2.2 Introduction

The efficiency in dealing with geodetic datums, geographic coordinates, areas, addresses, postal codes and map grids directly influence the efficiency of a large variety of services and products: postal/courier services, taxi, emergency services, weather forecasting, environment protection, natural resources management, public works management, transportation network management, travel information services, online and wireless location based services, maps, GPS receivers, street signs, etc. It was not a problem ten years ago for people to use descriptions and street addresses to represent locations because accurate locations were not available or at least very difficult to obtain. Many people did never think of the needs for changes until the introduction of Global Positioning Systems that can display accurate locations immediately everywhere.

Now a handheld GPS receiver can even measure a location to sub-meter accuracy. How exciting it is! However, as seeing the geographic coordinates displayed on GPS receivers, people have realized a serious problem that a pair of geographic coordinates to the resolution of house sizes or one meter requires more than 15 digits that are far too long for people to remember and communicate. These coordinates are nearly useless to our brains.

In order to overcome this problem, many GPS manufacturers add maps into GPS receivers to make the location information understandable. It indeed helps a lot for people to understand where they are, but the real problem is still there.

When people try to communicate their current location displayed on the map of a GPS receiver, they will feel powerless and the only way left will still be a traditional street address or an ambiguous description such as: “I am on Highway 400, about one hundred kilometers north of Toronto.” That has completely lost the meaning of a high resolution GPS receiver.

As wireless technology is getting more advanced, cellphones can directly tell accurate locations, even better than handheld GPS receivers, and many wireless location based services are been introduced. The problem of the inefficiency of geographic coordinates is becoming more and more urgent. The great advantage of a cellphone is its small size that can be easily carried. The small size of a cellphone can't display maps with much detail, and high resolution location can't be clearly shown on such a small map.

The small size of a cellphone also makes the input of characters inconvenient. For all wireless location based services, specifying locations is inevitable, but there is no way for consumers to specify all locations in the world. All they can use is street addresses that are not available in most locations. Not to mention specifying vast locations without addresses, but even the locations with street addresses, people have big problems too because street addresses are very long character strings that take long time to input, and may contain foreign characters that most people don’t know how to input.

As GPS technology is continuously advancing, wrist watches now can have the GPS functionality. Using accurate location information will become as important as using accurate time in our daily lives. With accurate location information available anywhere anytime, people can record all activities and events with accurate time and accurate locations. Since geographic coordinates do not make sense to consumers, a GPS watch must support maps. The tiny watch screen is even more difficult to display maps than a cellphone screen. The inclusion of maps on a wrist watch makes a watch larger, heavier, more expensive and shorter battery life that directly conflict with the main advantages of a wrist watch.

Since geographic coordinates are useless to consumers, all business cards, yellow pages and travel directories just list street addresses. Since street addresses are irregularly distributed, it takes long time and many steps for people to locate a street address on a printed street map. Even when the street is found, the location of the street address remains a great uncertainty. If the street is new and not listed on the street name indexes, the location will never be found on the map.

Since geographic coordinates are inefficient and useless to consumers, printed street maps usually do not have absolute geographic grids. Then, there are no direct connections between the displayed geographic coordinates of a GPS receiver and a street map.

There is also a serious problem in using GIS and mapping software that always need to retrieve maps and search information in given areas. Using geographic coordinates to specify an area requires four long coordinates that are difficult to remember, communicate and input. Using a postal code, a city name or telephone area code to specify an area has problems too: a) not all areas of interest have postal code or names, b) the definitions of postal codes are different in different countries, c) names of cities or towns are language dependent and may contain foreign characters that most people don't know how to input, and d) the mapping from postal codes, area names or telephone area codes requires geographic databases that are not always available.

All these problems of current methods specifying locations and areas have created an urgent demand for a new highly efficient system. The Natural Area Coding System is just the one to solve all the problems.

2.3 Description of the System

The Natural Area Coding System is a new geodetic system to standardize and integrate geodetic datums, geographic coordinates, geographic area codes, map grids, addresses and postal codes in the world. The system employs revolutionary approaches:

- It has unified the concepts of geodetic points, line sections, areas, and three-dimensional regions.
- It employs the 30 most popular characters in the world instead of ten digits and makes full use of these characters to produce the most efficient representations;
- It is defined only on the datum of WGS-84 to avoid any variations;
- It creates one standard and flexible representation for all these geographic units.

These approaches make the Natural Area Coding System superior over traditional systems. A set of coordinates of this system is called a Natural Area Code (NAC) that can represent a point, a line section, an area or a 3D block simultaneously. When representing a geodetic point to the same resolution, it requires only half of the number of characters as required by a longitude/latitude or UTM coordinates. Using NACs to represent line sections, rectangles or three-dimensional regions can save even more in required characters compared with other systems. In addition to all functions of traditional systems, the new system generates Universal Addresses for all locations in the world, Global Postal Codes, Universal Property Identifiers and Universal Map Grids for all kinds of maps in any scales and projections (a Natural Area Code is also called a Universal Area Code; a Global Postal Code is also called a Universal Postal Code).

The Natural Area Coding System has unified all these systems into one simple system and greatly simplifies the communication between different categories of science and engineering, different languages, different countries, different products and different services.

