed to visualize and analyze objects simultaneously through space and time; TC, Traditional Cartography; G, Geovisualization; CT, Clustering; CL, Colouring; SM, Symbolization; HL, Highlighting; PGC, Prior Geocollaboration; GC, Geocollabroration

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selecting the suitable tools [61]. Hence, a comprehensive survey is needed.

This paper reports the characterization and performance of Geographic Visual Display tools in displaying outbreak data and risk pattern for public health professionals [95], with special emphasis on spatial-temporal data representation, user perceived ease-of-use of the visual representation and behavioral intentions analysis from the aspects of quality attributes: cognition, interactivity, usability, flexibility, adaptability, diversity, interoperability, and variety[93].

2. Geographic visual display technique in epidemiology

Geographic visual display has played an important role in human history, from the early ancient times long before computer visualizations appeared. The earliest examples of geographic visualization are wall painting maps describing the life of our ancestors. Since then cartography, the art, and science of map-making, has evolved to computer-based geographic visualization that developed the large base of cartographic skills and knowledge. Well-known examples of the Geographic visual display are thematic maps that display the spatial pattern of a theme such as climate characteristics or population density. Today, the use of modern visualization technology offers many new prospects to explore, understand, and communicate spatial phenomenon [71].

Geographic Visualization or Geo-visualization is an emerging field [2,69]. It draws upon approaches from many disciplines, including Cartography, Scientific Visualization, Image Analysis, Information Visualization, Exploratory Data Analysis (EDA) and GIScience to provide theory, methods, and tools for the visual exploration, analysis, synthesis and presentation of data that contains geographic information [45]. The goals of geo-visualization are varied. The map use cube in Fig. 1 by Krrak [45] models the space of visualization goals with respect to three dimensions: (1) The task can range from disclosing unknowns and forming new knowledge to sharing existing knowledge; (2) The interaction with the visualization interface can range from passive low-level to high-level where users actively influence what they see; (3) Finally, the visualization use ranges from a single, private user to a large, public audience [49]. This cube has become an important guideline for researchers to design tools of representation that may cover different dimensions on how knowledge can be presented and use for cognitive-process.

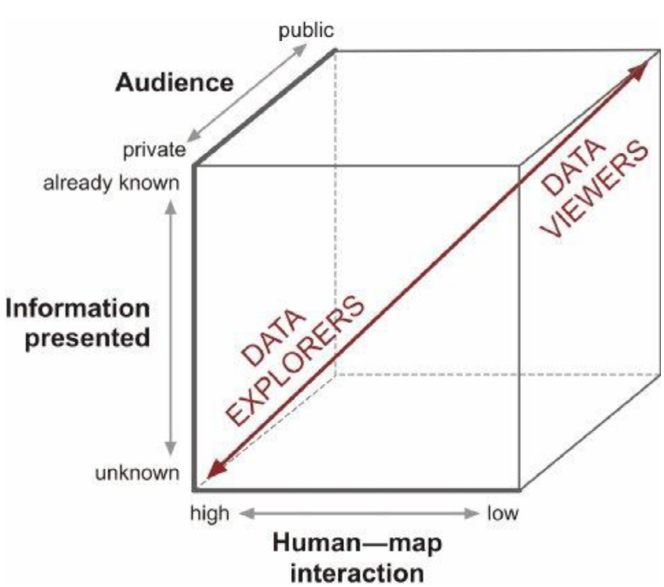

Fig. 1. Map use cub.

2.1. Epidemiology geographic visual display requirements

Earlier on, disease maps were used to show standardized mortality or morbidity (e.g., incidence) ratios (SMRs) for geographic areas such as countries, counties, or districts, with the rate in area "i" is estimated by the standardized mortality (or morbidity) ratio (SMRt), calculated as OilEi, where "Oi" is the observed number of deaths or incident cases of disease in the area and "Ei" is the expected number of cases (calculated by applying age- and sex-specific death or disease rates to population counts for the area) [38]. The aims and purposes of disease mapping describing the spatial variation in disease incidence for the formulation of a etiological hypotheses, identifying areas of unusually high risk in order to take preventive action and providing a reliable map of disease risk in a region to allow better resource allocation and risk assessment [38]. Geographic Visual Display is increasingly being used to inform public health research [60,65], planning and decision making in developed countries. It aids etiologic investigations and distribution of diseases, optimal deployment of limited resources and policy/regulation adoption. Additionally, Geographic Visual Display provides a better understanding of epidemiological problems by presenting statistical data in a spatially referenced way amongst health professional by using maps. With these tools, it will be possible for the epidemiologists to determine the geographic distribution of disease, to surveillance and control the infectious diseases, understand the trend of diseases, monitoring their expansion, planning strategies, and scaling risk population by creating disease maps by using GIS [23,85]. Modern geovisualization can conduct a knowledge discovery process for geographical analysis and presents the anomalies of events from groups of data that may help health researchers plan health resources for disease prevention and control by focusing on areas with significantly high mortality rates which aimed to support prediction of future risk level in the area [64,94].

As technologies emerged and populations in the world increased, a well-designed Geographic Visual Display tool is needed to facilitate health professional in analyzing big epidemic data [25]. Many Geographic Visual Display tools have been developed and available over the internet to assist professionals on their task and many research have been done to fulfill user requirements in this tool. In this paper, eight requirements and challenges for these techniques are defined and described as below:

- **Cognitive** is brain-based skills we need to carry out any task from the simplest to the most complex. They have more to do with the mechanisms of knowledge constructive on how we learn, remember, solving a problem and pay attention, rather than with any actual knowledge.
- **Usability** is the ease of use and learn-ability of a tool and is the degree to which a tool can be used by specified users to achieve quantified objectives with effectiveness, efficiency, and satisfaction in a quantified context of use.
- **Interactivity** is a quality or condition where normally refers to a computer's tools which respond to the user's actions by presenting content such as text, moving image, animation, video, audio, and video games.
- **Flexibility** is referring to designs that can adapt when external changes occur. Flexibility is the ability of a tool to respond to potential internal or external changes, in a timely and cost-effective manner and can respond to uncertainty in a manner to sustain or increase its value displayed. Uncertainty is a key element in the definition of flexibility. Uncertainty can create both risks and opportunities in a tool, and it is with the existence of uncertainty that flexibility becomes valuable.
- **Adaptability** is the ability of a tool to adapt itself efficiently and react fast in different circumstances. An adaptive tool is therefore an open tool that is able to fit its behavior according to change in its environment or in parts of the system itself.

- **Diversity** is the state of being diverse; variety or a range of different things. Diversity is the ability of a tool to expand its functionality to suit multi-variant data and multi-disciplinary or group work.
- **Interoperability** is a characteristic of a tool which interfaces are completely understood, to work with other products or systems in the present or future, in either implementation or access, without any restrictions.
- **Variety** is the presence of multi-components in the tool that grab user's attention and provide options for the user to select their preferred way of presentation.

2.2. Current geographic visualization technique

With rising data exploration, and as the level of sophistication of geo-visualization tools increases, designing efficient interactive composition techniques has become a critical issue. There are many tools have been developed over the internet and some are free to use by public health professionals to help them to analyze and visualize the complex data in infectious disease control [16].

