

Online community collaborative map

A geospatial and data visualization tool for cancer data

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Abstract

The aim of this study was to develop an online collaborative map to enable researchers to locate, explore, and share cancer data.

This 2-scale (global and country-level) cancer map adopts a database-driven model, which was implemented using the Google Map Application Programming Interface (API) and asynchronous JavaScript and XML (AJAX) technology. Seven visualization techniques were used to present data. Data on worldwide cancer mortality between 1950 and 2013 were taken from the International Agency for Research on Cancer (IARC) database. Incidence data were from the IARC CI5plus database. Survival data were from the IARC SURVCAN study. Prevalence data between 1990 and 2017 were from the Institute for Health Metrics and Evaluation's (IHME) catalog while demographic data were from the World Bank Data Catalog. Cancer data for Taiwan between 1991 and 2016 were obtained from the Department of Health and Welfare. This study used visualization techniques that included: a choropleth map to display the prevalence of cancer; a tornado diagram to show the age-standardized mortality rates of all cancers among men and women in 2013; a treemap to show a ranking of cancer mortality data; a sunburst chart to show mortality rates of all cancers by gender; a line chart to show mortality trends for all cancers; a bar chart to show mortality and incidence rates and a heatmap to show variations in cancer across different countries.

The world cancer map generated by this study can be accessed at <http://worldmap.csmu-liawyp.tw>. Country-level mortality data are presented as crude and age-standardized rates.

We used visualization methodologies and constructed an easily maintainable web-based user interface with cancer data from administrative regions in 150 countries. This serves as a platform that allows researchers to manage and disseminate cancer data.

Abbreviations: AJAX = asynchronous JavaScript and XML, API = Application Programming Interface, ASR = age-standardized mortality/incidence rate, CRS = cancer registry system, GIS = geographical information systems, IARC = International Agency for Research on Cancer, SVG = scaling vector graphic, WHO = World Health Organization.

Keywords: cancer mortality, data visualization, mapping, online atlas

1. Introduction

In the past decade, half of the new cases of cancer in the world have occurred in developing countries in Asia. Cancer has increased a considerable economic burden especially on countries that are underdeveloped.^[1] The Web Portal for the IARC

provides information about the current world cancer statistics.^[2] It contains data from 91 countries (i.e., about two-thirds of countries in the world). Cancer is one of the 10 leading causes of death in Taiwan. However, cancer data for Taiwan can neither be located nor explored at the web portal for the IARC, as it is not a member of the World Health Organization (WHO).

With the advancement of internet technology, various methods have been developed for implementing the global information system (GIS) as online maps. Moreover, it has been applied extensively in public health.^[3,4] For example, the National Cancer Institute (NCI) used the Common Gateway Interface (CGI) to develop cancer mortality maps that allow users to interact through user forms.^[5] The WHO used HTML5 technology to develop interactive maps, presenting health statistics from various countries in the world.^[6] In our previous publication, we used Scalable Vector Graphics (SVG) to develop a cancer platform to show variations in cancer mortality (in Taiwan) over a period of 40 years.^[7]

With the development of internet technology, operation models have changed. In the past, users could only access information on a website but were unable to participate in data maintenance. Tim O'Reilly put forward the concept of Web 2.0 in 2004^[8] and proposed that the contents of a website should be decentralized. It is no longer maintained by a specific group of people but is also generated by users altogether. The content can be shared by everyone. Public health programs require that

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everyone should participate and contribute their own information. Many studies have started to apply the concept of Web 2.0 to public health issues.^[9–12] With massive participation, a more effective mediation of complex health information has been achieved using visualization tools.^[13]

The aim of this study was to develop an online collaborative map that enables researchers to locate, explore, and share cancer data.

2. Materials and methods

2.1. Materials

In this study, we evaluated the mortality of cancer in various regions of the world using data available in the IARC database. The database contains information on approximately 30 types of cancer, including bladder, bone, brain, breast, cervix, uterus, uterine corpus uteri, colon, gallbladder, Hodgkin lymphoma, intestine, kidney, larynx, leukemia, lip, liver, lung, skin, mesothelioma, multiple myeloma, nasopharynx, lymph nodes, esophagus, ovary, pancreas, prostate, stomach, testis, thyroid, and the uterus as summarized in Table 1. The data span the period 1950 to 2013 (i.e., 64 years). The cancer mortality data for Taiwan (1991–2016) were made available by the Open Government Data Platform.^[14] To maintain consistency with the IARC, the mortality rates in Taiwan are age-standardized to the 1960 world standard population. Data used in the current study were de-identified, hence ethical approval and consents were not required. Incidence data were from the IARC CI5plus database, which contains 124 selected populations drawn from 108 cancer registries published in “Cancer Incidence in Five Continents (CI5),” for all cancers and 28 major types.^[15] Survival data were compiled from the IARC SURVCAN-2 project, which contains 31 registries from 14 countries in Africa, Asia, the Caribbean, and Central America.^[16] Data on cancer prevalence (over 30 major types of cancer in 191 countries) were from the Institute for Health Metrics and Evaluation’s (IHME) Catalog.^[17] Demographic data including

alcohol consumption, GNI per capita, smoking habits, and overweight were obtained from the World Bank Data Catalog.^[18]

Maps of the administrative regions of the world were taken from the DIVA-GIS website.^[19] This webpage provides free access to basic data for the entire world. The original data were available in shapefile format. In this study, data were downloaded from the DIVA-GIS website and converted into GeoJSON format using the QGIS software.^[20]

2.2. Method

Web design and visualization technologies have been used to present world cancer data. The concept of AJAX (Asynchronous JavaScript and XML) was introduced in 2005 by Jesse James Garrett allowing users to explore cancer maps by gender and other parameters.^[21] When variables of interest change, the information is obtained from the server and updated directly on the map without leaving the page. When data are acquired via an AJAX call, they are transferred using JSON (JavaScript Object Notation).^[22] This would help to improve the response time, as well as reduce the amount of data transfer between the client and the server. Interactive maps have been created using the Google Map API.^[23] AJAX has been used to integrate spatial distributions of cancer data. The geospatial model presented by Google Map uses the GeoJSON format. The model can be created using the QGIS software. The shapefile is converted into a GeoJSON format. To visualize various cancer data, height charts (a JavaScript charting library) are used to generate different types of charts on the web pages.^[24]

This study was based on a comprehensive application of the aforementioned technologies. The global cancer mortality map was constructed using data available in the IARC database. Data were stored in the database after normalization. Database-driven model^[9] and Google Map API were used to generate this webpage that can be explored by global cancer researchers. Through a simple user interface, they can search for and jointly

Table 1
List of cancer types.