Definition

The Natural Area Coding System is a new geodetic system with its origin defined at the earth gravitation center and axis extending to the infinitely distant universe. It employs a character set consisting of digits 0 to 9 and all English capital consonants since these characters are the most popular characters in the world. Each character in the character set represents an integer ranging from 0 to 29, as shown in the following table:

Table of the NAC Character and Integer Correspondences

Character	Integer	Character	Integer	Character	Integer
0	0	B	10	N	20
1	1	C	11	P	21
2	2	D	12	Q	22
3	3	F	13	R	23
4	4	G	14	S	24
5	5	H	15	T	25
6	6	J	16	V	26
7	7	K	17	W	27
8	8	L	18	X	28
9	9	M	19	Z	29

A Natural Area Code (NAC) consists of three character strings separated by blank spaces. The first character string represents longitude, the second string represents latitude, and the third string represents altitude. The system divides the whole range of longitude (0 - 360 degrees), latitude (0 - 180 degrees) and altitude (from the earth center to the infinite outer space) into 30 discrete divisions respectively, each of which is named by one character from the character set according to the order of the characters. Each resulting division is divided into 30 subdivisions, and each of the subdivisions is named by one character. The division process can continue to the third, fourth, and other levels. The resulting divisions in three dimensions form many three-dimensional regions called NAC blocks. Therefore, a first level NAC block can be represented by a NAC of three characters separated by blank spaces, each of which represents the character string for longitude, latitude and altitude respectively, for example, NAC: 5 6 7. A second level NAC block can be represented by a NAC of six characters to form three character strings: the first two characters form the longitudinal string, the third and fourth characters form the latitudinal string, and the last two characters form the altitudinal string. A blank space is placed between these strings, for example, NAC: JB KH LN represents a NAC block at the second level, in which the characters J, K and L represent coordinates of a first level NAC block which contains the second level NAC block, and the characters B, H and N are the relative coordinates of the second level NAC block in the first level NAC block. A region formed by sides at different division levels is called a NAC region and can be represented by a single NAC too. Any three NAC character strings can form a NAC which represents a completely defined region in the universe.

If the third string of a NAC is omitted, the resulting NAC represents an area on the earth surface, called a NAC area if the number of characters in the two coordinate strings are different, and called a NAC cell if the number of characters in the two coordinate strings is the same. Any two NAC character strings can form a NAC representing a completely defined area on the earth. When the sides are very different in length, a rectangular area will turn out to be a line section automatically. When the sides are relative small, a rectangular area will become a geodetic point.

Therefore, a NAC can represent a geodetic point anywhere in the universe, a line section of constant longitude or constant latitude on the earth, an area bounded by constant longitude and constant latitude anywhere on the earth and a three-dimensional region bounded by constant longitude, constant latitude and constant altitude anywhere in the universe.

The Natural Area Coding System and the World Geodetic System-1984

From (Longitude, Latitude, Altitude) to NAC. The NAC of a region that contains a geodetic point expressed by the longitude, latitude and altitude coordinates in the WGS-84 system can be determined by the following algorithm:

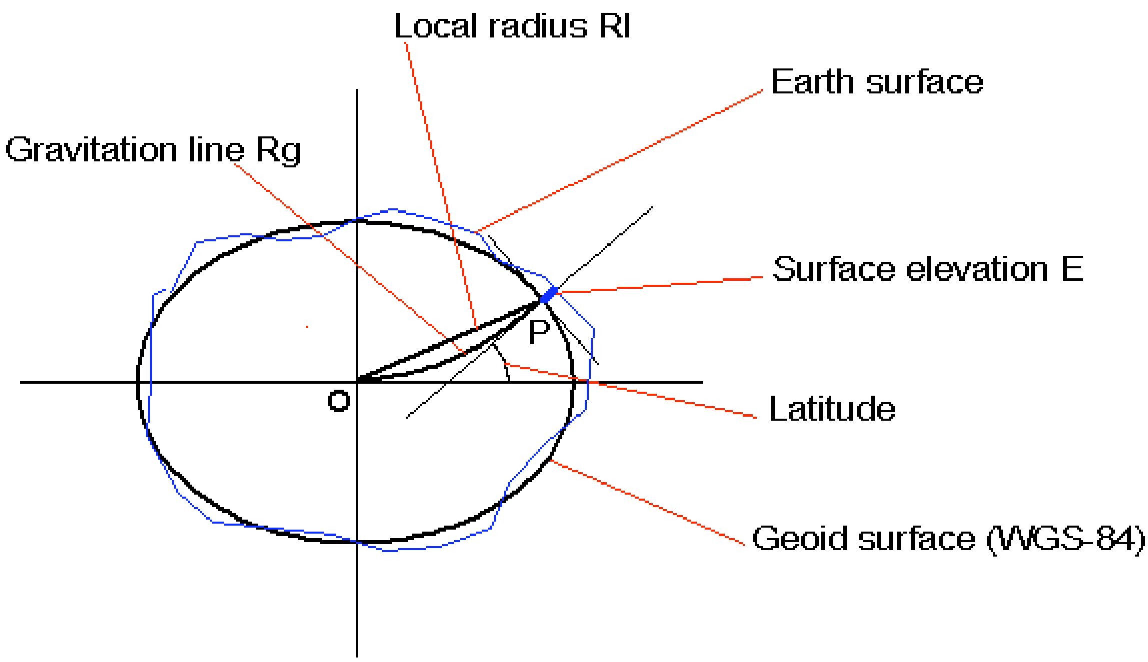
LONG = (Longitude + 180)/360
x_1 = Integer part of(LONG*30)
x_2 = Integer part of((LONG*30-x_1)*30)
x_3 = Integer part of(((LONG*30-x_1)*30-x_2)*30)
x_4 = Integer part of((((LONG*30-x_1)*30-x_2)*30-x_3)*30)
...