With the huge surge in innovative software, maps and web becoming synonymous in new cartographic technology, new techniques have been developed from interaction, social network analysis, open source library, scripting, and distributed processing. From Traditional Cartography Methods such as Census Block, Choropleth Map, Dot-density map, raster, vector, polygon and shape, statistical methods like Bayesian and kriging to a new and modern GIS technology such as Google Maps, open layer, leaflets, map box, fusion, Bing map, fusion table, tableau, and ArcGIS online. The latest techniques are able to handle very large datasets and real-time such as Google Maps, OpenLayers and Leaflet [84]. With the emergence of Web 2.0 technologies, Geographic Visual Display techniques have improved and designed with multi components. These Multi-component dynamic cartographic displays (MCDCDs) methods are used to provide users with more options and flexibility towards these Tools. When multi users from different groups share data within an integrated tool, a geo-collaboration group work appears utilizing the benefits from cloud-computing and mobile applications. The impact from geo-collaborations has led to the emergence of mashups, provides users more interesting, and interactive Geo-Vis tools. These tools were developed with the combinations of libraries such as Leaflet and D3.js or web mapping services like Google Maps combined with other in-house application to achieve a highly impact presentation. These techniques will be elaborate on the next sections.

2.3. Dataset used in geographic visual display

Epidemiology uses many data sources, including vital statistics data, government surveillance data and reports, CDC data, health surveys [82], and disease registries in order to study factors associated with certain diseases or conditions. Epidemic data often come from official or government sources. These data are abundant and continuously increasing over-time. Epidemic databases consist of demographic, health survey and disease information. The Epidemic dataset including population and mortality dataset and can be separate in categories: discrete or continuous, spatial or temporal. In the information age, there is more data out there that can be analyzed for research purposed.

Table 1 below listed dataset used for Geographic Visual Display Technique in the application domain of Epidemiology and selected Relational Study.

3. Adopted categorization approach

The current investigation is based on selected Geographic Visual Display techniques extracted from articles that are related to these techniques from cited publications and resources, such as ScienceDirect, Elsevier, ResearchGate, Scientific Research Publishing (SCIRP), he Institute of Electrical and Electronics Engineers (IEEE) Systems (Ibrahim, 2014), [3,30,62], CiteSeer, GIScience, CaGIS and International Cartographic Association (ICA). Industrial Information Integration Engineering (IIIE) [37] is a complex giant system that can advance and integrate the concepts, theory, and methods in each relevant discipline and open up a new discipline for industry information integration purposes. Scholars can stay up to date with the latest studies on IIIE and gain research ideas from the summarization and outlines (Nisar), [63]. Practitioners can also know new approaches and their effects [17,18]. There are several studies that have been done by researchers on Geographic Visual Display Techniques. The purpose of each study generally to achieve various objectives especially in highlighting the tools that suit the user's need and preferences in the context of Epidemiology. Most of the tools are developed by Geographic Research Unit and few are developed in silos for individual research tasks. To better understand approaches to meet these users' requirements, this paper characterizes these representative techniques by empirically divided them based on task done by previous researchers. These tasks were divided into subchapters: Generation of Geographic Visual Display, Interface Design, Metaphor, Schemata, Features and Functionality, Exploratory Analysis of Spatial and Temporal Data, Additional Features and components, Web GIS and Geo-collaboration [68].

3.1. Generation of geographic visual display

Over 40 years since the first map is created, Snow's dot-map of cholera deaths, 1854 cholera outbreak, Golden Square, Choropleth map has become the base map to the creation of various maps and Geographic Visual Display techniques until today. There are multi forms of map created in history knowingly Choropleth maps, Isopleth maps, Proportional symbol maps, dot maps and etc. The type of map grows from static/thematic, two-dimensional map, to dynamic interactive, three-dimensional map and with further advancement, the animated map with multi-linked views was created with added multi components/media like video and audio. These maps are still utilizing the basic techniques from Choropleth map which is shadings, coloring, placing of symbols to indicate differences in kind of an area data. The traditional Cartography shows limitation on spatial-temporal data analysis. A series of methods are being developed to address issues of usability in Traditional Cartography and support capabilities for the visual analysis of large spatiotemporal datasets through 'direct depiction'. Some of these are reported in geo-visualization of dynamics, movement, and change [88].

Aside from the well-known maps, some other efforts also have been done to improve Geographic Visual Display. Newell and Canessa [70] have proved that Ring map Improves comprehension when mapping many variables using a sampling of weekly color-coded disease alert levels. Rytkönen [81] The differences between methods used in disease maps and explained that Choropleth maps are used to display mortality or morbidity rates for defined geographical units by coloring, shading or hatching, while dot maps uses a pair of coordinates (x and y) to show each health event, whereas flow maps are able to show the distribution of health events spatially and temporally, and diagram maps provide added value to the presentation of quantitative data within a map. Koua [43] has done literature on the exploration of data framework (pattern and clustering) using computational algorithms approach: SOM, data mining, matrix distance on visual representation. Croner [22] It is capable to support collection, storage, retrieval and statistical manipulation of spatial-referenced observations and events. GIS database contains raster and vector file formats. Analysis was also conducted using Detection of a cluster, near neighbor analysis, quadrant analysis (cell count method with chi-square), joint-count method, second order analysis, spatial autocorrelation analysis, Monte Carlo method, multi-dimensional scaling, line analysis, kriging estimation, splining, empirical Bayes and Bayes. Both researchers agree that Dynamic mapping, spatial-temporal GIS visualization, and exploratory spatial data analysis

Table 1
Dataset used for geographic visual display techniques in application domain of epidemiology and selected relational study.

Category	Methods	Data category	Data Type	Map Type	Visual variables	Geographic visual display technique
Traditional Cartography (TC)	General Map	Discrete	tabular	Static	coastlines, lakes, rivers, boundaries, settlements, roads, rail lines	Base map: Atlas, wall maps, road map
	Thematic Mapping	Discrete	Census	Static	block	Census Block
		Discrete/continuous	Spatial	Static	Shape, color shade	Choropleth Map
		Discrete/continuous	Spatial	Static	Point, line, area	Isopleth Map
		Discrete/continuous	Spatial	Static	Dot, unit-vector	Dot-density Map
		Discrete/continuous	Spatial	Static	symbol	Proportional Symbol Map
		Discrete/continuous	Spatial	Static	Polygon, grid cell	Dasymetric
		Discrete/continuous	Location and Time series	Static	Concentric and segmented ring, Ring size, color	Ring maps
Geo-visualization (G)	Prior-Geo-collaboration	Discrete/continuous	Spatial and Temporal	Animated	Shape, vector, Dot, symbol	Choro dot (Merged of Choropleth and dot method)
		Continuous	Spatial (geo-referenced) and temporal	Dynamic	Layer, color, Shape, Point, line, area, dot	ESRI ArcGIS
		Continuous	Spatial and geo-referenced	Dynamic	Layer, color, Shape, Point, line, area, dot	STIS
		Continuous	Spatial and geo-referenced	Dynamic	Layer, color, Shape, Point, line, area, dot	Quantum GIS (QGIS)
		Continuous	Spatial and geo-referenced	Dynamic	Layer, Shape, color, Point, line, area, dot, trend	GeoVista Studio
	Geo-collaboration	Continuous	geo-coded, temporal, shape files	Dynamic	Point, color, size, marker, line, circle, icon, popup, toggle, zoom, scale,	Google Maps
		Discrete/continuous	geo-coded, temporal	Dynamic	Point, color, size, marker, line, circle, icon, popup, toggle, zoom, scale,	Open Layer
		Discrete/continuous	geo-coded, temporal	Dynamic	Point, color, size, marker, line, circle, circle group, icon, popup, toggle, zoom, scale,	Leaflet
		Discrete/continuous	geo-coded, temporal	Dynamic	Dot, color, size, marker, line, circle, icon, popup, toggle, zoom, scale,	Dot mapper
		Discrete/continuous	geo-coded, temporal	Dynamic	Point, color, size, marker, line, circle, icon, popup, toggle, zoom, scale, Animate, Video file, audio file	Umapper
		Discrete/continuous	geo-coded, temporal	Dynamic	Point, color, size, marker, line, circle, icon, popup, toggle, zoom, scale,	GeoJunction
		Discrete/continuous	geo-coded, temporal	Dynamic	Dot, color, size, marker, line, circle, icon, popup, toggle, zoom, scale, File sharing through Dialog function.	GeoJabber

are new areas in GIS that epidemiologists might find useful.