Cancer site	ICD-10		Cancer site	ICD-10	
	IARC	Taiwan		IARC	Taiwan
All cancers	C00–97,B21	C00–97	Larynx	C32	*
Bladder	C67	*	Leukemia	C91–C95	*
bone	C40–41	*	Lip, oral cavity and pharynx	C00–14	C00–C06, C09–C10, C12–C14
Brain, central nervous system	C70–72	C71	Liver (specified as primary)	C22	*
Breast	C50	*	Liver and biliary passages	C22–24	C22
Cervix uteri	C53	C53,C55	Lung	C33–34	*
Corpus uteri	C54	—	Melanoma of skin	C43	C43–C44
Colon	C18	C18–C21	Mesothelioma	C45	C45–C49
Colon, rectum, and anus	C18–21	*	Multiple myeloma	C88,C90	—
Gallbladder	C23–24	*	Nasopharynx	C11	*
Hodgkin lymphoma	C81	*	Non-Hodgkin lymphoma	C82–86,C96	C82–C85
Intestine	C17–21	C17	Esophagus	C15	*
Kidney	C64	*	Ovary	C56	C56, C57.0–C57.4
Pancreas	C25	*	Prostate	C61	*
Rectum and anus	C19–21	C18–21	Stomach	C16	*
Testis	C62	C60,C62,C63	Thyroid	C73	*
Uterus	C53–55	*			

* IARC and Taiwan Cancer Registry with the same ICD code: No data.

safeguard cancer information in countries around the world. In this study, several methods were used to display cancer data. They included

(1) Choropleth map

In 1854, John snow published a map demonstrating locations of cholera patients around London. He identified the source of the cholera outbreak and ways to control it from spreading. This is an indication that spatiotemporal visualization is important in determining spatial clustering of diseases, and in identifying preventive and control measures. Choropleth mapping is a common method for presenting inter-regional data. Different colors or patterns are used to depict ranges in data across different regions.^[25] The 4 classification methodologies available to a cartographer include the following: equal interval, natural breaks (Jenks), standard deviation, and quantile. The quantile classification method, commonly used in epidemiology, is the most suitable for mortality data.^[26] In this study, cancer mortality data for each country were divided into 7 levels using the quantile classification method. Red, orange, gold, white, light green, lime green, and dark green were used to represent country-level data on the choropleth map.

(2) Tornado diagram

Tornado diagrams are often used to provide a graphical representation of the degree to which the result is sensitive to the selected independent variables. To create a tornado diagram, a variable that produces the largest range of result is located at the top. When drawn in this manner, the graph will be displayed in the form of a tornado and can be used to depict the sensitivity of a result to changes in the selected variables. This study selected a country as the variable and displayed cancer mortality among men and women.

(3) Line chart

A line chart is one of the most commonly used statistical graphs. It shows cancer trends as a series of data points. In this study, cancer mortality data from various countries in the world were demonstrated using the interactive interface, thus allowing researchers to visually examine the overall spatial distribution. Where there exist significant regional mortality variations, line charts can be used to show the historical trend over a longer period of time.

(4) TreeMap

The nested rectangular structure and the area it occupies represent the proportion of observational data. The larger the area, the higher the proportion of data. In this study, a treemap was used to present a ranking of cancer mortality data by administrative areas in each country. The larger the area of the rectangle, the higher the mortality rate.

(5) Sunburst chart

An interactive sunburst chart represents hierarchical data, where each data node is represented by an annular segment within multilayered rings. The circle in the center represents the root node, with the hierarchy extending outward from the center. In this study, sunburst chart was used to present the annual cancer mortality rates among both sexes.

(6) Bar chart

Bar charts display data graphically using bars of different heights. They can be plotted vertically or horizontally and can be used to compare multiple data series. In this study, a bar

chart was used to compare cancer data or estimates across different countries Fig. 7.

(7) Heatmap

Heatmap originated in 2D displays of the values in a data matrix. It is a representation of data in the form of a diagram where colors are used to represent values. Via the heatmap, 2 continuous variables are needed on the x and y-axes. The third continuous variable is mapped to color and the data are presented in a matrix. In this study, the heatmap displays variations in cancer estimates across different countries by year as shown in Fig. 8.

This platform allows researchers to input cancer data based on the country and administrative regions. The first-level administrative units of each country were used when creating the map. For example, the first administrative unit in Taiwan is a county, whereas, in the United States, it is represented by a state. In this study, Taiwan was used for the purpose of demonstration, where county-level data were used to display trends from 1991 to 2016.

3. Results

The world cancer map we developed can be accessed at <http://worldmap.csmu-liawyp.tw>. It is designed with a 2-scale architecture and allows users to explore cancer mortality patterns and trends in various countries. Figure 1 shows the global cancer map with country-level mortality data presented as crude and age-standardized rates.

3.1. Using a choropleth map to present cancer mortality trends

In this study, cancer data for each country were divided into 7 levels, and the choropleth map was used to show the global distribution. Figure 2 is the choropleth map generated using global cancer mortality data. It can be explored freely by cancer researchers to determine regions with high mortality rates.

Besides the cancer mortality map, researchers can also access incidence and prevalence rates as well as demographic data. Figure 2 is a lung cancer prevalence map.

3.2. Using a tornado diagram to present overall differences between men and women

Figure 3 shows the Tornado diagram for age-standardized mortality rates of all cancers among men and women in 2013. On the basis of the diagram, the overall cancer mortality was highest in Hungary compared with all other countries. In addition, cancer deaths were higher in men than in women.

3.3. Using a line chart to present long-term trends

Understanding historical trends over time will help in the development of more effective cancer prevention strategies. Figure 4 is a line graph showing the mortality trend for all cancers from 1991 to 2016 in Taiwan. From this graph, it can be seen that the mortality rates decreased every year among men and women.

3.4. Using a treemap to display rankings of cancer mortality data

For every country, identifying cancers that threaten human lives can help health institutions to formulate appropriate policies to

