Accuracy Assessment on Making Measurements on Web Mapping Services

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ABSTRACT： The modern web mapping services (WMS) not only replace the traditional map for people obtaining the location, distance, and area, but also inspire versatile location-based services (LBS). But how accurate can these measurement achieve? A map is a projection of the Globe which inevitably contains distortions. In addition to the distortions of map projection, there are two types of error included in measurements. One is human error during the process of clicking the point on the monitor; the other is systematic error on web map platforms. To assess the accuracy of measurements, three popular WMS in Taiwan are chosen for the experiments, e.g. Google Earth, ESRI ArcGIS Earth, and Taiwan Electronic Maps. We click points and measure distances on the three WMS and compare each of distance measurement to the same distance calculated by the geodesic formula. The results of experiment shows that the human error is less than 1m, and the distance measurement of every arc degree is less than 2m on all three WMS.

1.INTRODUCTION

Since Google launched their first web mapping service(WMS), Google Maps, in 2005, WMS is very convenience and instinct than traditional maps for common people. More and more people like to use web map, according to the statistics in 2013, 54% of global smartphones users have ever downloaded the Google Maps application at least once. The web company allow individuals to produce and access information from web map, so people can not only make own map by themselves but also share the map into the Internet easily. Expect for producing the map , people can do the measurement on the WMS. But how accurate can these measurements achieve?In this research, we want to understand that the accuracy of measurement on WMS. A map is a projection of the Globe which contains distortions. Kinds of maps are created from different types of projections, and there is different distortion in types of projection. The projection of WMS is Web Mercator which is launched by Google Maps in 2005. Most of the WMS, such as ESRI ArcGIS Online or Taiwan Electronic Maps, all follow the same projection from Google Maps. But how web map distort and the distortion how to make impact when people used ?

Except for viewing the map, more and more people perfer to access the information on the web mapping services.With simple clicks, users can measure the coordinates, distance, or area on the WMS. Every click inevitably contains human errors which could be systematic or random. The distance or area measurement also contains systematic error from the distortion of map projection. To assess the accuracy of measurements, three popular WMS in Taiwan, Google Earth, ESRI ArcGIS Earth, and Taiwan Electronic Maps, are chosen for the experiments.

First ,we compare true value of point coordinates with point average coordinates which we click the same points ten times on Google Earth in order to know the accuracy of point by common people click the point on web map. Second, measuring the same distance ten times in the research area find out the precision of distance. Finally, each of the distance measurement is compared to the distance calculated by the geodesic formula .

2. LITERATURE REVIEW

2.1 Spherical Mercator Map Projection

Spherical Mercator Map Projection is called Web Mercator Projection , Pseudo Mercator or Google projection. EPSG code is 3857 and EPSG call Web Mercator Projection “Popular Visualization Pseudo Mercator(PVPM)”. Since Google launched Google Maps in 2005,web Mercator was adopted as the projection of web map first time.This projection is one of Mercator projection,but it simplify the formula of WGS84 reference ellipsoid which ignored First eccentricity(e).The radius(R) of spherical mercator Map Projection is equal to the semi-major axis of WGS84 ellipsoid. (Zinn, 2010)Although the web mercator treats the earth as a spherical instead of ellipsoidal ,spherical mercator coordinates is equal the WGS84 ellipsoidal datum.As a result,this projection is distortion on the projected Y coordinates(Tsai, 2014)Mediun and higher latiitudes with large distortion and provides an erroneous impression of distances and relative areas. (Jenny, 2012)

2.2 Map Tile

OGC(Open Geospatial Consortium) published OpenGIS® Web Map Tile Service Implementation Standard in 2010.Google was one of first company to proposed the concept of map tiles and the image streaming technology. These regular map tiles are actually cut from the map image based on the Web Mercator Projection. Map tiles is a map displayed in the browser by being made up of a lot of small images.Map tile use the different scales to present the same area,(Fig.1). Comparing with Web Map Tile Service(WMTS) and Web Map Service(WMS), WMTS use web serve that instantly return the result which user need. WMS spend more time on returning the result than WMTS. WMTS considered similar initiatives such as Google Maps, Arc GIS Earth and Taiwan Electronic map. (Chen et al.,2014)

