UNIVERSITI PUTRA MALAYSIA

ENHANCING GEOGRAPHIC COORDINATES REPRESENTATION STANDARD FOR REVERSE GEOCODING WEB SERVICES

MOHAMMED MUSTAFA ABDULRAHMAN AL-HABSHI

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By

MOHAMMED MUSTAFA ABDULRAHMAN AL-HABSHI

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MOHAMMED MUSTAFA AL-HABSHI

September 2018

Chairman : Associate Professor Helmi Zulhaidi Mohd. Shafri, PhD
Faculty : Engineering

Reverse-geocoding is Location Base Services (LBS) that supports mobile and web applications. Using a given geographical coordinates, it provides human-readable addresses and other related information. These days, regardless of Geographic Information System (GIS) and Spatial Data Infrastructure (SDI), reverse-geocoding web services provide the backbone of many of web, mobile, and Internet-of-Things (IoT) applications. These developments in Information and Communication Technologies (ICT) founded standardization diversity, where differences between web services providers and organizations committees, such International Standardization Organization (ISO) and Open Geospatial Consortium (OGC). This research interest in ISO6709 "standard representation of geographic point". The standard provides guidelines in term of geographic point location representation. While its main concern in having a constancy in data exchange, it lacks providing the basis of decimal degrees digits precision quality measurement. The digit precision has been mentioned in the ISO6709, but the basis of geospatial precision was not mentioned. In addition, the standard doesn't provide guidelines related impact of precision quality on data storage and internet bandwidth, where the majority of coordinates' format is text. Therefore, further effective standardization is in need. The research approach to tackle the precision quality of decimal degrees by utilizing European Petroleum Survey Group (EPSG) dataset of Coordinate Reference System and use it to identify the effect of rounding decimal digits in a metric measurement. The research developed a standardized Intuitive Geospatial Relational Query Model (IGRQM) that can be used to determine latest unique Coordinate Reference System (CRS) for a single geographic point. The IGRQM contains of 3341 spatial features with 6526 CRS and was used within a geospatial query process and tested against 100 generated and distributed geographic points with addresses around the globe, where the decimal digits are between 10 and 14. The development process was exploration research to discover patterns of non-unique CRS through qualitative analysis and embed them as rules of CRS exclusions in the IGRQM. The results were each of the 100 generated points have a single latest metric unique CRS, where the distinctive count of CRS is 93. The 100 points with their CRS were used to measure the

impact of decimal digits rounding on metric distance. These measurements summary was validated with World Geodetic System (WGS) 1984 spheroid results. Although the difference doesn't show high variation, the research findings provided an evidence and a method that respect and consider counties developed CRS. In addition, a simple table as guidelines was developed to show the bytes size of the decimal digit in scaling. Benchmarking the guidelines found the data is maintained within about 68% ± 1% of the original size without any algorithm compression. This study provides some basis for consideration when addressing geographic standards rather arbitrary.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
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MENINGKATKAN PIAWAIAN PERSEMBAHAN KOORDINAT GEOGRAFI UNTUK PERKHIDMATAN WEB PENGEOKODAN TERBALIK

Oleh

MOHAMMED MUSTAFA AL-HABSHI

September 2018

Pengerusi : Profesor Madya Helmi Zulhaidi Mohd. Shafri, PhD
Fakulti : Kejuruteraan