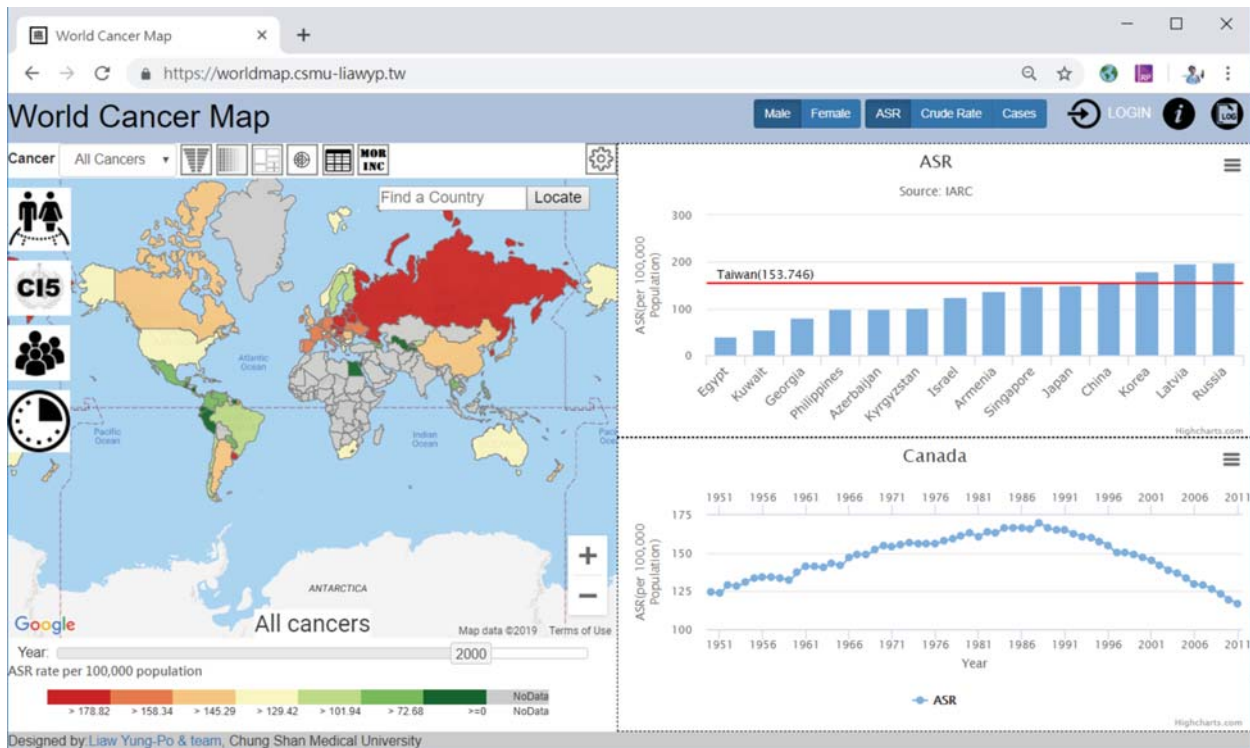


Figure 1. World cancer map developed using various visualization technologies located at <http://worldmap.csmu-liawyp.tw>.

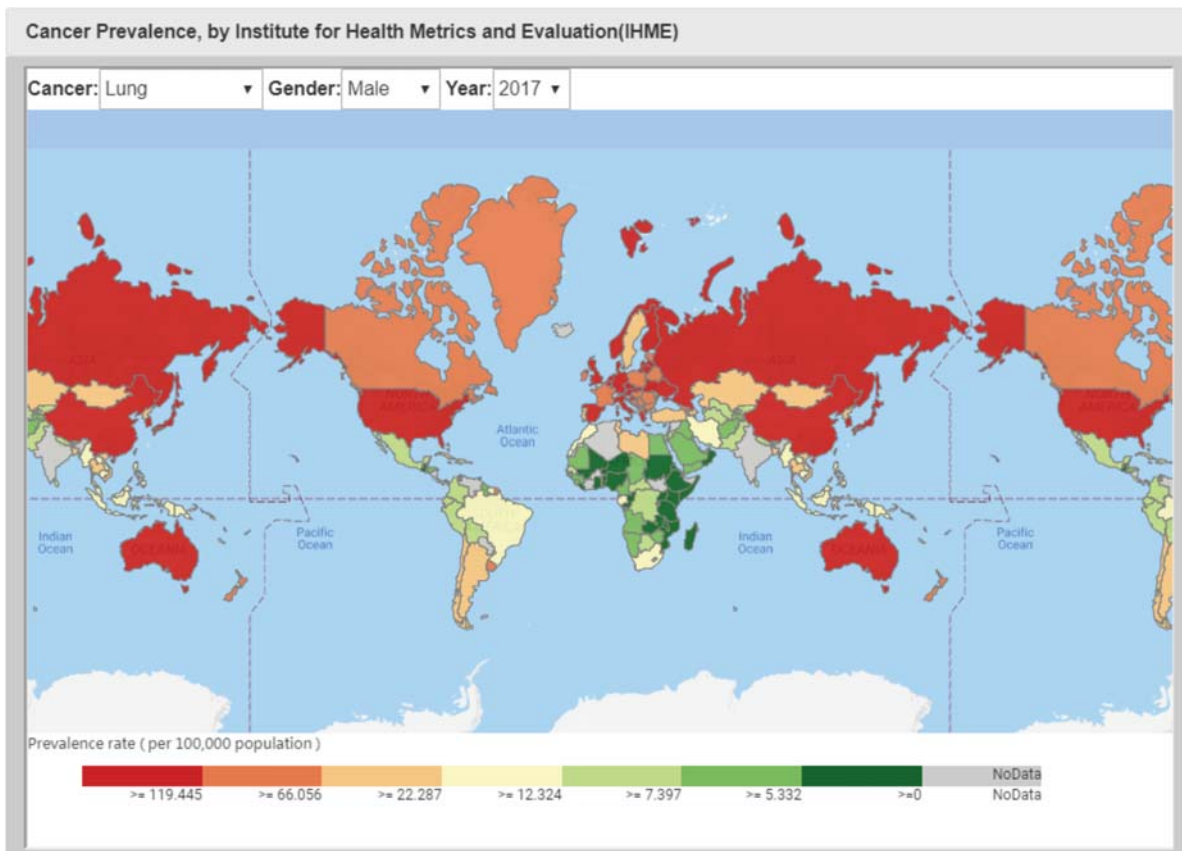


Figure 2. Choropleth map showing the prevalence of lung cancer in 2017.