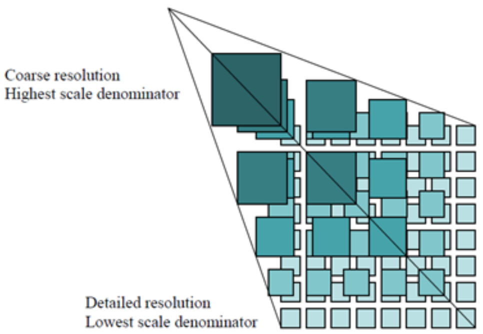

Fig.1 Map tiles in different scales (Chen et al.,2014)

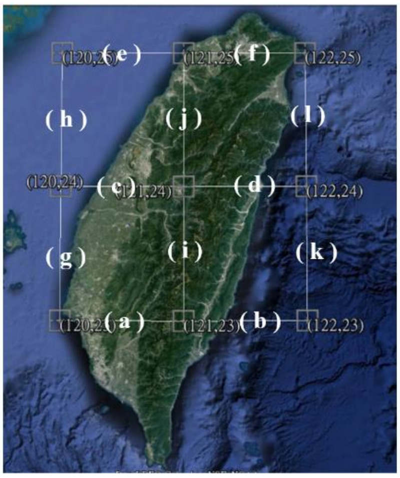

Fig. 2 The range of experiment and the denotion of measurement (on: Google Earth)

3.METHOD

This research area is focused on the Taiwan Island, ranging from 23°N to 25°N and from 120°E to 122°E .Three platforms of web maps that is Google Maps, Arc GIS Earth and Taiwan Electronic map are chosen for this experiment. This research area was given the symbolization from (a) to (l) on the range in order to discuss the results of this experiment quickly (Fig.2). There are 9 points and 12 distances which are measured within this research range. Two measurement errors are studied in experiments. One is human error caused by the clicking process, and the other is the projection distortion and systematic error of the WMTS. To minimize the influence of personal habit, we invited several people to click the same 9 points. The map is zoomed-in to its maximum scale and each point is clicked 10 times. So we can analyze the average and the standard deviation of these 9 coordinates. Then, these average coordinates are used for the 12 distance measurements on WMTS. Each of the distance measurement is compared to the distance calculated by the geodesic formula. The conceptual framework is Fig.3 .

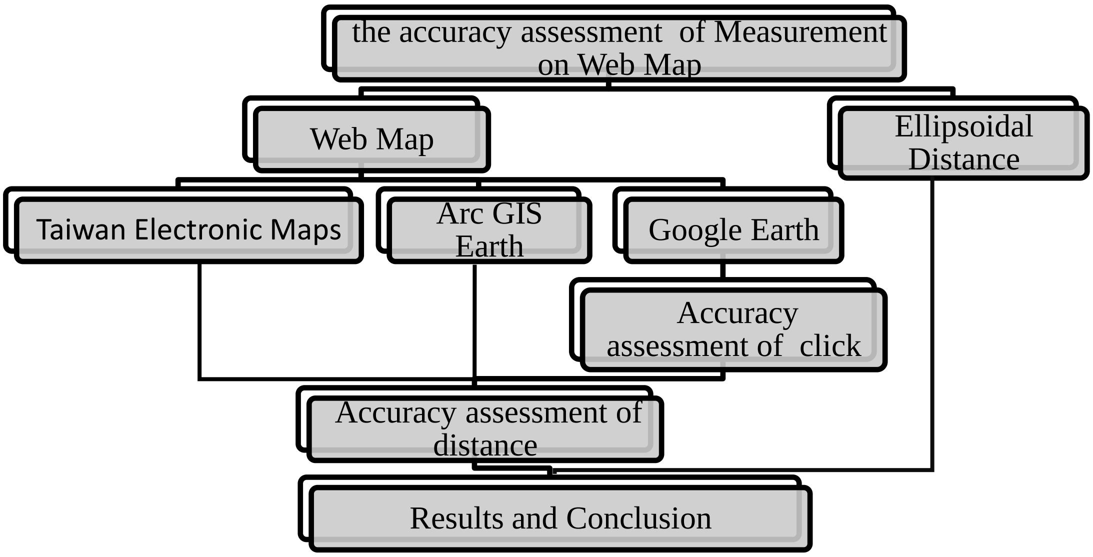

Fig. 3 Conceptual Framework

4.EXPERIMENTS

4.1 Clicking Points

Google Earth was chosen for the point experiment because the point can be export to KML file and the true coordination of point could be known by opening KML file with code editor. There are 9 points in the research area and participants should do the same method by clicking the 9 points. The map is zoomed-in to its maximum scale and each point is clicked 10 times. When we clicked the point , we found the problem that 22°59’60” is not equaled 23°00’00”(Fig.4). There is the same problem on ArcGIS Earth.