LAT = (Latitude + 90)/180
y_1 = Integer part of(LAT*30)
y_2 = Integer part of((LAT*30-y_1)*30)
y_3 = Integer part of(((LAT*30-y_1)*30-y_2)*30)
y_4 = Integer part of((((LAT*30-y_1)*30-y_2)*30-y_3)*30)
...

ALT = Arctan(Altitude/R)/90
z_1 = Integer part of(ALT*30)
z_2 = Integer part of((ALT*30-z_1)*30)
z_3 = Integer part of(((ALT*30-z_1)*30-z_2)*30)
z_4 = Integer part of((((ALT*30-z_1)*30-z_2)*30-z_3)*30)
...

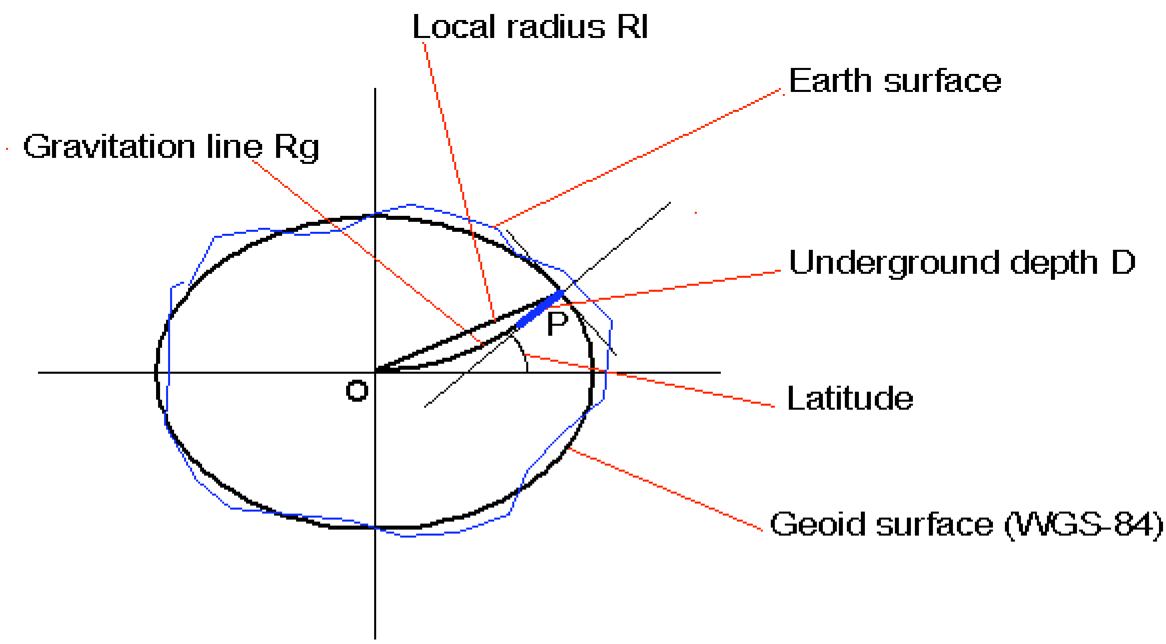
where Longitude is positive in the eastern hemisphere but negative in the western; Latitude is positive in the northern hemisphere but negative in the southern; both Longitude and Latitude are in degrees plus decimals; Altitude is measured along the gravitational force line from the center of the geoid of the earth in kilometers; symbol * is the multiplication sign; x_1, x_2, x_3, x_4, ..., y_1, y_2, y_3, y_4, ..., z_1, z_2, z_3, z_4, ... are integers ranging from 0 to 29 here; Arctan( ) is the arctangent function with value in degrees; R is in km the distance from the earth center along the gravitational force line to the geoid surface and can be approximated by the earth radius at the location:

$$R = \mathrm{sqrt}[b^2 + (a^2 - b^2)/(1+ b^2/a^2 * \tan^2(\mathrm{Latitude}))]$$