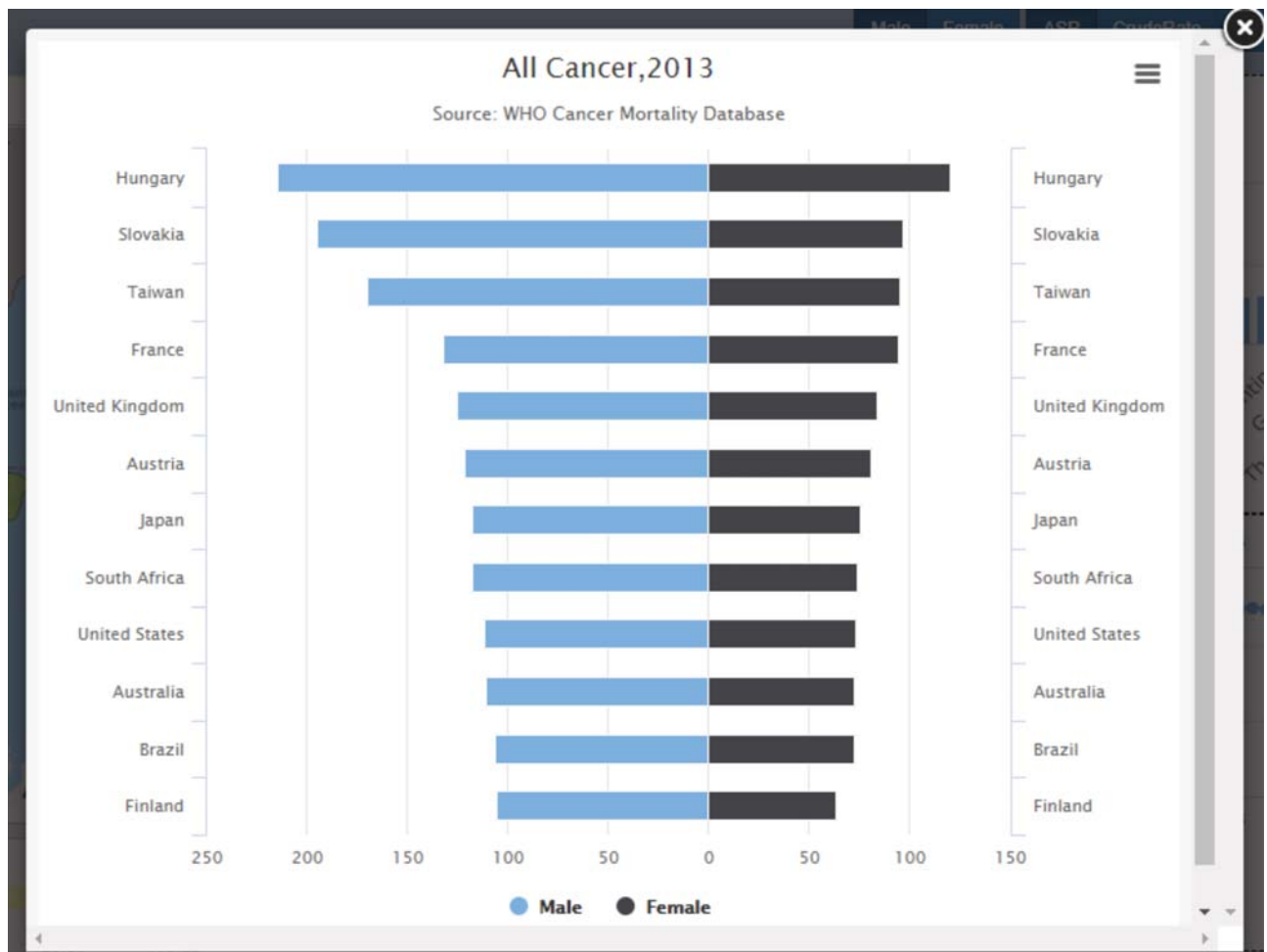


Figure 3. Tornado chart showing age-standardized mortality rates of all cancers among men and women in 2013.

reduce mortality. Figure 5 shows treemaps of cancer mortality in Taiwan (2013). From the figure, it can be seen that liver cancer was the leading cause of cancer death in 2013.

3.5. Using sunburst chart to visualize hierarchical data

The hierarchical presentation of data allows users to visualize and compare different variables. Figure 6 shows the annual mortality rates of all cancers among men and women in Taiwan. Users can simultaneously visualize changes in overall and specific cancer mortality rates. It could be seen from the chart that cancer mortality was higher in men than in women.

3.6. Heatmap

In this study, “year” and “country” are mapped to x and y-axes, and the colors in the matrix represent cancer data. The y-axis represents countries alphabetically ordered. The resulting heatmap shows variations in cancer estimates across different countries by year as shown in Fig. 8.

Cancer estimates across different countries can be compared based on demographic data such as alcohol consumption, income (GNI), overweight, and smoking habits as shown in Fig. 9.

This platform, generated using the Web 2.0 technology, was integrated with Facebook and Google as shown in Fig. 10. Users can view and manage data by logging on using their personal Facebook or Google accounts. The platform will store all transaction records to ensure the correctness of data (Fig. 11).

Clicking on any particular country will enable users to explore data by cancer type. In this study, we have successfully completed the construction of a web-based user interface with cancer mortality data obtained from administrative regions in 150 countries. It is a collaborative environment that will enable researchers from various countries to upload all cancer data. Figure 12 represents a country-specific cancer map, where Taiwan is used for the purpose of demonstration. The left section of the map shows the spatial and temporal variation in mortality of all cancers in Taiwan, while the top bottom right section (bar chart) shows the age-standardized mortality rates for each administrative district. The bottom right section of the map (line chart) shows the cancer mortality trend from 1991 to 2016. The country-level maps designed in this study can be explored by gender, cases, and rates (ASR and crude rate). Researchers can control their own variables to demonstrate the temporal and spatial variation in cancer mortality.

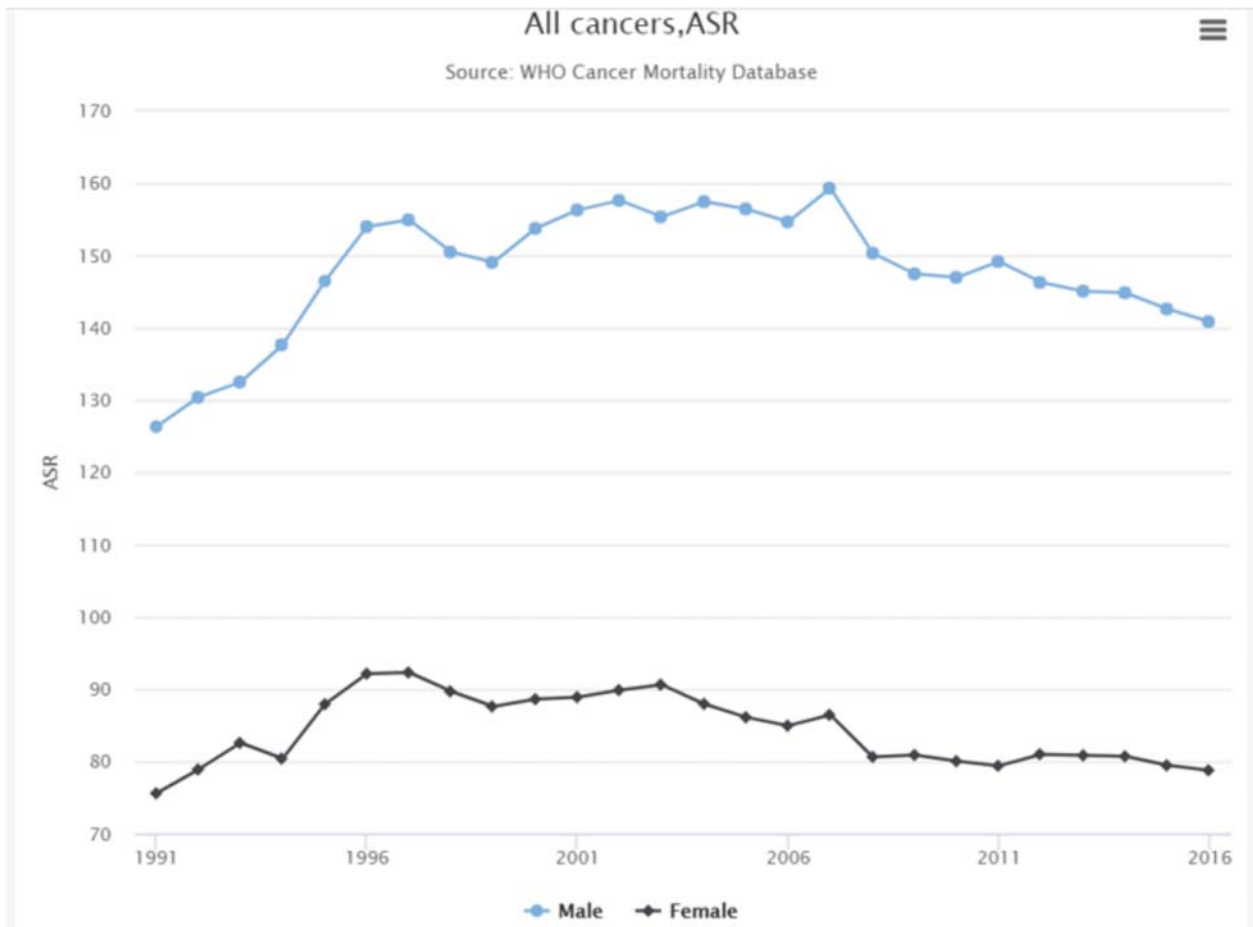


Figure 4. Line chart showing mortality trends for all cancers.