Pengekoda belakang adalah perkhidmatan berasaskan lokasi (LBS) yang menyokong mudah alih dan web aplikasi.Dengan menggunakan koordinat geografi yang telah diberi, ia menyediaka alamat-alamat yang boleh dibaca manusia dan maklumat lain yang berkaitan.Pada masa sekarang, tanpa mengira Sistem Maklumat Geografi (GIS) dan Infrastruktur Data Spatial (SDI), perkhidmatan web pengekoda belakang menyediakan tulang belakang banyak aplikasi web, mudah alih dan IoT. Perkembangan-perkembangan dalam teknologi maklumat dan komunikasi (ICT) ini berasaskan kepelbagaian piawaian, di mana perbezaan antara pembekal-pembekal perkhidmatan web dan organisasi Jawatankuasa seperti Organisasi Piawaian Antarabangsa (ISO) dan Konsortium Geospatial Terbuka (OGC). Penarikan penyelidikan ini dalam ISO6709 " perlambangan piawai titik geografi". Piawaian ini menyediakan panduan dari segi perlambangan lokasi titik geografi. Manakala kebimbangan utama perlambangan lokasi titik geografi dalam memiliki penukaran data yang berterusan, ia terdapat kekurangan dalam menyediakan asas ketepatan pengukuran kualiti dalam digit darjah perpuluhan. Ketepatan digit telah disebutkan di dalam ISO6709, tetapi ketepatan bagi dasar geospatial tidak disebut. Tambahan pula, piawaian tersebut tidak menyediakan garis panduan yang berkaitan dengan kesan kualiti ketepatan pada data simpanan dan internet jalur lebar, di mana majoriti format koordinat adalah dalam bentuk teks. Oleh itu, standardisasi yang lebih berkesan adalah amat diperlukan. Pendekatan penyelidikan ini adalah untuk menangani kualiti ketepatan bagi darjah perpuluhan dengan menggunakan dataset Kumpulan Tinjauan Petroleum Eropah (EPSG) dari Menyelaras Sistem Rujukan (CRS) dan menggunakannya untuk mengenal pasti kesan bundaran digit perpuluhan dalam ukuran metrik. Kajian ini telah menghasilkan intuitif Geospatial hubungan pertanyaan Model (IGRQM) yang boleh digunakan untuk menentukan CRS unik yang terkini untuk satu titik geografi. IGRQM mengandungi 3341 ciri-ciri spatial dengan 6526 CRS dan telah digunakan dalam proses pertanyaan geospatial dan diuji dengan menggunakan 100 titik geografi yang telah dijana dan titik-titik geografi bersama alamat yang telah diedarkan di seluruh dunia, di mana digit perpuluhannya adalah di antara 10 dan 14. Proses penghasilan adalah peneroakaan penyelidikan untuk mengetahui pola-

pola CRS yang tidak unik melalui analisis kualitatif dan menerapkannyasebagai peraturan pengecualian CRS dalam IGRQM ini. Keputusan di mana setiap 100 titik yang dijana mengandungi satu metrik CRS unik, di mana kiraan CRS yang tersendiri adalah 93. 100 titik dengan CRS mereka telah digunakan untuk mengukur kesan ke atas bundaran angka perpuluhan pada jarak metrik. Ringkasan daripada pengukuran-pengukuran ini telah disahkan dengan menggunakan keputusan spheroid Sistem Geodetik Dunia 1984 (WGS84). Walaupun perbezaannya tidak menunjukkan perubahan yang tinggi, hasil penyelidikan ini telah menyediakan bukti dan kaedah yang menghormati dan mempertimbangkan daerah-daerah yang telah membangunkan CRS. Di samping itu, satu jadual mudah sebagai panduan telah dihasilkan untuk menunjukkan saiz bait angka perpuluhan dalam bentuk skala. Penanda aras bagi panduan telah menunjukkan data tersebut adalah sama dalam kira-kira 68% ± 1% daripada saiz asal tanpa sebarang pemampatan algoritma. Kajian ini menyediakan beberapa asas untuk dipertimbangkan apabila mengalamatkan piawaian geografi dan tidak melakukannya secara sewenang-wenangnya.

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Helmi Zulhaidi bin Mohd Shafri, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Noordin Ahmad, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Abdul Rashid bin Mohamed Shariff, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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LIST OF ABBREVIATIONS

ADT	Abstract Data Types
API	Application Programmable Interface
BIM	Building Information Model
CGI	Common Gateway Interface
CRS	Coordinate Reference System
DHCP	Dynamic Host Configuration Protocol
EPSG	(European Petroleum Survey Group) standards for coordinate reference system
EIF	European Interoperability Framework
G2C	Government Service To Citizen
GCI	Geocode Certainty Indicator
GIS	Geographical Information System
GNSS	Global Navigation Satellite System
GPL	General Public License
GPS	Global Positioning System
GUI	Graphical User Interface
HTTP	Hyper Text Transfer Protocol
HTTPS	HTTP secured
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
IGRQM	Geospatial Relational Query Model
INSPIRE	Infrastructure for Spatial Information in the European Community
IP	Internet Protocol
ISO	International Standardization Organization
ISO/AWI	ISO Approved Working Item