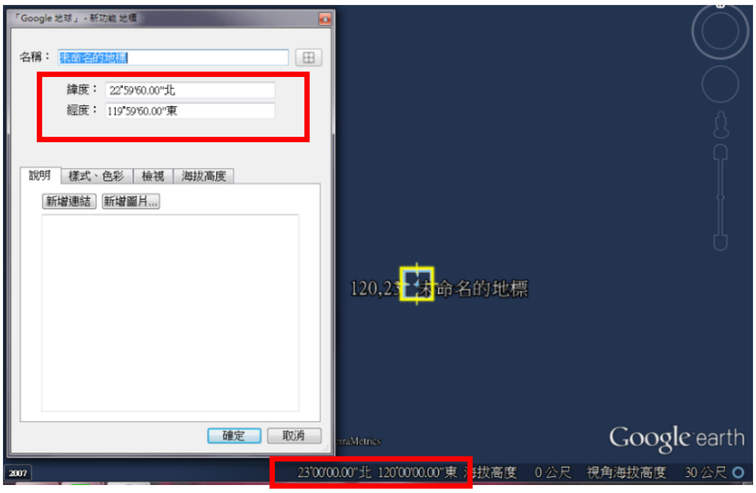

Fig. 4 The problem of Google Earth while clicking point. The latitude and longitude on the up left columns are not exactly as same as the below.

The participants were required to click the point of latitude 23°N and longitude 120°E for 10 times. They clicked while their cursor were mostly approach the value of 23°N and 120°E, according to the number Google earth displays. The clicked coordinate is hardly to be the same as the true value according to KML file. The average value of the 10 clicks were used to compare with the true value. Every points and the average are plotted in Fig.5. In this experiment, there are the same pattern on 9 coordinates scatter plot. All average fall into the first quadrant of the scatter plot. To minimize the influence of personal habit, we invited several people to click the same 9 points. So we can analyze the average and the standard deviation of these 9 coordinates. The results from different people all show the same deviation. Almost all points fall in the first quadrant of scatter plot, which could be considered as systematic error.