Researchers can also use this platform to collaborate and maintain cancer data. Figure 13 is a screenshot that shows how to become a member of the collaboration. To provide users with an interface to view county-level data, Taiwan is used for the purpose of demonstration (Fig. 14). When a user accesses the cancer map, if data have not yet been established, a prompt message will be displayed. If available, the user can upload cancer information to the platform through the data editing function.

The country-scale data can be managed and expanded by a researcher year by year. To facilitate the management of the web content, administrators can select a corresponding panel (Fig. 15).

4. Discussion

Web-based GIS provides a good tool for public health research. It offers opportunities to analyze complex geospatial data, making it easier for people to understand relevant health information.^[27,28] However, commercial Web-GIS software is expensive. Therefore, many studies have attempted to use open source technology to construct online public health maps so that health data can be more widely publicized through the internet.^[29–31]

For transnational cancer research, the IARC Cancer Mortality Database provides cancer mortality data for various countries. Researchers can search and download cancer mortality data for

various countries through the web search interface. The current IARC website provides information on cancer (over 30 cancer types) from 1950 to 2013. The webpage allows users to produce tables, charts, and visual descriptions of cancer burden by region. In addition to presenting cancer data in a traditional way, IARC has also used emerging visualization technologies to design the “Cancer Today” theme page, which provides visualization methods, including a map, circle pack chart, parallel sets chart, sunburst, and force layout.^[32] However, data contained on this page are limited to 2018. Furthermore, current online cancer maps (including IARC) have mainly provided 1-way data.

In our study, the concept of Web 2.0 was used, hence creating an option for users to drill down in order to contribute their own country-level data. This helps to improve data collection. There are 2 main advantages to data management and architectural perspective.

From the architectural perspective, this study used the Google Map API as a basis to develop a lightweight, low-cost, high-performance, and a cross-platform with front-end web technologies and visualization packages to develop a cancer map. There are several advantages to this approach:

(1) Low cost

The architecture proposed in this study was implemented using Open-Source Software.

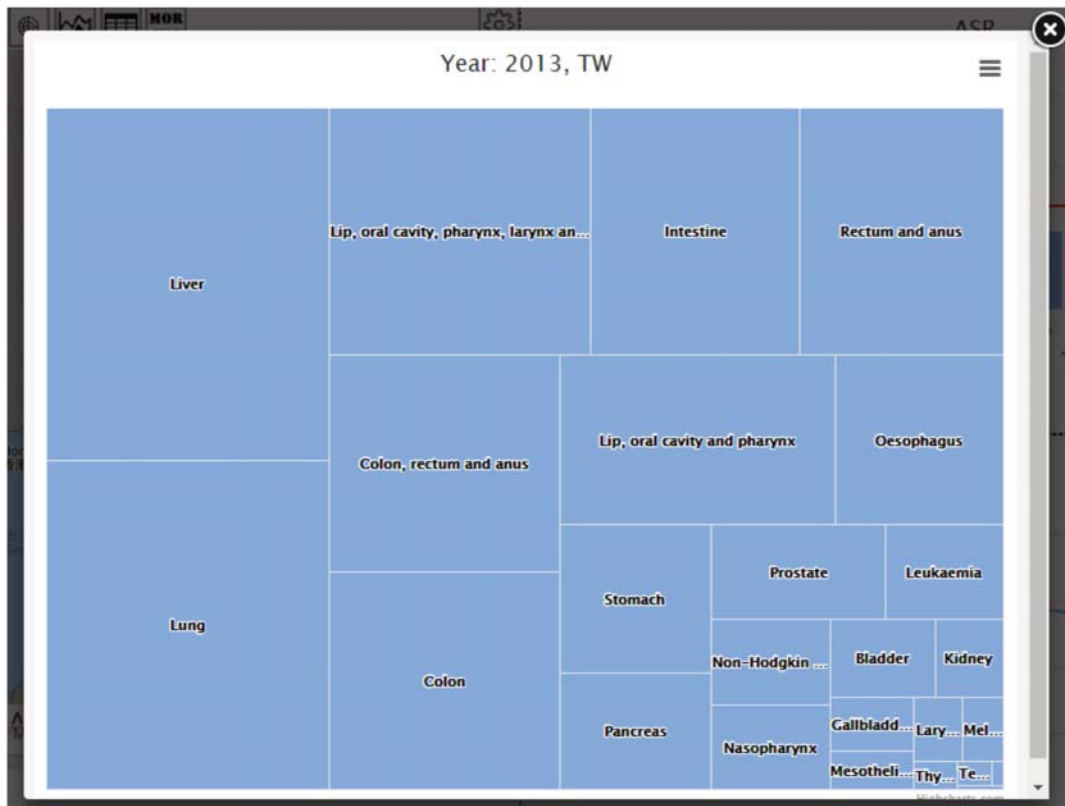


Figure 5. Tree-Maps of cancer mortality in Taiwan (2013).

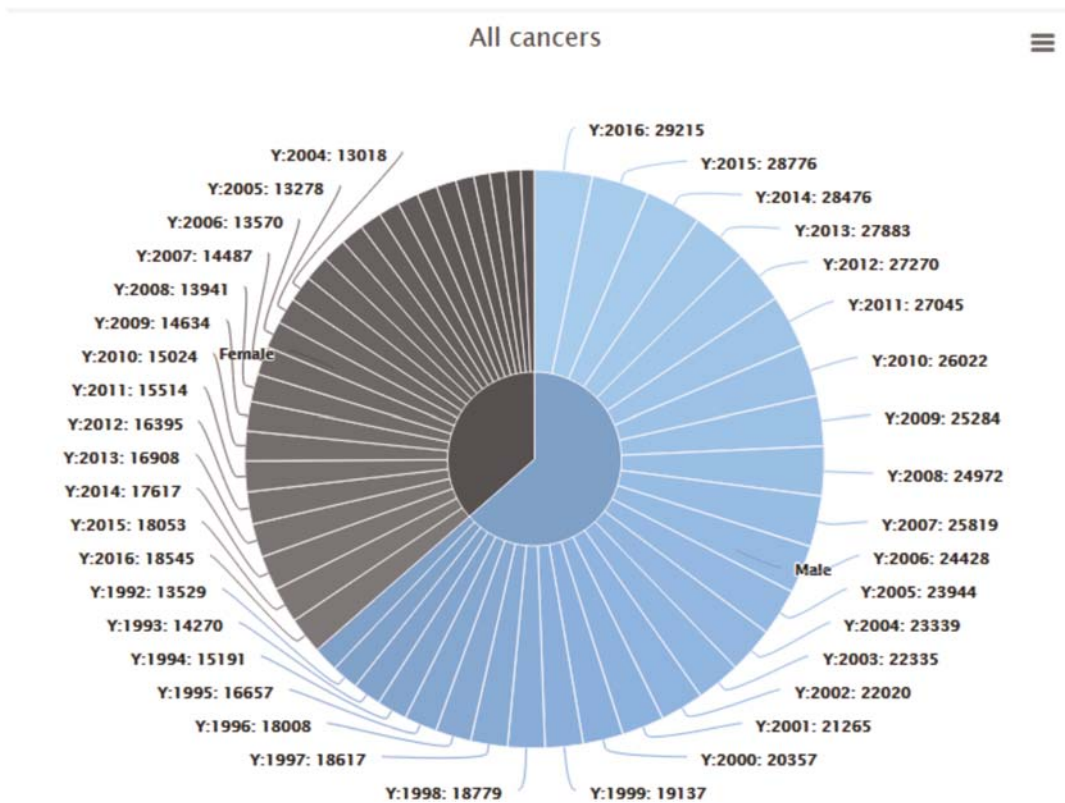


Figure 6. Sunburst chart showing mortality rates of all cancers among men and women in Taiwan (1991–2016).