ISO/CD	ISO Committee Draft
ISO/DIS	ISO Draft international Standard
ISO/WD	ISO working Draft
ISO/TC	ISO Technical Committee
ISO/TR	ISO Technical Report
LBA	Location Based Application
LBS	Location Based Services
LD	Linked Data
LDW	Linked Data Web
LCBS	Location and Context-Based Services
LGPL	Lesser General Public License
LOC	Line Of Code
OASIS	Organization for the Advancement of Structured Information Standards
OGC	Open Geospatial Consortium
OMA	Open Mobile Alliance
ORDBMS	Object Relational Database Management System
OS	Operating Systems
OSGeo	Open Source Geospatial Foundation
OSS	Open Source Software
OWA	Ordered Weighted Averaging
OWL	OWL Web Ontology Language
MOSS4G	Mobile Open Source Software for Geoinformatics
MRDB	Multi Representation database
NWIP	New work item proposal
PHP	Hypertext Pre-processor (a web programming Language)
POI	Point Of Interest

RDBMS	Relational Database Management System
RDF	Resource Description Framework
REST	Representational State Transfer
RSO	Rectified Skewed Orthomorphic coordinate system
SDI	Spatial Data Infrastructure
SQL	Structured Query Language
SRID	Spatial Reference IDentifier
SRS	Spatial Reference System
TCP/IP	Transfer Control Protocol / Internet Protocol
TOCG	ISO/ TC211- OGC coordination group
UML	Unified Modelling Language
UPU	Universal Postal Union
URI	Unified Resource Identifier
URL	Unified Resource Locator
US FGDC	United State Federal Geographic Data Committee
UTM	Universal Transverse Mercator coordinate system
VGI	Volunteered Geographic Information
W3C	World Wide Web Consortium
WGS84	World Geodetic System 1984 coordinate system
XML	eXtensible Markup Language
XSD	XML Schema Definition
$\forall$	for all; for any; for each
$\Rightarrow$	implies

CHAPTER 1

INTRODUCTION

1.1 Background

Within the last decade, Location Based Services (LBS) have seen rapid development in both web and mobile technologies, (Ahson & Ilyas, 2011; Brimicombe & Li, 2009; Gartner & Ortag, 2011; Gartner & Rehrl, 2008; Karimi, 2013; Kolodziej & Hjelm, 2006; Krisp, 2013; Küpper, 2005; Schiller & Voisard, 2004; Uhler & Mehta, 2013).

To encourage Location-Based Application (LBA) development and utilize location-aware sensors, mobile systems vendors and LBS providers announces competitions hoping for wider adoption of the technology. Nowadays, researchers in LBS have extended the research to include social network and augmented reality hoping to understand users behaviours and to widen applications variates (Brimicombe & Li, 2009; Gartner & Ortag, 2011; Gartner & Rehrl, 2008; Karimi, 2013; Krisp, 2013; Uhler & Mehta, 2013). However as researchers try to find new challenges in augmenting LBS technical aspects and adoption in these days community and technology vendors, there is limited research on quality issues of geospatial web-based data sources of these services have been granted publicly (Brimicombe & Li, 2009; Gartner & Ortag, 2011; Goldberg, 2013; Krisp, 2013; Uhler & Mehta, 2013).

Quality issues and measurement still have ambiguity. The ambiguity includes issues of accuracy, precision, coverage, missing data, in-correctness, fitness-for-user and improper definition metadata. Though it seems these data and metadata are a machine generated, its issues of ambiguity are mostly human error made, and therefore they are known as under-reporting.

Under-reporting is not new to researchers and investigators where a lot multiple disciplines of science and research publications mentioned it as issues in data collection and statistical analysis. It effects statistical analysis that is required to provide an evidence of phenomenon or fact existence. Such evidence assist decision makers, planners and strategists in selecting the right choice, and standardized the resources and the path for a national development. In this context, decision makers and planners that make use of LBS are casual mobile phone and internet users that use theses service in their daily life; therefore, it impacts on the public.