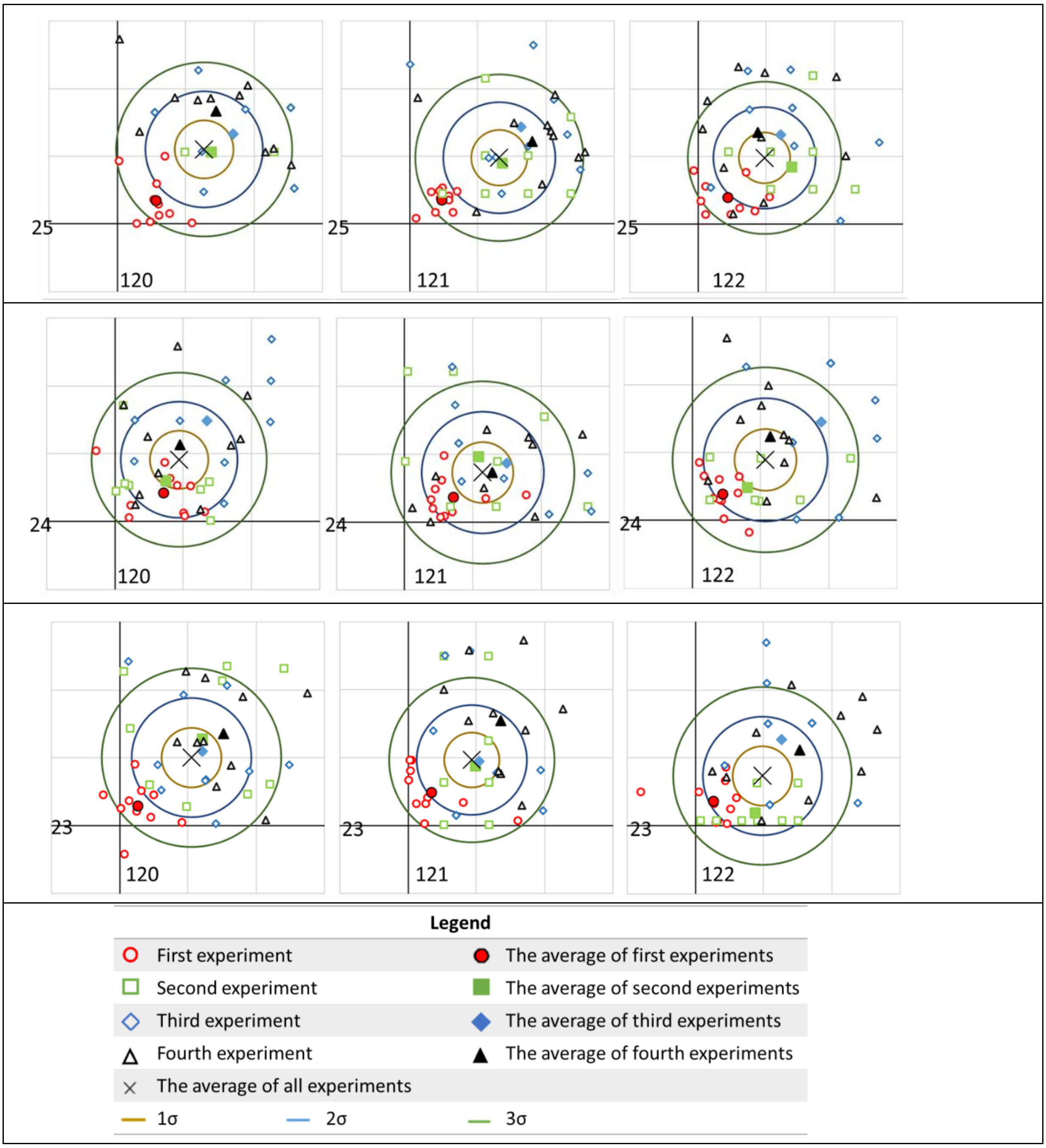

Fig. 5 The Scatter Plot results from the ten clicks

4.2 Measuring Distances

4.2.1 Precision of Distance

The distance measurement contains systematic error from the distortion of map projection. To access the accuracy and precision of measurements,three WMS in Taiwan, Google Earth, ArcGIS Earth, Taiwan Electronic Maps are chosen for the experiments. Measuring 12 distances ,the map is zoomed-in to its maximum scale , turn off all unnecessary layers and each distance is measured 10times in the research area. To construct the histogram, each distance calculate the average distance,and each times distance minus the average distance. The width of a class interval in a histogram will be approximately equal the number standard deviation of these 12 distances,0.5m,on ArcGIS Earth and Taiwan Electronic Maps. Almost difference numbers of Google Earth are less than ±0.5m,we adopted 0.05m as class interval on Google Earth. The pattern of Google Earth histogram almost distribute Bell Curve, but symbol (i) and (j) distribute on random(Fig.6). The longitude of two distances is 121°E that is almost mountain terrain in Taiwan. The pattern of ArcGIS Earth histogram almost distribute random, but (e),(f),(g),(h),(k),(l) distribute on central tendency(Fig.7) Six distances are located on ocean or flat terrain. The accuracy of ArcGIS Earth can achieve millimeter, but we cannot turn off the 3D terrain when we measured. All measurement distances measured above the 3D terrain, so the measurement precision of distance is very dispersion. The pattern of Taiwan Electronic Maps histogram almost distribute bell curve, but the accuracy only can achieve meter (Fig.8).When we measured the distance on Taiwan Electronic Maps, the results of distance usually are same number or difference within 1 meter.