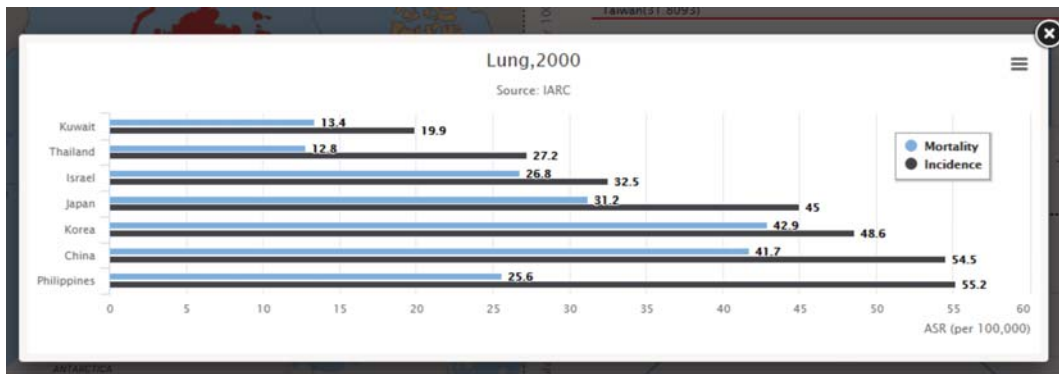


Figure 7. Bar chart showing lung cancer incidence and mortality in different countries.

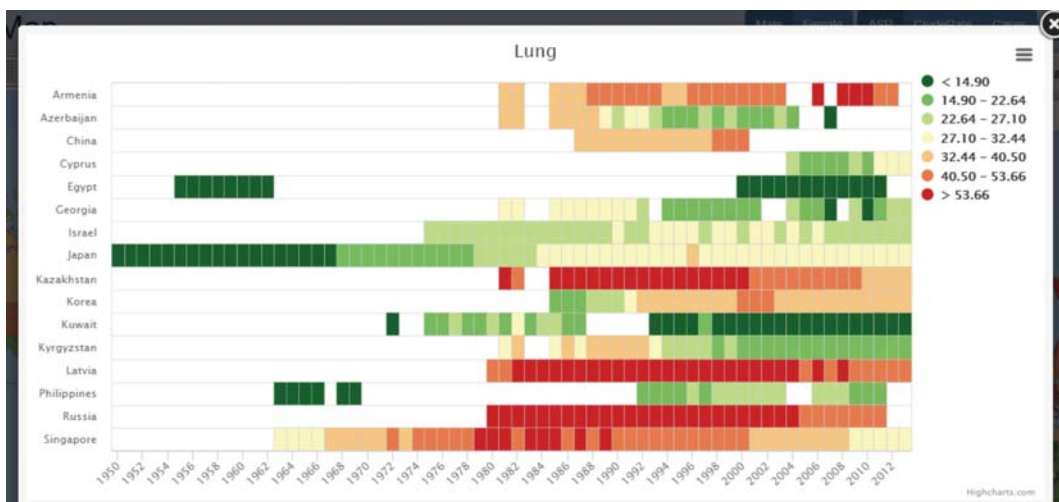


Figure 8. Heatmap showing variations in lung cancer across different countries by year.

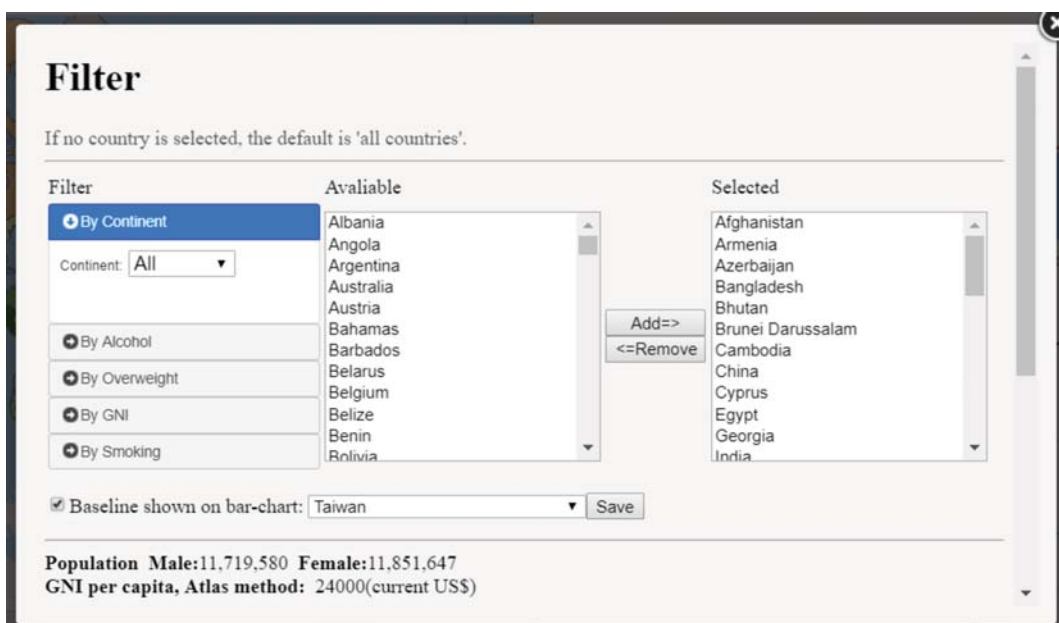


Figure 9. Filter panel, which allows users to assess and compare data in different countries.



Figure 10. Single Sign-On Support (using Google or Facebook) to view and manage data.

(2) Reusability

Maps of the administrative regions of the world and cancer data were downloaded from the DIVA-GIS website and converted into a GeoJSON format using the QGIS software.

(3) Expandability

This study adopts a data-driven approach. Therefore, new data are easy to update on this platform.

(4) User interactivity

In addition to displaying cancer data via the browser, the interactive web page technology is fully utilized to allow users to control the actions of the map. Users can adjust and display scale and location on the map. They can also visualize spatial patterns of cancer data to better understand the long-term health changes.

(5) Multiscale

This platform provides 2 types of map scale for specific countries and their administrative areas. Overall, the

platform was constructed based on data obtained from administrative regions in 150 countries.

From the perspective of data management, there are several advantages to this approach:

(6) Data integrity

According to the United Nations (UN), 249 countries and regions have been universally recognized, of which 193 are UN member states. In this study, our primary data source was the IARC database. However, it does not have data for every country. For example, of all cancer shown in 2013, data were collected from 66 countries. This accounted for only one-third of the world's countries. This interactive platform is open to data from non-WHO member countries (like Taiwan).