Reverse-Geocoding service is one the core LBS services that is based on the request-response, also known as request-reply and messaging pattern. It requires spatial data with attributes to extract textual address. The data, either licensed or public domain, are being served by web services providers. However, programmers and users use information

from these providers as an authoritative source without knowing the correctness of the information. The problem can be realized when switching from one service provider to another; as result, for a single point, one provider's Reverse-Geocoding service has many differences from the other. The standardization effort of reverse-Geocoding Services was addressed by Open Geospatial Consortium (OGC) as core service of OpenGIS® Location Service (OpenLS); however, the standards cover the service quality aspects and not the data. These cases need a study to provide a standardized solution.

1.2 Justification

A lot of people these days uses internet web and mobile connected devices to access information that supports their daily life activities. However, they are not aware neither concern of some errors and missing data as they use it by casual means. In contrast, mobile and web application developers link particular parts of data from different sources that present an application model to deliver information of interest to end-users the case of LBS nowadays, the link starts with one of location-awareness enabling technologies connected to reverse geocoding service and further to the application model.

Reverse geocoding services depend on spatial data; and if it is different in content and metadata, it may lead to wrong addresses; within the application model, and it may mislead the end-users with a different direction. Until this study, there are sparse researches and publications on errors in reverse geocoding services this study as under-reporting.

1.3 Problem Statement

Public reverse geocoding web services for LBA and LBS have received acceptance of majority of web and mobile developers, as it is believed that its data quality and current standards (de jure and de facto) is sufficient for LBA and LBS development with its readable representation models (Lisboa-Filho et al., 2013; Krisp, 2013; Yue, 2013; Kresse et al., 2012; ISO/TC 211, 2009).

Though Reverse-Geocoding with its aspects (request and response) was addressed in OGC OpenLS standard with XML schema template, however, the representation models of data were not meant for automated computer processing as in Semantic web (Knapena et al., 2013). In addition, a computer could not resolve address ambiguity it requires more data collection and effort from the programmers, which is inefficient (Gaitanis and Winter, 2014; Garcia-Rojas et al., 2013; Knapena et al., 2013). Aspect of address presentation, abbreviations, incomplete data and granularity of dataset provide an obstacles in providing quality data (Dang et al., 2013; Zandbergen et al., 2012; Goldberg, 2010; Behr, 2010) .

These limitations provide prevent of having seamless integration with other services. Where such technological trends such semantic web and Internet of Things (IoT) requires data and devices to be inter-linked seamlessly (Behkamal, 2014; Fetahu et al., 2014; Assaf and Senart, 2012).

The effectiveness of quality control on request and response were ignored leaving it as user's preference with limited of guidelines, especially for public services till year 2018 (Mabrouk, 2008). For example, coordinates presentation was addressed in ISO 6709:2008, it didn't provide guidelines nor refer to other established standard (ISO/TC 211, 2008a), where geo-precision is either overused and underused by users (Nelson, 2013; Loohuis, 2010), and optimizing its digits needed for tuning data storage and transaction (Nelson, 2013; Harding, 2006; Vauglin, 2002). Though coordinates geo-precision accuracy was determined for distances measurement, (Wikipedia, 2015; Nelson, 2013; Bessel et al., 2010; Cook, 2008), based on WGS84 datum and oblate spheroid earth model (Acree, 2014; Bénard, 2014), local and governmental authorities still prefer using national coordinate system (Wang, 2013; Dima and Covaciu, 2012).

The standardization of geo-precision for public reverse geocoding web service requests, thus, requires accuracy comparison between spheroid model and latest developed national coordinate system, where its development progress varies from one region to another and selection criteria are heterogeneous. The solution to these issues requires improving reverse geocoding web service aspects standards (request and response). The request aspect requires guidelines in tuning geo-precision considering WGS84 and national projected coordinate system; whereas, the response requires dynamic representation models with linked data that consider national jurisdictions divisions.

1.4 Research Aim

From the problem statement point of view, it is clear the main objective is to improve a standard for reverse geocoding services aspects for a street level quality. The standard should be able to address possible aspects of under-reporting issues with concerns of coordinates precision and differences of administrative jurisdiction divisions' representation. To do so, it is required to define research questions that can quantify aspects of reverse geocoding.