Clarke's [20] research objectives was to bridge the gap between principles of GIS, technology of GIS, discipline of geography, health science [66]. Thus they intro methods for epidemiologist to visualize disease data using function of GIS, data exploratory concept and required hardware and software. Some apply artificial intelligence in their visual process. Yasobant [90] compared conventional GIS methods and newer web based GIS tools (Geo-visualization) and found that web-based oriented has more to offer for today's data analysis requirement.

The continuous effort from researchers together with cartographer has led to multiple tools development in Geo-visualization. AvRuskin [4] describe their project of STIS uses shape-files and provide *map view* displays: zooming, panning, selecting, and querying. Histograms scatter plots, and box plots are designed to be animated over time. Animated table view and Time plot graph allow users to visualizes the movement and attribute changes of spatial objects (including cases, controls, arsenic producing industries, and municipal water supplies) but also allows the user to compare values of these objects over time by time-linking windows [4]. They have done a case study on bladder cancer and performed a human-centered assessment involving 1400 participants.

Bui and Pham [14] describe the design and implementation of three web-based geo-visualization and geo-collaboration applications developed with GeoVista Studio (Pennsylvania Cancer Atlas, Health GeoJunction and Geo-Explication Web Portal) for the domain of public health [66].

Cartographers have conducted number of studies to test the effectiveness of Geographic Visual Display methods, but their effort is limited by the technologies available during their times, applying only one or two techniques that prevent further exploratory and discovery in their studies. In the context of epidemiology, studies found that Geographic Visual Display tools are many and available to be used from the internet. However, the number of users applying these tools in their task is not many. Issues and concerns may relate to user's perceived ease of use and user intention behavior matter. Thus, in the next section, important elements of these tools requirement were listed and explained.

3.2. Interface design, metaphor, schemata, features and functionality

Interface design, Schemata, Metaphor, Features, and functionality play important roles in geographic visualization. To understand about user's requirements on tools design one must understand how the human visual process works. The visual reasoning is the process of manipulating one's mental image of an object in order to reach a certain conclusion like a process where mentally constructing a piece of tools to experiment with the different mechanism [27]. Therefore, Interface design, metaphor, features, and functionality are important in producing the mental image to human cognitive process. The choice of colors for displaying data can also affect interpretation [12]. Maps of the same data drawn at different scales of resolution can result in very different visual patterns [58].

Most empirical efforts to assess different uncertainty representation strategies for maps focus on whether map users can interpret the uncertainty representation correctly and the extent to which different visual variables support this task. Leitner [51] went beyond this to consider the impact of different representation methods on map interpretation for decision making.

Several user-centered approaches have been done to collect feedback from user's point of view regarding on specific geographic visualization tool. Robinson [75] has stated several key findings on GeoVista Studio and claims that users gravitated toward the scatterplot as a starting point in almost every case while bivariate maps are difficult for some users to understand, particularly in terms of deciphering the color scheme whereas Parallel Coordinate Plot's, despite their maturity in the information visualization realm, are not widely known or understood by health analysts.

Caroll [16] has conducted studies highlighting user preferences for data abstraction and their result showed that users expressed a strong interest in dynamic, interactive graphics that allow them to review their data at different levels (e.g. population or individual level). With multiple functions, users felt they could explore more data with finer details where they are able to value common interface features such as zoom, pan, search, filter, save, undo, work history, high quality automated layouts and customizable features (e.g. color, size, shape), multiple views or panels, easy navigation between views and synchronized browsing to facilitate understanding of the data [16].

Few case studies have been done to prove the functionality of GIS. Dogru [23] study about GIS and their integration, interdisciplinary function for case study in Istanbul, Turkey while Cromley [21] has done two graph approach for case study of low birth weight by town in Connecticut and Lyme disease where incidence is detected by town in Connecticut in relation to income using Cumulative frequency legends. Choropleth map and shape file, two sets of health data are mapped in ArcGIS ESRI 9.2.

Bhowmick [9] has performed user-centered approach with key-informant interviews and systematic analysis of published scientific literature and found the limitation of functionality in GIS. A comment by one participant described the problem: "though it GIS is powerful and useful, there are too many steps involved while trying to overlay multiple layers—no easy way of cutting and pasting. Therefore, it is very time consuming. If there was a memory of the steps that can be used, " This idea of capturing and reusing sequences of actions was also reflected in a comment from one participant who wanted more flexibility in "storing of different paths" from which data are accessed [11].

Rashid [74] has performed exploration of disease data correlator with the use of Google Geo-visualization API and Geoviz then suggest that some added value could be done in both applications such as to handle other events like changing the slider data range of the yearly trend data view, rows or columns selection of tabular data browsers. Furthermore, due to time constraints, an optimal viewing was derived using manual dimension setting both for the Google Visualization API and the web interface and these inflexibilities can be removed in a future version to make the layout more dynamic where a number of other filtering conditions could be added to represent the data in a more readable format, for example, a filter that could select one or more states instead of all states at once would improve the degree of comprehension of the trend and correlator views [74].

Kraak [47] claims that the important step in the design of visualization tools will rely on how user make interpretations of the information spaces, and the choice for a representation metaphor is important to encourage the use of tool. Therefore, new research and continuous effort which apply latest technologies are needed to discover the potential engineering and designs can be done to deliver a successful tool to users.

3.3. Exploratory analysis of spatial and temporal data

Current GeoVis tools encourage wide data exploration. As the volume of epidemic data gets bigger and can be accessed easily over the internet, this has encouraged exploratory Analysis and knowledge building amongst epidemiologist. Several studies have been conducted preliminary to get the overview on analysis method used by users in Geovis tools and how those data are explored and utilized to its usefulness.

Robinson [75] has done a user-centered approach with Exploratory Spatial-Temporal Analysis Toolkit (ESTAT) using scatter plot, bivariate map, parallel coordinate plot, time-series graph which resulting guidance for the development of geo-visual exploratory tools. Elliot [24] focused on a number of challenges that face the practitioner of spatial epidemiology, including issues of data availability and quality, confidentiality, exposure assessment, exposure mapping, and study design.

Meliker [57] conducted a case study of bladder cancer in Michigan and a thorough assessment was done emphasizing Temporal Dimension using the latest STIS: Space-time map, space-time queries, life-lines, STIS™ (TerraSeer, Ann Arbor, MI). They claimed that STIS has broad application for examining spatial and temporal-specific relationships between exposures to environmental risk factors and disease somehow beyond visualization, however, statistical analyses are still necessary to identify significant relationships between timing or location of exposure and subsequent disease development [57].

Zhang [94] believes two crucial stages for GIS mapping of epidemiological data is to precisely clusters areas according to their health rate and efficiently presents the clustering result on GIS map which aims to help health researchers plan health resources and disease surveillance control. Thus, cluster algorithms were conducted for health data exploration, namely Self Organizing Maps (SOM) and K-means and resulting K-means produce better clustering results compared to SOM itself [94].

Beale [6] review major limitation of spatial epidemiology and discuss emerging technologies that can help to overcome these issues by using statistical approaches, geographical approaches, tools approaches and highlights on methodological issues, data problem, and uncertainty.