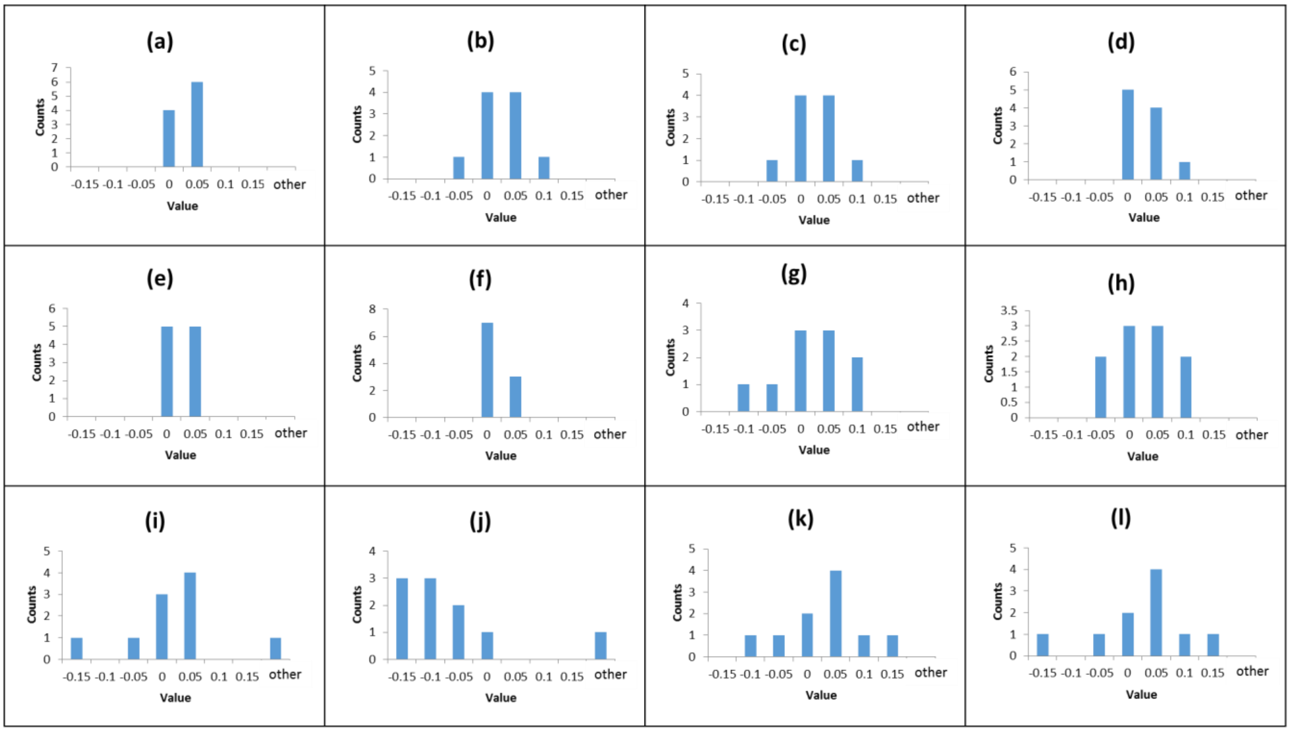

Fig.6.Google Earth Histogram

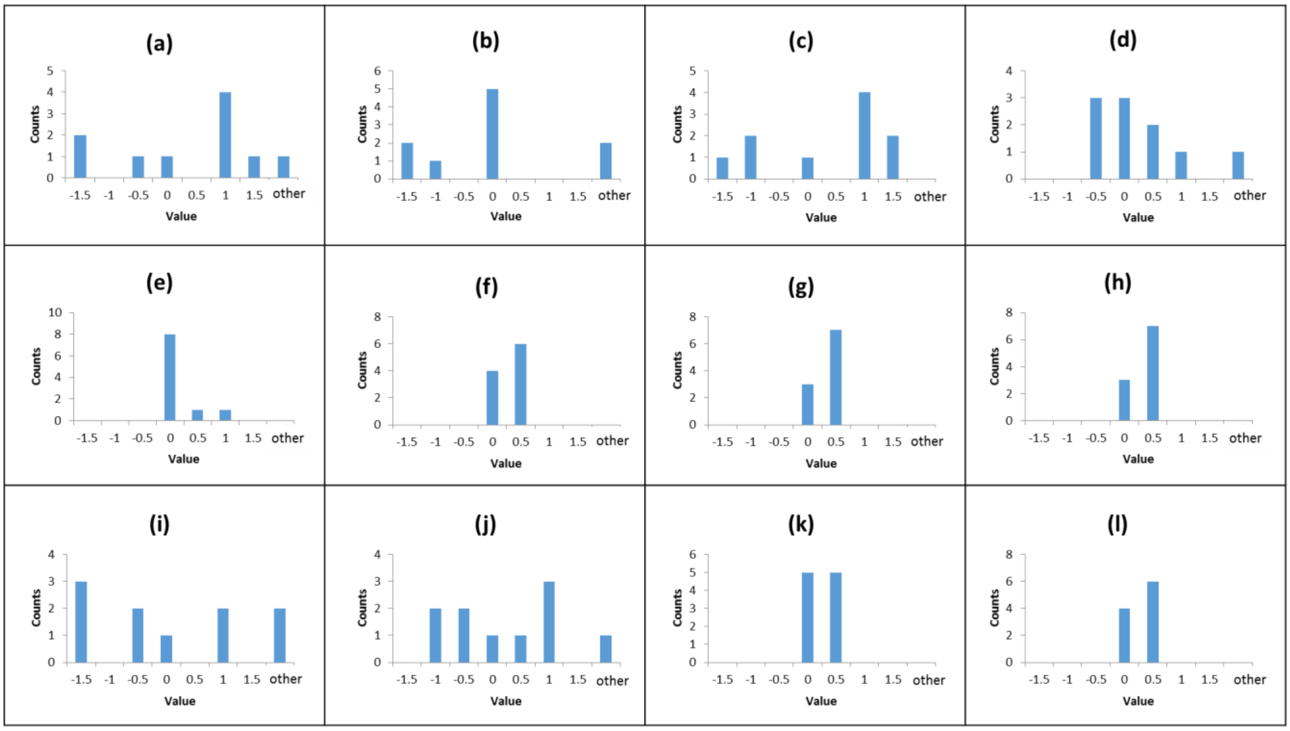

Fig.7 ArcGIS Earth Histogram

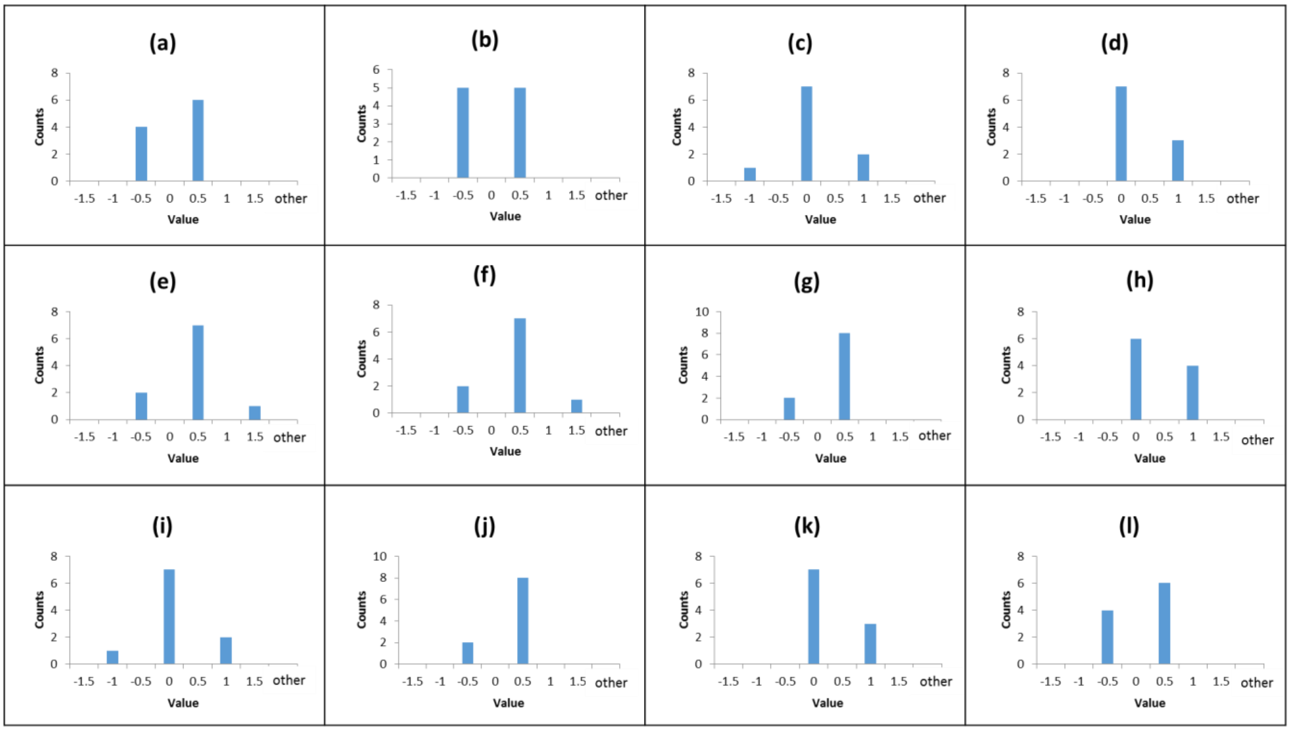

Fig.8 Taiwan Electronic Maps Histogram

4.2.2 Accuracy of Distance

The shortest distance between two points on the ellipsoid is called Geodesic. Except for measuring the distance in the research area, each of the distance measurement is compared to the distance calculated by the geodesic formula. .We calculated the same 12 distances by the geodesic formula which Australian Government-Geoscience Australia offer. (http://www.ga.gov.au/geodesy/datums/vincenty_inverse.jsp) There