Surface altitude = Rg + E ~ Rl + E

Figure 1. Definition of Surface Altitude



Underground altitude = Rg - D ~ Rl - D

Figure 2. Definition of Underground Altitude

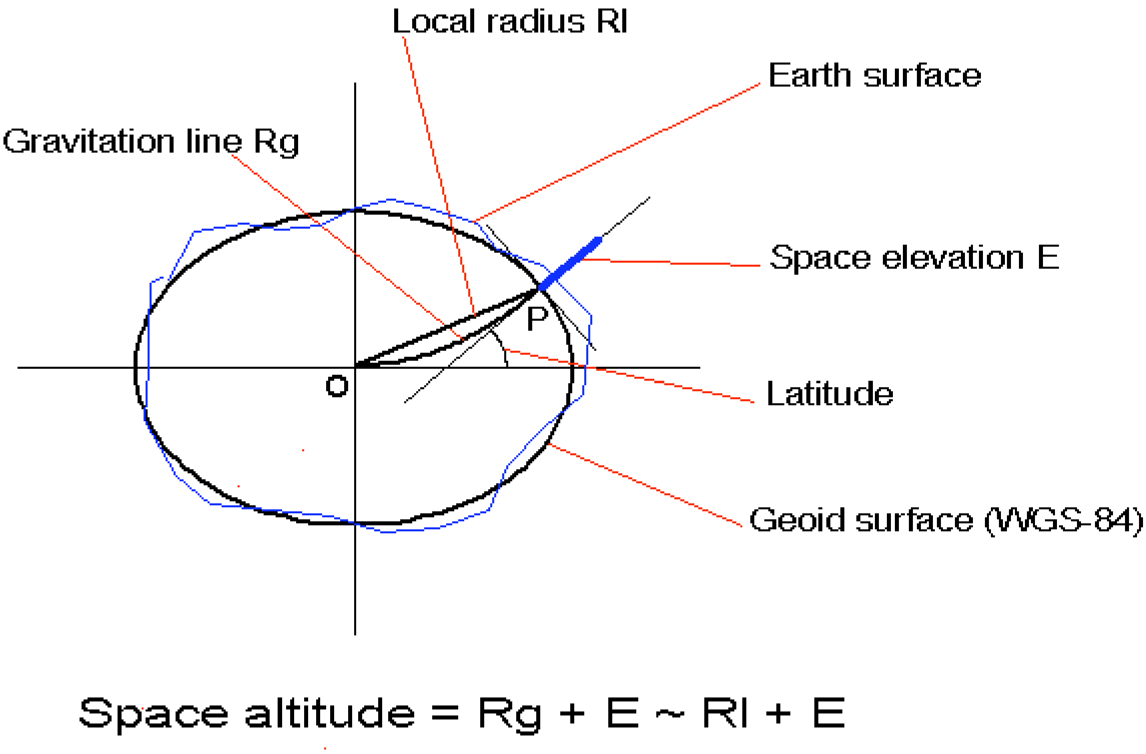


Figure 3. Definition of Space Altitude

or more accurately the distance from the gravitation center to the geoid surface along a parabola passing the gravitation center and perpendicular to the geoid surface:

$$C_1 = [1 - 2*(1 - b^2/a^2)]*\tan(Latitude)$$
$$C_2 = (1 - b^2/a^2)*\tan(Latitude)*\mathrm{sqrt}[a^2 + b^2*\tan^2(Latitude)]/a^2$$
$$C_3 = 2*a*C_2/\mathrm{sqrt}[1 + b^2/a^2*\tan^2(Latitude)] + C_1$$
$$C_4 = C_3*\mathrm{sqrt}(1 + C_3^2) + \mathrm{Asinh}(C_3)$$
$$C_5 = C_1*\mathrm{sqrt}(1+C_1^2) + \mathrm{Asinh}(C_1)$$
$$R = (C_4 - C_5)/4/C_2$$

where a is the semi-major earth axis (ellipsoid equatorial radius) equal to 6378.1370 km; b is the semi- minor earth axis (ellipsoid polar radius) equal to 6356.7523 km; sqrt( ) is the square root function; tan( ) is a triangular tangent function; Asinh( ) is the inverse hyperbolic sine function; symbol / is the division sign.

Once x_1, x_2, x_3, x_4, ..., y_1, y_2, y_3, y_4, ..., z_1, z_2, z_3, z_4, ... are calculated, the corresponding characters can be found from the Table of the NAC Character and Integer

Correspondences: X_1, X_2, X_3, X_4, ..., Y_1, Y_2, Y_3, Y_4, ..., Z_1, Z_2, Z_3, Z_4, ... Then, the Natural Area Code of the region is written as:

NAC: $X_1X_2X_3X_4$... Y1Y2Y3Y4... $Z_1Z_2Z_3Z_4$...

with a blank space between any two character strings. The first character string of a NAC represents longitude, the second string represents latitude, and the third represents altitude.

If a NAC has only two character strings, then the NAC represents an area on the earth surface and the two character strings represent the longitude and latitude respectively, as defined in the beginning of this chapter. For example, NAC: 8KD8 PGGK represents a 25 by 37 meter area in White House; NAC: 8KD8 PGGK H000 represents a region 25 meters wide, 37 meters long and 25 meters high measured from the geoid surface under White House.

The number of characters to be used in a character string of a NAC representing the geodetic point is determined by the required resolution or the resolution of the original coordinates of the longitude, latitude and altitude. A NAC using more characters represents a smaller area or region. The smallest area or region containing the geodetic point is the one of the size equal to the error range of the coordinates. Therefore, when a NAC is used to represent a geodetic point, it contains the information of both the location and its error range.

From NAC to (Longitude, Latitude, Altitude). If the NAC of a region is known, then the longitude, latitude and altitude of the southwestern lower corner of the region can be calculated by the following procedure:

First, convert all characters X_1, X_2, X_3, X_4, ... Y_1, Y_2, Y_3, Y_4, ... Z_1, Z_2, Z_3, Z_4, ... into integers x_1, x_2, x_3, x_4, ... y_1, y_2, y_3, y_4, ... z_1, z_2, z_3, z_4, ... according to the Table of the NAC Character and Integer Correspondences.

Then use the following formulae to calculate coordinates:

$$\text{Longitude} = (x_1/30 + x_2/30^2 + x_3/30^3 + x_4/30^4 + ...)*360 - 180$$
$$\text{Latitude} = (y_1/30 + y_2/30^2 + y_3/30^3 + y_4/30^4 + ...)*180 - 90$$
$$\text{Altitude} = R*\tan((z_1/30 + z_2/30^2 + z_3/30^3 + z_4/30^4 + ...)*90)$$

where R is the distance from the earth center to the geoid surface along gravitational line. The northeastern upper corner of the region can be calculated by repeating the same procedure with the same integers except adding 1 to the integer corresponding to the last character of each string of the NAC. Then, the region can be completely determined by the coordinates of these two geodetic points.