3.4. Additional features and components

The need to display more and more information is growing as cartographers try to represent more spatial information for more complex problems. MacVeigh [55] believe the need for incorporating the auditory information in visual displays is becoming increasingly important, due to the complexity of information and the reduction in the screen size on portable devices. The areas where auditory information is to be of most benefit are potential: environments where the user's visual attention needs to be directed elsewhere especially in domains of complex information visualization, where the visual channel is often overloaded, due to the multivariate nature of the data [11].

Modern geo-visualization tool is developed with more functionalities, support complex queries, multi-view displays in windows which linked to one another from 2 dimensions to 3 dimensions and animation. Such tool provides more dynamic representation of spatial-temporal data. Advanced geo-visualization tools which known as Multi-Component Dynamic Cartographic Display (MCDCDs) have many more to offer for the works of cartography and in epidemiology as it supports variety and flexibility on displaying various type of data.

Opach [71] agreed that multi-component dynamic cartographic displays (MCDCD), seem to be an appropriate way in analyzing complex, multivariate, spatial-temporal data as in provides main map window with subs display components offering secondary views on the same data. Multi-component dynamic cartographic displays (MCDCDs) could be effective to depict spatial-temporal phenomena, but need to be carefully designed as it may cause split attention and misinterpretation when too many information presented in single display [71].

The potential impact of voice over and redundant aural cues on cartographic communication will be a great interest to the cartographer.

Krygie [48] highlights the use of sound for representing geographic data, including a series of sound variables for mapping. He explained that abstract sound variables may consist of location, loudness, pitch, register, timbre, duration, rate of change, order, attack/decay and etc.

The paper by Lodha [52] believes that sensory disabilities can also have the considerable impact on the success of geo-visualization methods where potential visual impairments include color blindness, low vision, and total blindness itself. A dynamic representation is not restricted to only visual channels; several authors have proposed sonification as a way to encode uncertainty along with data and at the same time improve vision-impaired users' access to big data collections.

Ibrahim and Hunt [35] defined Sonification application as a piece of software with a specific usage in a specific domain and using one or more specific sonification technique(s) to transform data into sound representation and It is used especially for blind or visually impaired users or in situations where the user's eyes are occupied with other tasks (such as driving, or looking at a patient, or monitoring the surrounding area when using sound to detect landmines) [36].

Lodha [52] describes using multiple sounds for multiple types of uncertainty, e.g., pitch for different instruments to represent different uncertainty components, enabling more than one measure to be aurally signified at once. Brewster [13], Lodha [52] and Jeong [39] studies have proven that adding sound along with visual information improves the readability, the understanding and the information retention of map users.

Bearman [7] created an extension in ESRI ArcGIS to allow spatial data to be represented using sound by sonifying any raster data layer with Visual Basic Application (VBA) and represent it using piano notes. His focus group results suggest that continuous data sets could be sonified and understood more easily than discrete ones because of the lower variability of the data [7].

Robinson [77] emphasized new geo-visualization tools in development at research labs and GIS software companies will feature increasingly diverse sets of visual representations and integrate new data types such as text, pictures, sound, and video. His project focuses on synthesis characterization and design for epidemiologists at the World Health Organization (WHO) with the case study on the spread of Avian Influenza.

The problem of collecting, organizing, and making sense out of groups of the analytical results-A stage of analysis called synthesizing results in Geo-visualization by Robinson [77] has led to the development of another techniques which uses available analytical results combined with other available data like video and audio. Such techniques can be found in available on-line application like UMapper and Mapfaire.

3.5. Web GIS and geo-collaboration

Web GIS offers GIS functionality in a Web environment and uses web maps allowing end users gain analytical capabilities in web mapping. In the Web-based environment with basic GIS functionalities, the map becomes dynamic, interactive and accessible to a wide selection of users as a visual communication tool. Khan [42] mentioned that spatial data can be analyzed easily and large amounts of data can be viewed on small screens by zooming and panning the map where with all these features, effective web-based GIS applications should be designed in a way that they should be easy to use and understand for users. However, common issues always related to the tool's usability and adaptability.

Thus, researchers have done multi approaches apart from improving usability and adaptability, on the other hand, is to synchronize their tools with current technologies requirements.

Cinnamon [19] presents the results of a usability test of static, animated and interactive maps of injury rates and socio-demographic determinants of injury by a sample of potential end-users in Toronto, Canada. Fabrikant [26] conducted dynamic design framework by evaluating the level of interactivity and cognitive approach using eye movement data collection approach, animation approach with saliency map and series of controlled (static and dynamic) map.

Robinson [75] tested the usability of ESTAT (scatterplot, bivariate mapping tool, parallel coordinate plot (PCP), and time series graph) in interactivity and usability assessment using card sorting, verbal protocol analysis, focus group, ethnographic case studies. Boulos [11] present several examples of maps designed as a navigational aid for Web resources: Health Cyber Map uses GIS, Map Net. Map, Web Map, Visual Net PubMed (3D map view), Kohonen Self-Organizing Map Algorithm.

Koua [43] has done an exploratory of geospatial data and usability of GIS where different options of map-based and interactive visualizations of the output of a Self-Organizing Map (SOM) are used to explore a socio-demographic dataset. The study emphasizes the knowledge discovery process based on exploratory tasks and visualization operations where key exploratory tasks for knowledge construction can be identified through *categorize, classify, compare* and *reflect* [44].

Joshi [40] developed a mixed methods approach combining qualitative and quantitative assessments were utilized in the cross-sectional study where data was gathered using previously tested questionnaire surveys and in-person interviews and their study proved that Google maps were the most common GeoVis application that the users were familiar with.

Preliminary research has shown that animation can reveal subtle space-time patterns that are not evident in static representations, even to expert users who are highly familiar with the data [54]. The use of alternative, if not unusual, graphics representations stimulate the visual thinking. The objective is to demonstrate the usefulness of geo-visualization and, in particular, how alternative graphic representations can stimulate the visual thought process [45].The challenge will be to design geo-visualization methods so that they can be adjusted to the cognitive characteristics of individual users to incorporate with their needs and fulfilled their particular requirement [83].

Geo-collaboration is collaboration among place-based subjects that is facilitated with and through geographic information and technologies. Geo-collaboration is a field of study that is multidisciplinary in nature, incorporating theory and methods from HCI, computer science, and psychology [87] Geo-collaboration support from same time same place, same time different place, different time same place and different time at different time of workgroup to work together sharing geospatial information through an interactive geographic visual display's tool. Fig. 2 illustrated the Geo-collaboration place-time matrix [92]. described Geo-collaboration as collaboration using geospatial information and has become something of a buzzword recently and the familiar example of geo-collaboration is a crisis management situation such as the emergency response to an oncoming hurricane where teams from various emergency response agencies – government (federal, state and local), non-governmental organizations (NGOs), and private-sector companies – all must work effectively together, often utilizing geospatial information, to respond to an imminent humanitarian disaster.

Google Earth provides the capability to create simple geospatial features and even three- dimensional models that are regularly shared on the World Wide Web. Open standards such as web services and Geography Markup Language (GML) allow users of every stripe to connect to web map and feature servers, yet all of this open sharing presents a number of challenges. Köbben et al. [41] explained that Google Maps initially did not originally have a public application programming interface (API), but developers reverse-engineered it to use the system for their own purposes, and eventually, Google released their API.

Roth [80] produced a competitive analysis and assessment survey over geovisualization technologies. His matrix reveals variation between specialist technologies designed to support specific functions (e.g., CloudMade Editor, Mapnik), multipurpose technologies supporting numerous functions (e.g., D3, Google Maps, Leaflet, OpenLayers), Individual technologies with the following categories: (1) frameworks (e.g., GeoMoose, MapServer), (2) open libraries (e.g., D3, Modest Maps, Leaflet, OpenLayers, Polymaps, Raphaël), (3) closed APIs (e.g., Bing Maps, Google Maps, MapQuest), and (4) tile rendering services (e.g., Cloudmade, Mapnik, TillMill, TileStache). Responses to his work however shows that only the Google Maps API was used by a majority of participants in the past few years ($n = 11$), with OpenLayers ($n = 9$), ArcGIS Server ($n = 8$), and Adobe Flash ($n = 6$) used in the past years by a large minority [80].