are the value of 12 average distances measurements on three WMS and ellipsoidal distance. (Fig.9) Each ellipsoidal distance minus each measurement distance in order to understand the measurement accuracy of distance for each WMS.(Fig.10) Comparing with the geodesic formula,the distance measurement errors of 1 arc degree is rough 1m on Google Earth.The error is less than 0.5m on Taiwan Electronic Maps. On ArcGIS Earth , the error is less than 1m on flat terrain,the other area that the error is more than 2m.We want to separate human errors and systematic errors, so we export the line to KML file and open KML file with code editor.Finally, we modify the coordinate to the real coordinate and compare with ellipsoidal distance.For example,the error of distance which ranging 23°N and from 120°E to 121°E is 1.093m on Google Earth..The triple standard deviation of 23°N and 120°E is 0.141m. The triple standard deviation of 23°N and 121°E is 0.129m. The systematic error of distance which ranging 23°N and from 120°E to 121°E is 1.097.As a result, the total of the triple standard deviation of two points is less than the systematic error of distance.

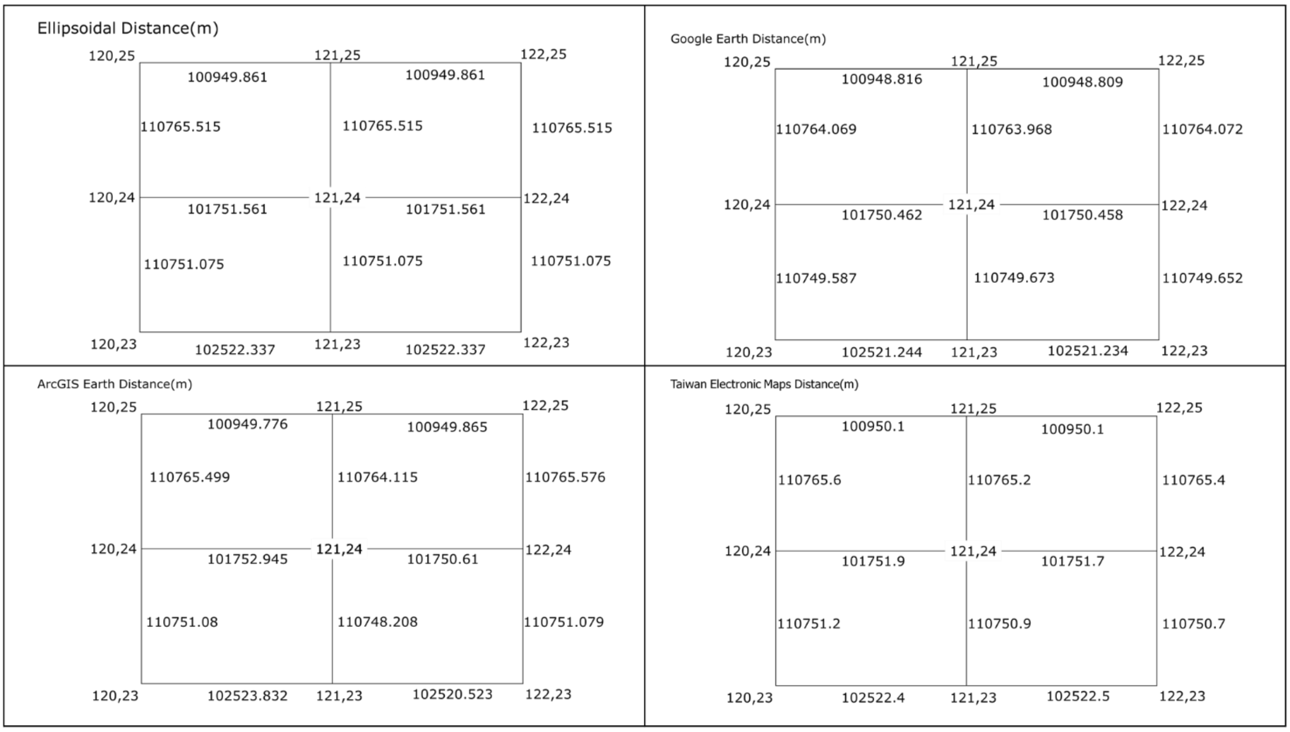

Fig. 9 The ellipsoidal distance and the measurement on the three WMS.