NAC Algebra

In the Natural Area Coding System, several algebraic rules have been introduced to simplify the notations and operations of NACs. Some of the rules are defined in the following, where symbol = represents the equivalency and symbol + represents the sum of two NAC regions or areas.

If there are a series of neighboring NAC regions in the universe, which exactly fill a region bounded by surfaces of constant longitude, constant latitude and constant altitude, then the whole region can be represented by a single group NAC which uses a hyphen to link the relative coordinate characters of the first NAC with the relative coordinate characters of the last NAC in each direction with multiple NAC regions respectively, for example:

NAC: NHJ-L TH KJH
= NAC: NHJ TH KJH + NAC: NHK TH KJH + NAC: NHL TH KJH

NAC: NHJ-L TH-J KJH
= NAC: NHJ TH KJH + NAC: NHK TH KJH + NAC: NHL TH KJH
+ NAC: NHJ TJ KJH + NAC: NHK TJ KJH + NAC: NHL TJ KJH

NAC: NHJ-L TH-J KJH-J
= NAC: NHJ TH KJH + NAC: NHK TH KJH + NAC: NHL TH KJH
+ NAC: NHJ TJ KJH + NAC: NHK TJ KJH + NAC: NHL TJ KJH
+ NAC: NHJ TH KJJ + NAC: NHK TH KJJ + NAC: NHL TH KJJ
+ NAC: NHJ TJ KJJ + NAC: NHK TJ KJJ + NAC: NHL TJ KJJ

The number of characters after the hyphen in a character string represents the number of the characters of the relative coordinate. The characters before the hyphen in a character string represent the first NAC region coordinate in this direction. The characters before the hyphen with its last characters replaced by the characters after the hyphen in the character string represent the last

NAC region coordinate in this direction. For example, NAC: NHJ-LZ TH KJH represents a three-dimensional region which starts from the region of NAC: NHJ TH KJH and ends by the region of NAC: NLZ TH KJH, that is,

NAC: NHJ-LZ TH KJH
= NAC: NHJ-Z TH KJH + NAC: NK0-Z TH KJH + NAC: NL0-Z TH KJH

It is the same for NACs with hyphens in two or three character strings, such as:

NAC: FP-GZ TH-ZK HJK
= NAC: FP-Z TH-Z HJK + NAC: G0-Z TH-Z HJK
+ NAC: FP-Z V0-Z HJK + NAC: G0-Z V0-Z HJK
+ NAC: FP-Z W0-Z HJK + NAC: G0-Z W0-Z HJK
+ NAC: FP-Z X0-Z HJK + NAC: G0-Z X0-Z HJK
+ NAC: FP-Z Z0-K HJK + NAC: G0-Z Z0-K HJK

When a NAC with 0-Z at the end of its character string, these three characters can be omitted in the character string provided there are some characters left in the character string, for example:

NAC: JJ0-Z KKL HG = NAC: JJ KKL HG

NAC: JJ0-Z KKL0-Z HG0-Z = NAC: JJ KKL HG

An exponent has been introduced to represent the repetition of one same character in a NAC coordinate string, for example:

NAC: RGJJJJK RDF FDS = NAC: RGJ(4)K RDF FDS

NAC: RGGGH HFF ZZZZZ = NAC: RG(3)H HF(2) Z(5)

The exponential expressions will be very useful in representing far distant objects in the universe.

If a character after a hyphen in a string of a NAC represents a number smaller than that represented by the character before the hyphen, it means that the range goes through the end of the next higher level division boundary. For example,

NAC: JK-6 HJ GH = NAC: JK-Z HJ GH + NAC: L0-6 HJ GH

If there are a series of neighboring NAC areas on the earth which exactly fill an area bounded by lines of constant longitude and constant latitude, then the whole area can be represented by a single group NAC which uses a hyphen to link the relative coordinate characters of the first NAC with the relative coordinate characters of the last NAC in each direction with multiple NAC areas respectively. The exponential expression can be applied to the two-dimensional NAC too.

There are special cases which need to be further explained. A group NAC such as NAC: HJ K0-Z can be simplified as NAC: HJ K since 0-Z covers all NAC divisions in the higher level division, but NAC: 0-Z HF is not allowed to be written into NAC: HF because any simplification is only to shorten the coordinate string but not remove the whole string.

With the above definitions, the concept of NAC regions has been extended to include any regions in the universe, bounded by surfaces of constant longitude, constant latitude and constant altitude, and the concept of NAC areas has been extended to include any areas on the earth, bounded by lines of constant longitude and constant latitude. Every NAC region or NAC area can be expressed by a single group NAC. Since the side ratios and size of a NAC area or region can be any values, a NAC in fact can represent any point in the universe, any line section of constant longitude or constant latitude on the earth, any area bounded by lines of constant longitude and constant latitude on the earth, any region bounded by surfaces of constant longitude, constant latitude and constant altitude in the universe.

Efficiency of NAC

Natural Area Codes can be used to represent geodetic points, line sections, areas and 3D regions with high efficiency. When a NAC is used to represent a point, it tells not only where the point is but also how accurate the representation is.