1.5 Research Questions

Therefore, the questions are as follows:

1. What is the specific relation between reverse geocoding web services, ISO6709 and OGC OpenLS?

2. What are the possible difference in metric distance measurements between spheroid earth model and any national coordinates system based on geo-precision to justify in reverse-geocoding web service?

3. How to measure decimal degrees digit precision having variation of multiple CRS?

4. What is the relationship between decimal degrees digit precision quality, and data size (storage and internet transition)?

From these questions, and to answer them, specific objectives are addressed in the next section.

1.6 Objectives

The research aims and questions address specific objectives that should be achieved in this research as follows:

i) To develop and standardized an Initiative Geospatial Relational Query Model (IGRQM), dataset and process, for determining latest unique metric Coordinate Reference System (CRS) for a single geographic point.

ii) To develop an algorithm for generating random bounded sample points by valid address to be tested with IGRQM, where each point must have one CRS.

iii) To measure decimal degrees precision accuracy based on Multiple CRS and rounding digits, validate the results against WGS 84 decimal degrees precision and benchmark the data size of the geospatial textual file.

1.7 The Knowledge Gap and Research Contribution

Such research questions may lead to defining standards specifically for Reverse-Geocoding since some of them is based on weak compromise without conformance testing (Cooper, 2012; Kresse et al., 2012). In this regards, OGC OpenLS –Location Utility Service standard have shortage where its basis are made upon use case scenarios; in addition, the technical aspects focus on Extendable Markup Language (XML) and its derivatives.

1.8 Research Scope and Limitation

The research tries to investigate issues of address model in two-dimension coordinates, as well outdoor geocode. Three-dimensional coordinates and indoor geocode requires more detailed data, handling privacy topics and possible integration with Building Information Model (BIM), which is out of the scope of this research.

The data collection of addresses are made using public geo-web services providers. Though it is possible to employ Volunteered Geographic Information (VGI), setting up the platform and handling unresolved issues of quality and reliability imposes challenges of validation, correction and verification which is out of the scope.

1.9 Thesis Layout

This thesis is organized in five chapters: Introduction, Literature Review, Methodology, Results and discussion, and conclusion. The objectives of this research were explored with some limitations due the nature of the findings. The objectives were addressed in methodology and its outcome were debated in the results and discussion. The last chapter conclude the finding and achievement.

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BIODATA OF STUDENT

His first name is Mohammed, His Father's name is Mustafa and his family name is Al-Habshi. He was born in Aden, Yemen (1974), and raised in Saudi Arabia with his parents. He grew with interest for video games which leaded him to home computers and Basic programming. At his intermediate education, he got a Personal Computer where he practiced system maintenance. After the second gulf war, he returned to Yemen to continue his academic education.

He entered the Engineering Faculty, Sana'a University where he joined Architecture and Urban Design department due to limitation (at that time) of the electronic engineering and popularity of Architecture in Yemen. After graduation, he tried to find a job; however, the unemployment was the common case in Yemen. He gave computer course in private institutes.

He tried to obtain scholarship through Ministry of Planning and Development (MPD) in Yemen, where he found a vacancy of contractor supervisor for computer network in-building implementation. He worked with MPD where he also worked as short-term consultant for the Germen Technical Cooperation (GTZ) and later he works for advisory Service for the ministry (AS-MPD), a project funded and supported by UNDP.

At his work with MPD, he obtained two certificate of enterprise networking. Also, his awareness has grew of finding free and cheap alternatives of commercial software for developing countries information technology infrastructure implementation have raised, where he found open-source software provide the suitable solution for such global problem while restricting expenditure internally within the country.

He approaches to continue his Master studies by obtaining the Islamic Development Bank Scholarship, where he found GIS is a new field suite his background in Urban Development. However, his first initial proposal for M.Sc found obstacle in find data resource from Yemen for GIS application, where he found LBS application possible to accomplish for M.Sc. He worked in Malaysia as tutor, software development and integrator in cooperation with RSRC, MIRO, CampusCity institute, CTH technologies, Sarawak Forestry, Wildlife.

He interests lays in 3D modelling and visualization, computer languages, web application and services, databases, distributed mobile computing, engineering computerized methods, communication, e-leaning, wireless sensing and creative design.

LIST OF PUBLICATIONS

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