(7) Visualization

The current IARC website mainly presents cancer data in traditional tables and statistical charts. This study presents cancer data of countries in the form of maps, making it easier for researchers to see the spatial distribution.

(8) Decentralization

On this platform, any participant can collaboratively disseminate and maintain cancer data. This makes data production or collaboration easier and more complete.

5. Conclusion

This study used visualization methodologies to present cancer data and allows researchers to jointly maintain cancer data, hence making it more complete. The platform was created using data from administrative regions in 150 countries and serves as a user interface for these countries to manage and share cancer data.

United States - All cancers Cancer

Mortality Incidence Prevalence Survival

New Record

Year	ASR(per 100,000)	CrudeRate(per 100,000)	Death	Source	Function
2013	111.4	196.1	308068	IARC	History
2012	114	196.5	306174	IARC	History
2011	115.8	195.9	302801	IARC	History
2010	118.8	196.8	301656	IARC	History
2009	120.3	195.7	297405	IARC	History
2008	122.9	196.6	295943	IARC	History
2007	124.9	196.8	293538	IARC	History
2006	127	196.8	290759	IARC	History
2005	130.7	198.9	291186	IARC	History
2004	132	198.3	287585	IARC	History
2003	135.3	200.8	288699	IARC	History

Figure 11. Assessment and management of country-level data.

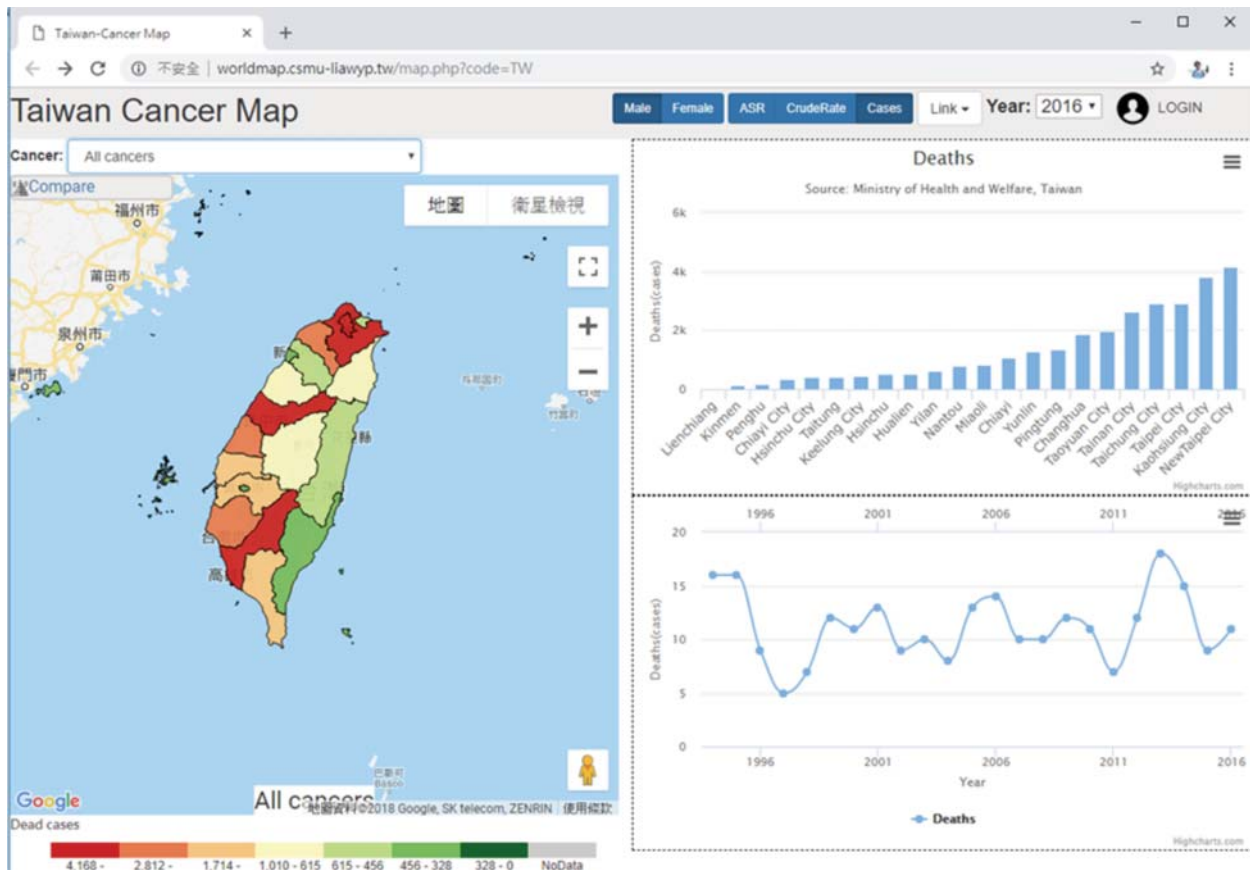


Figure 12. A country-specific cancer map, where Taiwan is used for the purpose of demonstration.

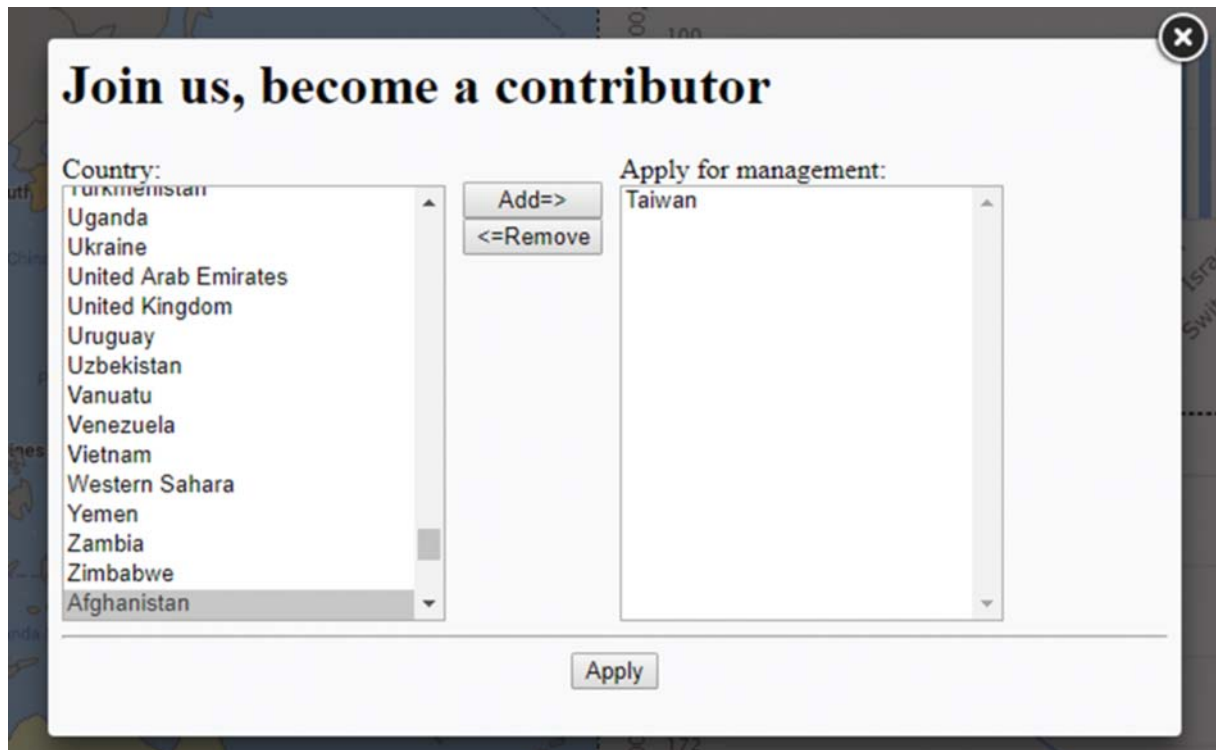


Figure 13. A screenshot showing how a researcher can apply to become a contributor.