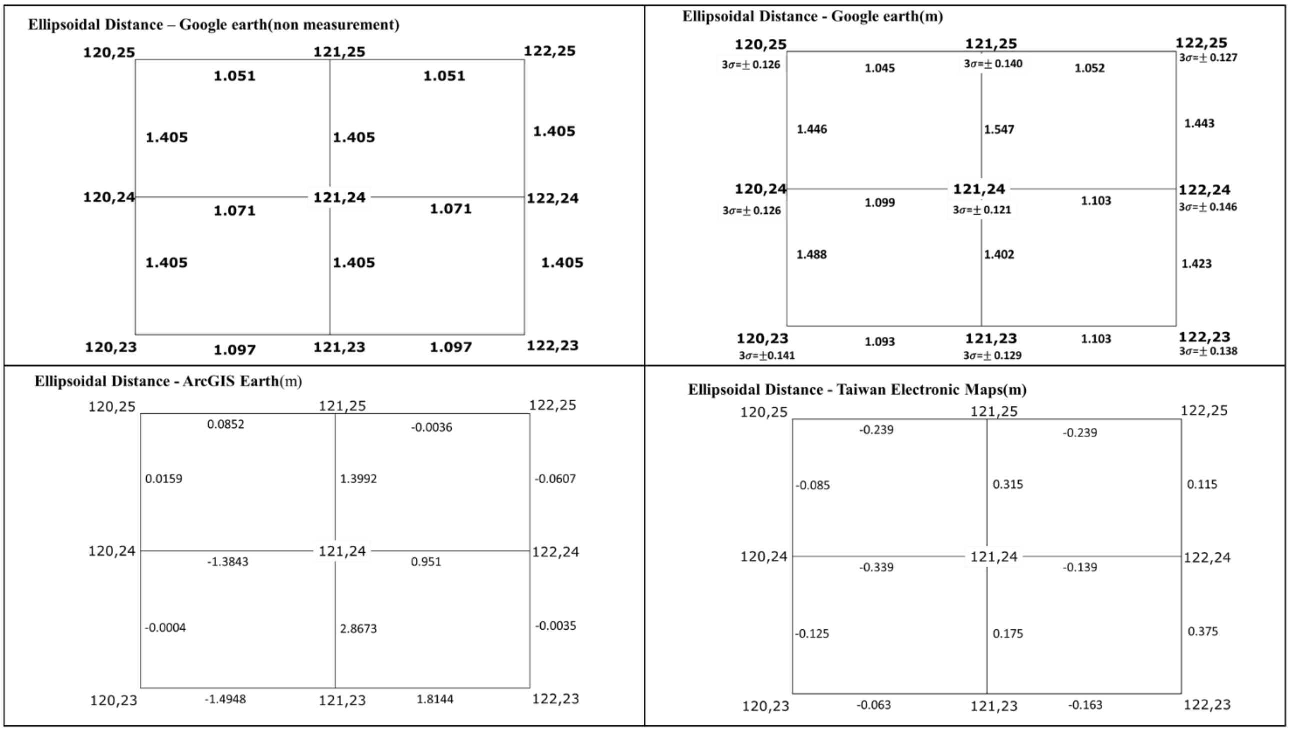

Fig.10 The differences between measurements on the three WMS to the ellipsoidal distance.

5. CONCLUSION

Two measurement errors are included in this experiment, one is human error created by the users during the process of clicking the point on the monitor; the other is projection error and systematic error on web map platforms. The WMS how accurate can these measurements achieve is that the results shows the human error is less than 1m, and the distance measurement of 1 arc degree is less than 2m on all three WMS.The results of each point experiment show that almost points by clicking are in the first quadrant of scatter plot . There is propably systematic error on the Google Earth. Each point is compared with the true value and the error is about .013m .

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