The presence of these technologies which support cloud-computing in mobile or any handheld devices makes epidemiology or any other disciplines to easily customize and use in handling multivariate data display according to their preferences and requirements. The use of multi-sources with integrated multi-tools has led to technologies mash-ups and contributes to today's research opportunities and challenges.

4. Taxonomy of Geo-visualization techniques

From the techniques that we have discussed here, we classified each technique into two categories: Traditional Cartography (TC) and Geo-visualization (G). Fig. 3 below described the categorization of existing techniques which are analyzed in this survey to see their usage for epidemiology requirements. The figure also shows the further categorization of each sub classifier: Traditional Cartography (TC) is divided into general maps (GM) and thematic maps (TM) while Geo-visualization (G) is divided into Prior Geo-collaboration (PGC) and Geo-collaboration (GC). Each sub classifier is divided into subcategories: GM representing atlas, wall maps, and road maps, while TM techniques are divided as Clustering, Coloring and Symbolization. However, for Geo-visualization, Hybrid Symbolization, Highlighting and Multiple Component Dynamic Cartographic Display (MCDCDs) are the sub-categories of Prior Geo-collaboration (PGC) techniques while for Geo-collaboration (GC) is divided into two categories: Mash-ups (MU) and Hybrid

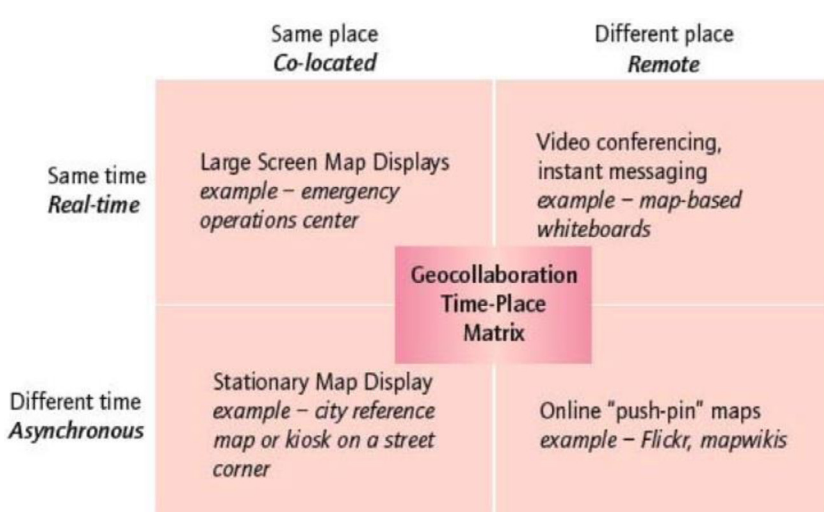

Fig. 2. Geo-collaboration place-time matrix [87].

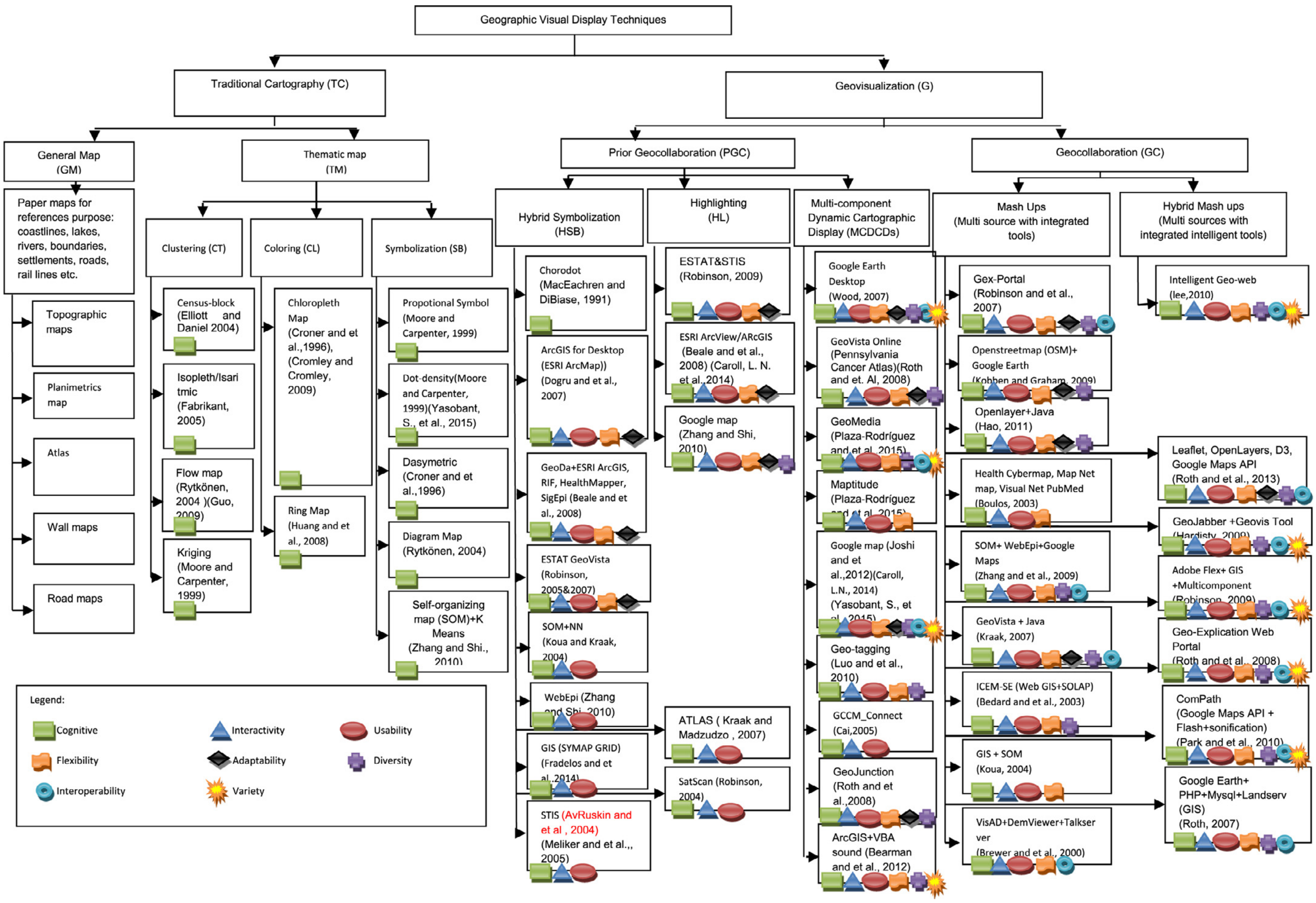

Fig. 3. Taxonomy of geographic visual techniques: traditional cartography (TC) and geovisualization (G).

Mash-ups (HMU) techniques.

5. Comparison of geographical visualization technique on epidemiology requirements

The graphical visualization techniques can be divided into two classifiers: Traditional Cartography (TC) and Geo-visualization (G). This study presents in detail the generation of TC and G techniques of epidemiology requirements in present technologies and highlights the vital concern or issues in this research. The strength of each technique is explained to provide a clear view of their efficiency in handling epidemic data. This analysis creates a standard reference for the development of geographic visualization tools in future. Table 3 relates the categorized Geographic Visual Display techniques in the aspects of Cognitive, Usability, Interactivity, Flexibility, Adaptability, Diversity, interoperability and variety.