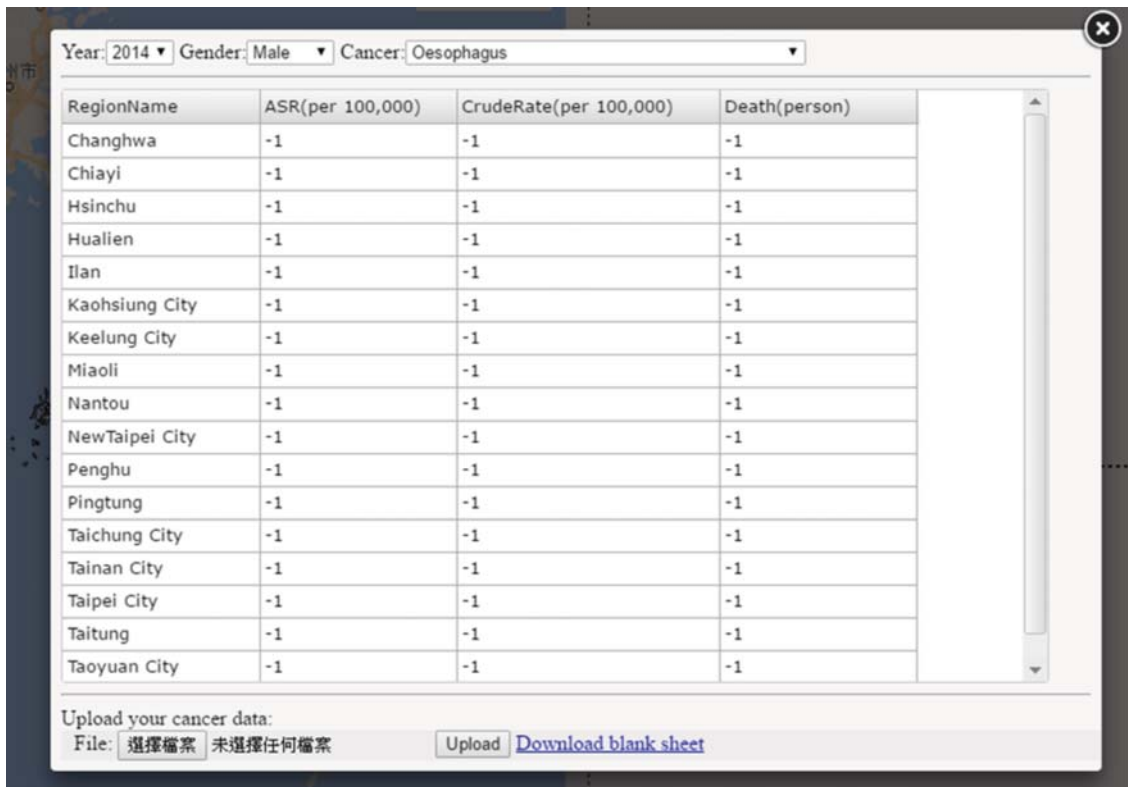


Figure 14. A screenshot showing online maintenance for cancer data.

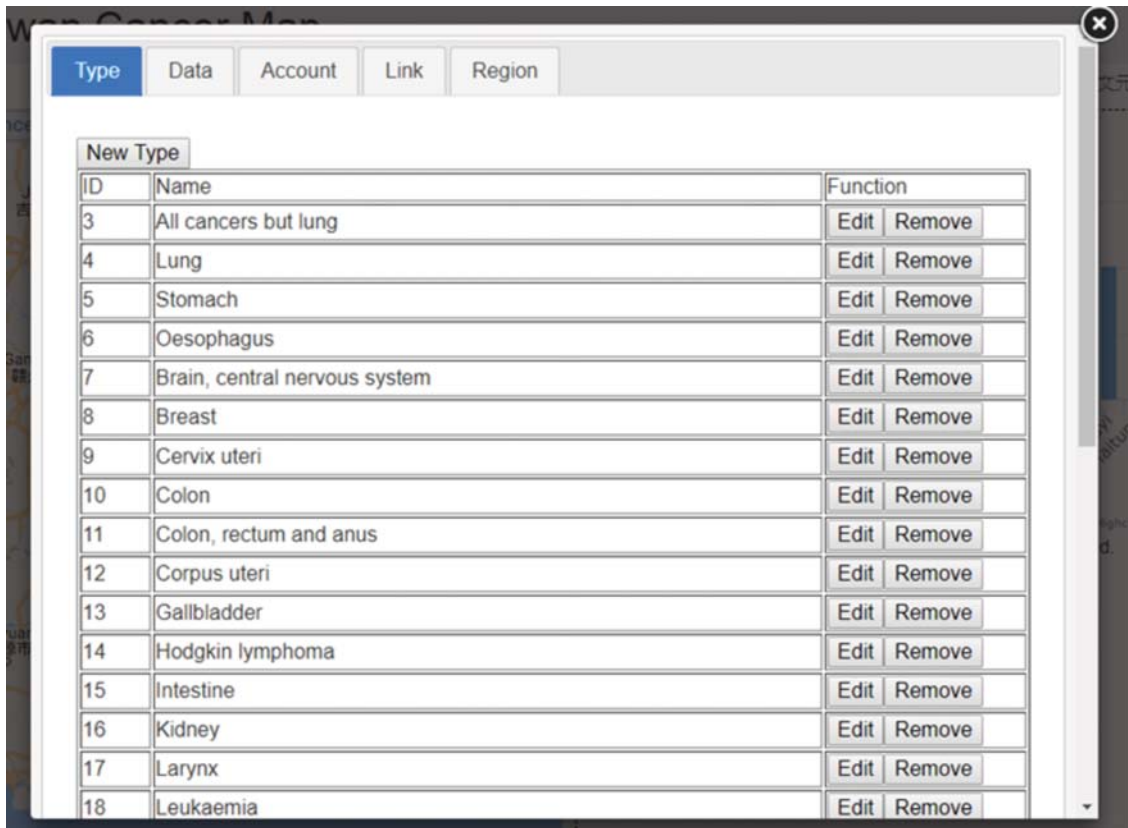


Figure 15. A screenshot showing how administrators can manage and expand the website.

Author contributions

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Writing – original draft: Wen-Yuan Ku.

Writing – review & editing: Oswald Ndi Nfor, Disline Manli Tantoh, Shu-Yi Hsu, Lee Wang, Yung-Po Liaw.

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