For a geodetic point, the following are equivalent:

NAC: 2CHD Q87M

Longitude West 151.3947, Latitude North 43.6508 in WGS-84 accurate to about 30 meters

For a line section, the following are equivalent:

NAC: 2C Q87M

Piont 1: Longitude West 151.5902, Latitude North 43.6508 Point 2: Longitude West 151.1902, Latitude North 43.6508 Coordinates are in WGS-84

For an area, the following are equivalent:

NAC: 2C Q8

Northwest corner: Longitude West 151.5902, Latitude North 43.8033 Southwest corner: Longitude West 151.5902, Latitude North 43.6033 Northeast corner: Longitude West 151.1902, Latitude North 43.8033 Southeast corner: Longitude West 151.1902, Latitude North 43.6033 Coordinates are in WGS-84

For a three-dimensional region, the following are equivalent:

NAC: 2C Q8 H000

In WGS-84, it is expressed by The bottom surface has the height = 0 meter above the geoid surface and four corners on the surface are: Northwest corner: Longitude West 151.5902, Latitude North 43.8033 Southwest corner: Longitude West 151.5902, Latitude North 43.6033

Northeast corner: Longitude West 151.1902, Latitude North 43.8033
Southeast corner: Longitude West 151.1902, Latitude North 43.6033

The top surface has the height = 25 meters above the geoid surface and four corners on the surface are:

Northwest corner: Longitude West 151.5902, Latitude North 43.8033
Southwest corner: Longitude West 151.5902, Latitude North 43.6033
Northeast corner: Longitude West 151.1902, Latitude North 43.8033
Southeast corner: Longitude West 151.1902, Latitude North 43.6033

The efficiency of the Natural Area Coding System is so significant that it can save 50% of characters in representing points, 75% in representing line sections, 87% in representing areas and 94% in representing three-dimensional regions.

2.4 The Universal Address System

Traditional addresses are very complicated. It is not possible to prescribe a simple, mechanical rule for locating and interpret essential address components. Just in the United States, there are more than 50 variations in address formats plus many non-standard abbreviations and local addressing conventions. These have made automatically parsing traditional addresses extremely difficult.

Locating physical addresses is what travellers, taxi drivers, and emergency services face everyday. Locating unfamiliar places with traditional addresses is not only a time consuming work but very often results in complete failure no matter how emergent you feel. People can't directly pinpoint these addresses on maps or figure out the distance and direction from them. Although GPS has been widely used in many areas such as highway snow removing, efficient farm operations, driver assessment, driving speed review, and even in golfing. But the irrelevance between addresses and geographic coordinates and inconvenience in inputting addresses into GPS receivers make GPS useless to average consumers looking for addresses.

Handling and geocoding addresses have constituted the most time-consuming and expensive part in many GIS projects. It is difficult to design a standard form for inputting all conventional addresses in GIS. Even when an input form for limited formats of addresses is created, inputting addresses into such a form is still very time consuming.

Therefore, highly efficient standard universal addresses for mail automation, locating and GIS applications are demanded. A substantial study of addresses and geographic coordinates has led to the birth of the Universal Address System that is derived from the Natural Area Coding System.

A Universal Addresses is defined by an eight- or ten-character NAC that uniquely represents an address anywhere in the world. The major advantages of a Universal Address are:

- Language and culture independent.
- Easy to be handled by computers and electronic devices because of only most popular characters and standard format used.
- Political neutral.
- Easy to remember because of short strings and clear spatial logic.
- No needs to be geocoded.
- Obtainable through many channels: maps, GPS receivers, and other surveying methods.
- No needs to be assigned and maintained by government or companies.

- Never change.
- Can be pinpointed on maps, and navigated with GPS receivers.
- Existing at all locations in the world.

With Universal Addresses, no matter from where and speaking what language, people can easily find their destinations with NAC enhanced maps or GPS receivers. If a city has marked all its street signs and house number plates with Universal Addresses, people can find their destinations efficiently in the city by comparing the current Universal Address and the destination Universal Address even without any helps from maps, GPS or people, that will greatly benefit residents, tourists, taxi drivers, delivery companies, and especially emergency services.

It is a wise practice to include the Universal Address as part of a traditional address on business cards, advertisements and business directories such as:

Figure 4. How to Add Universal Address on Business Card

Thus, it can be used immediately no matter how many people know it. If they know what a Universal Address, they can take the advantages of the Universal Address. If they don't know, they can simply ignore it.

General consumers can use Universal Addresses to specify locations on online and wireless location based services to

- Reduce 80% of input keys
- Avoid difficulties in inputting addresses with foreign characters
- Eliminate errors from address databases
- Specify all locations no matter whether there are addresses or not

Taxi drivers can use Universal Addresses to pinpoint any locations on all street maps with Universal Map Grids. Travellers with GPS navigation systems can directly locate Universal Addresses, record and communicate the Universal Addresses of their favourite locations for camping, fishing, exploring, etc. They can also use Universal Addresses to orally communicate their real-time locations for emergency help, road side help, or just keeping their family or friends informed where they are. Mail sorting systems may use Universal Addresses to sort all mail automatically.