5.1. Performance of traditional cartography (TC) methods

This section outlines the analysis of Traditional Cartography techniques. General Map only presented manual map such as paper map: atlas, wall maps, road maps and etc. whereby Thematic map (TM) is divided into Clustering (CT), Coloring (CL) and Symbolization (SB). Each technique was explained below:

- **Clustering (CT)** in epidemiology defined a cluster as a number of health events situated close together in space and/or time. This technique uses a cluster, layer, block, line, cell and etc. to represent an event on a map. Isopleth maps depict smooth continuous phenomena such as precipitation or elevation. Each line-bounded area on this type of map represents a region with the same value. For example, on an elevation map, each elevation line indicates an area at the listed elevation. While an Isarithmic map is a planimetric graphic representation of a 3-D surface which requires 3-D thinking for surfaces that vary spatially.
- **Coloring (CL)** method uses shaded color as standard legend in the map representing the range of different data. The next method uses hatching, hue or heat to show phenomenon on a map. In choropleth, the reader would need to count the number of units on the map shaded the same interval color to evaluate the percentage of the event falling within that interval. This type of mapping shows statistical data aggregated over predefined regions, such as counties or states, by coloring or shading these regions. For example, countries with higher rates of infant mortality might appear darker on a choropleth map. This technique assumes a relatively even distribution of the measured phenomenon within each region. Ring map shows more than geographic positions; it creates infographics that can organize and display several types of data organized using the simplicity and clarity of a map. Ring maps provide a straightforward and innovative way to display GIS data with segmented multi-colored ring representing around the appropriate map [70].
- **Symbolization (SB)** method uses symbols like dot, marker, circle, icon, grid and coordinates to represent spatial data. The proportional symbol technique uses symbols of different sizes to represent data associated with different areas or locations within the map. For example, a flag may be shown at the location of each city in a map which corresponding to the population of the city. Dot-density map also known as dot distribution map used to locate each occurrence

Table 2
Summary of performance between traditional cartography (tc) and geovisualization (G).

Main Type	Pros & Cons	Type	Visual Properties	Tools
Traditional Cartography (TC)	**Pros**: pure, direct-depict, keep data privately. **Cons**: Static, non-interactive, problem displaying continuous complex spatial-temporal data	Static, thematic, dotted	Polygon, cluster, dot-density, line, shades	Choropleth and Isopleth Map, Bayesian, census-block, custering, kriging, Ring Map.
Geovisualization (G)	**Pros**: Dynamic and Interactive and multi-view analysis. Multi-function and control based on user preference, superior spatial data display. Encourage knowledge sharing through social network. Documented and easy to learn. Open source and free to use. Geo-coded, spatially change accordingly. Display chronological events. **Cons**: adaptability issues (for specific users)	Dynamic, interactive, multiview, 2D&3D, MCDCDs	Polygon, Shape, dot, color, layers, Layers, clusters, shape, dot, color, circle, marker, icon, popup, toggle (zoom, scale and pan).	ArcView, ArcGIS, GeoVista Studio, ESTAT, Google maps, OpenLayer, Leaflet, GeoJabber, Gex-Portal etc

of a phenomenon. At where appropriate, a dot may indicate any number of entities, for example, one dot for every 100 voters or each dot represented one death as in Dr. Snow's map due to the cholera outbreak. This method is direct but may appear to be crowded and messy to display on a map when it is not well-designed to be displayed on a particular map.

The traditional Cartography approach involves the direct depiction of each record in a data set so as to allow the analyst to extract noteworthy patterns by looking at the displays and interacting with them. However, multivariate data sets of unknown size and complexity are growing at rapid speed, effective visual exploration may offer opportunities for analyzing these data sets in a timely fashion, but current techniques may not be effective when applied to the visual analysis of the kinds of large and complex data sets that are increasingly common (Dykes, 2008). These methods do not support interactivity, usability and further user's requirements because of its limitation on ability factors.

Geo-visualization (G) methods in the next category applied Human-computer Interaction methods. Geo-visualization software commonly provides users with multiple interactive, live-linked views of geographic information to encourage visual exploration in support of hypothesis generation and knowledge construction. Most early geo-visualization tools were developed as desktop applications. Prior Geo-collaboration (PGC) is categorized in this paper representing the basic visual properties and functions available on each individual tool before they were used in web 2.0 to support wide group interaction—Geo-collaboration. Prior Geo-collaboration were divided into three sub-categories to show its chronological order generated from Traditional Cartography. These categories are Hybrid Symbolization (HB), Highlighting (HL) and Multiple-component Dynamic Cartographic Displays (MCDCDs).

5.2. Performance of geovisualization (G) methods

- **Hybrid symbolization**techniques first appeared resulting from mixing method used in Thematic Cartographic, for example, Choro dot map represented by a combination of Chloropleth and Dot-density map to display multiple events within an interactive map. Hybrid Symbolization is the improvement from previous Geographic Visual Display- from static to dynamic and multiple-linked view, improved further with three-dimension and animation. This technique supports Exploratory of Data analysis mainly on spatial and temporal data. Researchers in GeoVista Center uses Exploratory Spatial-Temporal Analysis Toolkits to improve their application on GeoVista Studio to support advanced user's requirements.
- **Highlighting** Griffin and Robinson [29] explained that a key advantage of interactive geo-visualization tools is that users are able to quickly explore data across multiple views which supported with a transient visual effect applied around the edges of an object during a mouse selection or rollover. Earlier work called this effect *transient paint* [8] and *indication* [53]. The information visualization literature primarily refers to these techniques as *highlighting* [86] which we can find in today's geo-visualization such as zooming, panning, toggle, scaling and info popup providing user more functions and options to present visual variables on their map.
- **Multiple-component dynamic cartographic display (MCDCDs)** typically consists of the main map window, complemented by supplementary display components offering additional views on the same data, or additional datasets. One can imagine an animated interactive map in the main window, linked to additional static or dynamic maps, charts, diagrams, cross-sections, 3D views, etc. All windows are linked by means of interactive tools. How many components should be included in an MCDCD will probably depend on the theme of the investigation, and the inference and decision-making tasks the MCDCD should support [71].Geo-collaboration

Table 3
Analysis of geographic visual display technique for epidemiology and selected relational study.