2.5 The Global Postal Code System

Traditional addresses are very complicated. It is not possible to prescribe a simple, mechanical rule for locating and interpret essential address components. Just in the United States, there are more than 50 variations in address formats plus many non-standard abbreviations and local addressing conventions. In order to facilitate efficient mail processing, many countries have introduced postal codes such as US ZIP codes. A 9-digit ZIP can identify an area known as a "segment" such as a side of a street between intersections. With 9-digit ZIP codes, domestic mail can be automatically sorted to the mailbags for single USPS employees with significant improvement in efficiency. However, most postal codes mapping national postal service hierarchies inherit many limitations, and become useless in sorting international mail. Any changes in mail delivery hierarchies result in the changes of postal codes that create many troubles for both residents (remembering new codes, informing people of the changes, facing loss of mail, etc) and post offices (settling complains, paying compensations, rerouting mail, etc). Therefore, a global postal code system independent from any mail delivery hierarchies is demanded for fully automating mail sorting.

The Global Postal Code System has been developed as an application of the Natural Area Coding System. A Global Postal Code is an eight- character two-dimensional Natural Area Code representing an area about 25 by 40 meters anywhere on the earth surface, plus an extension if necessary. The Global Postal Code for an individual house, an apartment or P.O. Box is defined in the following:

1. If an eight-character NAC represents an area with only one house, then the Global Postal Code of the house is the same as the NAC, for example, NAC: 7HGG KJ9L.

2. If the NAC represents an area with several houses, the Global Postal Code of each house in the area is the NAC plus a locally defined third character string which people themselves can define using a family name, a location name or a name of their choice. The locally defined third string should employ characters from digits or English capital letters, should have at least one vowel other than I or O, not include blank spaces, and should be unique in the NAC area, for example,

   NAC: 7HGG KJ9L DAVID

   The requirement of at least one vowel other than I and O is to distinguish the third string from the altitude NAC string which does not include any vowels: A, E, I, O, U, Y. The characters I and O look too similar to 1 and 0; so they are not clear enough to distinguish the locally defined string from the altitude string.

3. If the NAC represents a high-rise building with many apartments, the Global Postal Code for each apartment is the NAC of the front door of the building plus a locally defined string named in a way similar to case 2, for example,

   NAC: HGJK PLLT A509

4. If a NAC represents an area split by a postal zone border, and a house is located in the larger part of the area, then the Global Postal Code of the house is the NAC or the NAC plus a locally defined string; if a house is completely within the smaller part of the area, then its Global Postal Code should be a nine or ten-character NAC to specify the location of the house more accurately, instead of an eight-character NAC; if a house in the smaller part of the area occupies part of another NAC area called B which belongs to the same postal zone as the house and is not split by any postal zone borders, then the Global Postal Code of the house is the NAC of area B or the NAC of area B plus a locally defined third string.

5. The longitudinal distance of the area represented by an eight-character NAC becomes small when it is close to the poles. For this situation, a seven- or six-character NAC can be used as the global postal code of the area such as:

   NAC: 8CNJ X3S

6. If a house itself is split by a postal zone border, the Global Postal Code of the house will be a nine- or ten-character NAC representing the location of its main entrance.

7. For a PO Box of a postal office, the Global Postal Code can be defined as the NAC of the postal office plus an extension starting with U followed by the box number such as:

   NAC: JK5G Q8GK U1365

Having obtained the Global Postal Code, people can start to include it on a letter as extra information immediately no matter how many post offices have already started sorting mail based on the codes. If some post offices have been sorting mail based on the codes, a letter with a Global Postal Code can be sent faster.

The writing convention of the Global Postal Code on a letter is to write it on an extra line at the bottom of the traditional address and domestic postal codes no matter what kind of language and address order are used. For example:

Figure 5. How to Include a Universal Address on Mail

This writing convention allows post offices to sort mail by either domestic postal codes or Global Postal Codes. Therefore, the domestic postal code systems can be replaced by the Global Postal Code System gradually.

Post offices can use character recognition technology to read addresses. If the last line of an address starts with NAC, then the following character strings will be processed as a Global Postal Code. One of the algorithms for computers to sort mail based on the Global Postal Code is explained in the following:

If postal services do not want to change anything except the mail sorting software, then the software can be programmed according to the following procedure:

1. Convert the first two character strings of a Global Postal Code into decimal longitude and latitude;

2. Use the city boundary file to check whether the destination is within the city or not;

3. If the destination is within the city, then use the boundary files of the inner city areas to find out the area of the destination and to transport the mail to the post office in charge of the area;

4. If it is not within the city, then use the boundary file of the country to check whether the destination is in the country;

5. If the destination is in the country, use the boundary files of postal zones at the city level to find out the postal zone containing the destination and to transport the mail to the postal terminal in charge of the postal zone;

6. If it is outside the country, then use the boundary files of countries to find out the mail destination country and to transport the mail to the country's postal terminal closest to the destination;

To check whether the destination is within an area, the mail sorting program can first calculate the distance R between the destination and the reference point of the area, and then compare R with the maximum distance R_{max} from any point in the area to the reference point. If $R > R_{max}$, then the destination is outside the area. If $R < R_{max}$, then the program can compare R with the minimum distance R_{min} from any boundary node to the reference point. If $R < R_{min}$, then the destination is within the area. If $R > R_{min}$, the program has to calculate the angle a of the vector from the reference point to the destination. Assume that each boundary node is represented by the angle and length of the vector from the reference point to the boundary node. Assume that there is only one boundary node corresponding to one angle in the area, while a complicated area should be divided into several such simple areas. Therefore, the program can find out two boundary nodes: the vector from the reference point to one of the nodes has a length R1 and angle a1 equal to the maximum angle smaller than a; the vector from the reference point to the other node has a length R2 and an angle a2 equal to the minimum angle larger than a. Then the program can determine that the destination is within the area if $R_1*R*\sin(a - a_1) + R*R_2*\sin(a_2 - a) < R_1*R_2*\sin(a_2 - a_1)$, otherwise it is outside the area.