Gegraphic visual display techniques		Authors	Epidemic data geographic visualization requirements							
			Cognitive	Usability	Interactivity	Flexibility	Adaptability	Diversity	Interoperability	Variety
Traditional cartography (TC)										
General map (GM)										
Thematic map (TM)										
Clustering	Census-block	Elliott and Daniel (2004)	✓							
	Isopleth/Isaritmic	Fabrikant, [26]	✓							
	Flow map	Rytkönen [81]	✓							
	Kriging	Moore and Carpenter [59]								
Coloring	Chloropleth Map	Clarke [20], Croner [22], Cromley and Cromley [21]	✓							
	Ring Map	Huang (2008)	✓							
Symbolization	Propotional Symbol	Moore and Carpenter [59]	✓							
	Dot-density	Yasobant, S., et al. [91]	✓							
	Dasymetric	Croner [22]	✓							
	Diagram Map	Rytkönen [81]	✓							
	Self-organizing map (SOM)	Zhang and Shi. (2010)	✓							
Geovisualization (G)										
Prior Geocollaboration (PGC)										
Hybrid Symbolization	Chorodot	MacEachren and DiBiase (1991)	✓							
	ArcGIS for Desktop (ESRI ArcMap)	Dogru [23]	✓	✓	✓	✓	✓	✓		
	GeoDa + ESRI ArcGIS, RIF, HealthMapper, SigEpi	Beale [6]	✓	✓	✓	✓	✓	✓		
	ESTAT GeoVista	Robinson [75,76]	✓	✓	✓	✓	✓	✓		
	SOM + NN	Koua and Kraak (2004)	✓							
	WebEpi	Zhang and Shi, (2010)	✓	✓	✓					
	GIS (SYMAP GRID)	Fradelos [28]	✓	✓	✓					
	STIS	AvRuskin [4], Meliker [57]	✓	✓	✓					
	ATLAS	Kraak and Madzudzo (2007)	✓	✓	✓					
	SatScan	Robinson [76]	✓	✓	✓					
Highlighting	ESTAT&STIS	Robinson [77]	✓	✓	✓	✓	✓			
	ESRI ArcView/ARcGIS	Beale [6], Caroll [16]	✓	✓	✓	✓	✓			
	Google map	Zhang and Shi (2010)	✓	✓	✓	✓	✓	✓		
MCDCDs	Google Earth Desktop	Wood [89]	✓	✓	✓	✓	✓	✓	✓	✓
	GeoVista Online	Bui and Pham [14]	✓	✓	✓	✓	✓	✓	✓	
	GeoMedia	Plaza-Rodríguez [73]	✓	✓	✓	✓	✓	✓	✓	✓
	Maptitude	Plaza-Rodríguez [73]	✓	✓	✓	✓				
	Google map	Joshi [40], Caroll, [16], Yasobant, [90]	✓	✓	✓	✓	✓	✓	✓	✓
	Geo-tagging	Luo	✓	✓	✓	✓		✓		
	GCCM_Connect	Cai [15]	✓	✓	✓	✓				
	GeoJunction	Bui and Pham [14]	✓	✓	✓	✓	✓	✓	✓	
	ArcGIS + VBA	Bearman [7]	✓	✓	✓	✓				
Geocollaboration (GC)										
Mash-ups	Gex-Portal	Robinson [75]	✓	✓	✓	✓	✓	✓	✓	✓
	Openlayer + Java	Hao [31]	✓	✓	✓	✓				
	Health Cybermap, Map Net map, Visual Net PubMed	Boulos [10]	✓	✓	✓	✓	✓			
	SOM + WebEpi + Google map	Zhang [94]	✓	✓	✓	✓		✓	✓	
	GeoVista + Java	Kraak [46]	✓	✓	✓	✓		✓	✓	✓
	ICEM-SE (Web GIS + SOLAP)	Bedard	✓	✓	✓	✓		✓	✓	✓
	GIS + SOM	Koua [43]	✓	✓	✓	✓		✓	✓	✓
	VisAD + DemViewer + Talkserver	Brewer (2002)	✓	✓	✓	✓		✓	✓	✓
	Openstreetmap (OSM) + Google Earth	Kobben and Graham (2009)	✓	✓	✓	✓	✓	✓		
	Leaflet, OpenLayers, D3, Google Maps API	Roth [80]	✓	✓	✓	✓	✓	✓	✓	✓
	GeoJabber + Geovis Tool	Hardisty [33]	✓	✓	✓	✓				
	Adobe Flex + GIS + Multicomponent	Robinson [78]	✓	✓	✓	✓	✓	✓	✓	✓
	Geo-Explication Web Portal	Bui and Pham [14]				✓	✓	✓	✓	✓
	ComPath (Google Maps API + Flash + sonification)	Park [72]	✓	✓	✓		✓	✓	✓	✓

(continued on next page)

Table 3 (*continued*)

Gegraphic visual display techniques		Authors	Epidemic data geographic visualization requirements							
			Cognitive	Usability	Interactivity	Flexibility	Adaptability	Diversity	Interoperability	Variety
Hybrid mash-ups	Google Earth + PHP + Mysql + Landserv (GIS)	Bui and Pham [14]	✓	✓	✓	✓	✓	✓	✓	✓
	Intelligent Geo-web	Lee [50]	✓	✓	✓	✓		✓	✓	✓

(GC) is an emerging platform examining how spatial information and communication technologies can be designed and adapted to support group interactions that use geographically referenced data and information [5]. These group interactions normally focus on tasks such as spatial data access and exploration, problem-solving, planning, and decision-making. Geo-collaboration is this paper is categorized into two groups: Mash-Ups (MU) and Hybrid Mash-Ups (HMU).

- **Mashup (MU)** in context of geo-visualization can be defined as a geo web application that combines data from more than one source into a single integrated tool, is a kind of realization of web 2.0. This trend and advancement of web technology cause researchers in GIS communities to flourish web mapping based on mashup techniques. There are several types of mashup: the mashup between heterogeneous data, mashup using different open APIs [50]. Google map maker in Google Map API supports mapping application with collaborative features. Although Google allows flexible mash up style use of their raster map images, the MapMaker system presents a one-way flow at the level of raw map data, from the community to Google (with the exception of some areas where the special provision of shape files have been granted for humanitarian reasons). With the advanced technology of Web 2.0, applications like Geo-Vista Studio also developed to integrate with Java to provide more flexibility of functions and become more diversify in terms of supporting multiple disciplinary. The G-EX Portal allows users to upload artifacts derived from analysis sessions; these range from simple screenshots or textual notes to geospatial datasets and multimedia tutorials [79]. Hao [31] conducted a geospatial web utilizing social networking benefits approach by exploring online epidemiology information tracking newsfeed with annotation method. He used open layer, Java, and PostgreSQL to test on his work. Hardisty [33] introduced GeoJabber concept, protocol, and working prototype software which applied same-time, different-place collaborative geo-visualization. It leverages three key Open Source technologies: The GeoViz Toolkit, the Jabber protocol, and XStream and is the first project to support same-time different-place geo-visualization tool state sharing. The mash-ups methods seem to be more interesting as this technique is more interactive, has the potential for adaptability, provides various components where different technologies were used to support multi-disciplinary requirements.
- **Hybrid mash-ups (HMU)** involved intelligent web services in handling geo-based resources and applications. Lee [50] believes intelligent Geo-web with Hybrid Mash-Upss capable of executing more analytical and functional process from other existing services or sources. The hybrid mashup suggested in his work is towards more intelligent web services handling geo-based resources, for example, a Client web browser displays mashup pages to the user that may perform mashup logic implemented using JavaScript, ActiveX or other technologies [50]. This hybrid Mash-ups techniques support flexibility, interoperability, diversity, and variety of Geographic Visual Display as it involved multiple technologies and resources together although it yet to be used in epidemiology field as it is still very new and have many more to explore.

Table 3 presents facts for each geographic visual display category: TC and G. Clustering, Coloring and Symbolization technique in traditional cartography support cognitive process in the early study of disease mapping. Efficiency in display reveals the feasibility of this method when it faces a large number of data and it doesn't support interactivity that allowed information change-over-time. Geo-visualization technique, including hybrid symbolization, highlighting and multi-component dynamic cartographic display (MCDCD) supports interactivity display thus improved usability of tool amongst users as it fulfilled user requirements on spatial-temporal analysis. Advanced geo-visualization technique in technology mash-ups and hybrid mash-ups ensures

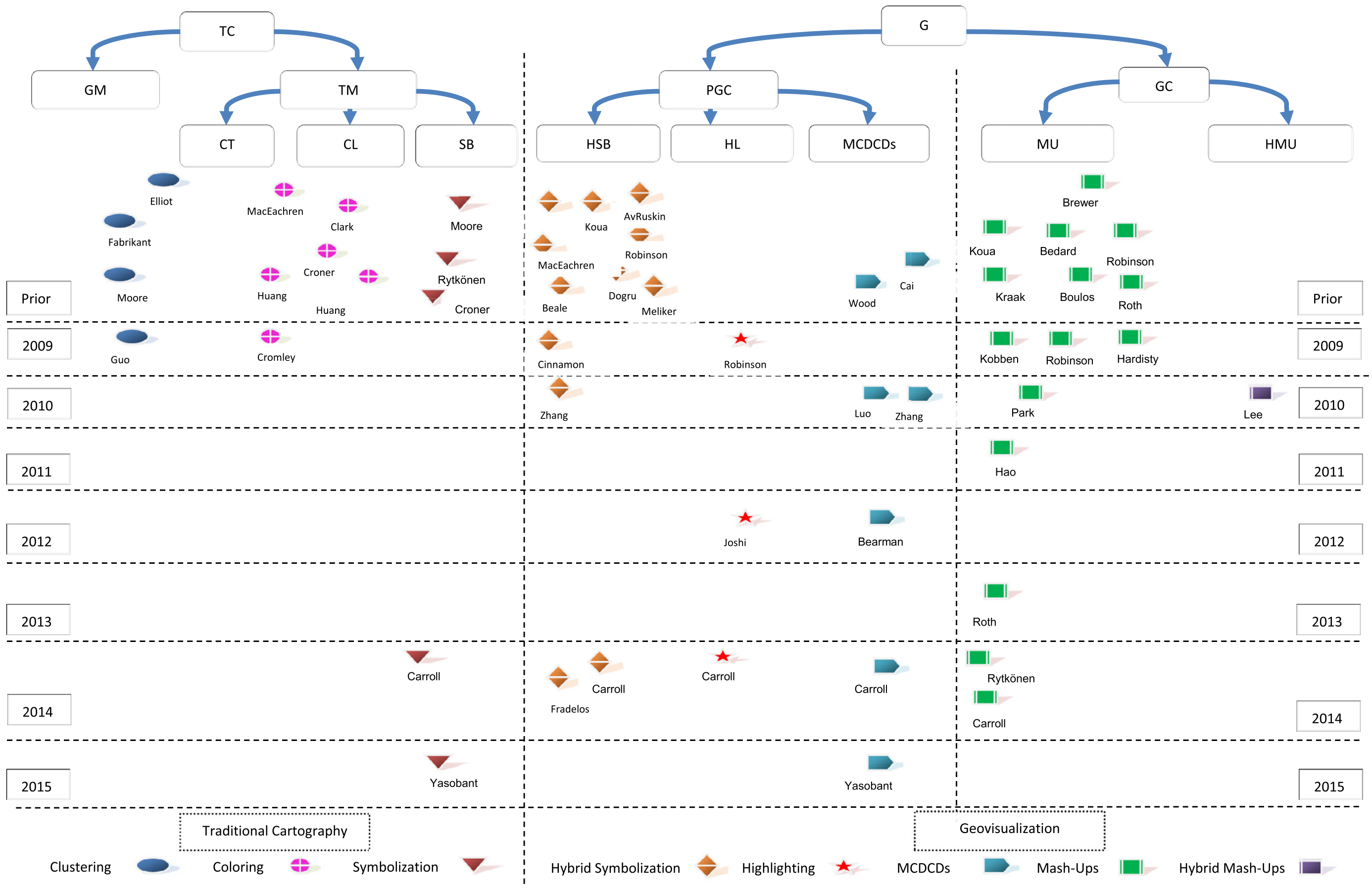

Fig. 4. Chronological order of geographic visual display.

cognitive, interactivity, usability, and adaptability as well as support diversity, interoperability and variety for complex geographic visual display with large multivariate data (Table 2).

6. Discussion

Early Geographic Visual Display techniques in Traditional Cartography have contributed to the development of today's advanced Geographic Visual Display Techniques known as geo-visualization. As we can see from the chronological order of Geographic Visual Display in Fig. 4, some of the traditional techniques are actually applied in current modern geo-visualization tools. With advanced computer-aided software and web technologies, combination of these techniques provides a powerful representation of today's Geographic Visual Display.

This paper elaborates advantages and limitations for both categories of Geographic Visual Display Techniques. The decision of which technique to be used depends on the purpose. For example, Traditional Cartography techniques are better for in-depth spatial data analysis while Geo-visualization has superior and provides variety of spatial data display (Hanieh, 2010), [56,67]. As the volume and complexity of infectious disease data increases, public health professionals must synthesize highly disparate data to facilitate communication with the public and inform decisions regarding measures to protect the public's health.

This survey identified there are many advanced Geographic Visual Display Technique mash-ups tools that are yet to be used by epidemiologist and matters are related to user-perceived ease of use and user intention-behavior towards the currently available tools [32]. On selected relational study shows that the exploration of this topics [1] are very wide as many efforts have been done by previous researchers to develop tool which combines multiple sources and media such as text from newsfeed and audio-video which can be customized to be used in epidemiology, taking benefits from social networking and semantic web application (YouTube, Facebook and etc.). Some works provide a dialog tool as a component within the tool itself to support Multiple-component Dynamic Cartography display (MCDCDs) representation and further effort use intelligent web technologies leading to geo hybrid-mashups that provides more opportunities to explore in this topic.

Several themes have to be taken under consideration including users' needs, preferences, and computer literacy; integration of tools into the routine workflow; complications associated with understanding and use of visualizations; and the role of user trust and organizational support in the adoption of these tools [16]. Interoperability also emerged as a prominent theme, highlighting challenges associated with the increasingly collaborative and interdisciplinary nature of infectious disease control and prevention.

Slocum et al. [83] suggested, "The most sophisticated technology will be of little use if people cannot utilize it effectively". Though, some technologies are still incoherent due to the interest on business and other factors. Several important issues have been discussed repeatedly in many studies are related mostly on: what information is represented especially involving spatial and temporal aspects of data in the process; how information is represented to impact on representational choice and methods that allow users to explore and understand; and what are the mechanisms provided for interaction with the information particularly the potential use of multi-component to support human sensibility.

7. Conclusion

This paper outlined a categorization of existing geographic visualization techniques used in Public Health. The objectives of this survey is to analyze the geographic visualization requirements for epidemiology as well as to present generation of geo-visualization technique to provides researchers an idea on how to develop a representation tool that may solve the problem of uncertainty, usability, and adaptability as a major concern in the development of such tools nowadays. In the taxonomy, Geographic Visualization Techniques were compared and classified as Traditional Cartography (TC) and Geo-visualization (G). Research were studied and analyzed for epidemiology requirements by focusing more on Geo-collaboration tools as the modern techniques used currently. However, the important aspect of each category was highlighted to show the capability of each techniques which meant to lead future researchers to improve techniques in the geographic visual display. To conclude, Geo-visualization specifically geo-collaboration is more suitable for the current epidemiology requirements in today's dynamic and fast-moving world, since they support real-time monitoring, allowed multiple component displays and more adaptable and prominent to large data handling. Geo-collaboration techniques which utilized our other sense of ability is assessed to increase more usability of geographic visualization technique allowing the important data to be captured in the field immediately displayed in the system. Events like the H1N1 disease, Ebola, Zika and other critical diseases would benefit from analytical monitoring tools like these. This process will result in information about public health being transmitted simultaneously while captured. This type of analytical monitoring tool can be designed so that it can be shown on various platforms around the globe to stimulate a healthy geo-collaboration.

Future work is required to develop the understanding and integrated technologies that make it possible to take advantage of the potential offered by virtual environments, direct manipulation interfaces, and related multimodal technologies in purpose to satisfy epidemiology or other discipline requirements like Cognitive, Usability, Flexibility, Interactivity, Adaptability, Diversity, Interoperability and Variety.

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