The mail sorting software based on this algorithm can work together with the existing structure of post offices and help sort all mail from the international level to the final address automatically. Moreover, since the current distribution structure of postal corporations are not optimal, this mail sorting program also allows the post offices to adjust their mail transportation routes to send mail more efficiently. For example, Canada Post Corporation may set up more international postal terminals. Other countries can send mail to a specific Canadian postal terminal if the distance from the mail destination to the terminal is the shortest. This adjustment can prevent some situations such as a letter from Seattle to Vancouver being sent through New York City and Toronto and then to Vancouver - an unnecessary long trip which wastes both time and money.

In addition, the Global Postal Code System has many other advantages over current postal code systems:

- The Global Postal Code is assigned to every mailing address in the world, with much higher resolution than any other postal codes. With a Global Postal Code, a letter can be sorted from the world level to the final address automatically.
- The code is permanently attached to the area and never changes. This quality can prevent both the user and the post office from unnecessary inconvenience in changing postal codes, a wasting of time and money and a resulting loss of mail.
- The Global Postal Code does not need to be assigned by a post office, which can

help people living in newly developed areas to get their postal services immediately.

- The code can be used instead of the domestic postal code to save costs in revising and publishing postal code books and postal zone atlases periodically.
- The code can be used for all other services related to addresses such as emergency services, taxi and delivery services, and in the future, telephone, fax and internet services.
- The code can be obtained from maps with the Universal Map Grids or by Global Positioning System (GPS) receivers with NAC display. It can also be derived from the longitude and latitude coordinates obtained from ordinary maps or measured by other methods.
- The codes can be used to determine the distance, direction and natural time difference between any two addresses and their relative locations in the world.
- The code can be directly used in navigation to find addresses or locations by ambulances, trucks, airplanes and individuals equipped with GPS receivers.
- The code can help people to pinpoint an address on a map with Universal Map Grids conveniently in spite of the amount of detail and the scale of the map.
- The code can be easily remembered because of its clear meaning, reasonable length, multiple uses and frequent accesses.
- The system is self-motivated. Since the system can start to work immediately parallel to the current domestic postal code systems, it does not need any international agreements to initiate the system. Any country can start to use the system directly when it is ready itself and will receive all the benefits of the system instantly.
- The code has certain self-error-detecting function. There is more than 80% chance for a computerized mail sorting program to find out a wrong Global Postal Code since a random NAC may represent an area in oceans where no people live. This property can avoid most mail with wrong codes being sent to wrong places.
- Global Postal Codes can also help people to understand, interpret and communicate all geographic, geologic, ecological, meteorological, oceanographic, archeological, environmental and astronomic information represented by Natural Area Codes because of the direct relationship between Global Postal Codes and Natural Area Codes.

A possible disadvantage is that a Global Postal Code can only be sorted efficiently by computers but not by human beings due to the handling of postal zone boundary files. However, the continuous decrease of computer prices have made computers cheaper and cheaper, and most post offices in developed countries already have the ability to sort mail automatically.

2.6 The Universal Map Grid System

There are many map grid systems developed in the history such as Longitude/Latitude based grids for world maps, UTM grids for regional maps, and customized local grids for street maps. The grid coordinates of these different systems are not directly related and the location information on these maps can not be easily connected. The main reason why a street map does not use longitude/latitude or UTM grids is that the resulted grid coordinates are too long for consumers to use. Since the customized local grid coordinates do not have direct meaning outside its corresponding maps, nobody will include them as part of addresses. Therefore, people have to go through many steps (lookup on street name list, locate a grid cell, scan all streets in the cell to find the street, and estimate the location of the street address on the street) to locate a street address on such a map and the found location is still of uncertainties. People can't locate the longitude/latitude coordinates displayed on a GPS receiver on such a map. There are serious gaps between addresses and maps, addresses and GPS receivers, maps and GPS receivers, and many other GIS, GPS and geographic products and service.

All these demand a standard, efficient and connected system that can be applied onto all geographic products and services in the world. This is the Natural Area Coding System. When the Natural Area Coding System is presented as a map grid system on maps, it called the Universal Map Grid System.

The Universal Map Grid System uses specifically selected constant longitude lines and constant latitude lines to form grid cells. There are a series of grid levels in the Universal Map Grid System. The first level grid lines in the south-north direction are the lines on which their constant longitude equals to:

> Longitude West 180, 168, 156, 144, 132, 120, 108, 96, 84, 72, 60, 48, 36, 24, 12, 0 degrees, and Longitude East 12, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, 168 degrees, respectively.

The first level grid lines in the east-west direction are the lines on which their constant latitude equals to:

Latitude South 90, 84, 78, 72, 66, 60, 54, 48, 42, 36, 30, 24, 18, 12, 6, 0 degrees, and
Latitude North 6, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, 72, 78, 84, 90 degrees, respectively.

Each resulting cell is assigned one character from the **Table of the NAC Character and Integer Correspondences** in both the east-west direction and the south-north direction in the order as appeared in the table, that is, NAC: 0 0 is the NAC grid index of the first cell bounded by lines of constant longitude: Longitude West 180 degrees, Longitude West 168 degrees, and constant latitude: Latitude South 90 degrees and Latitude South 84 degrees. The first 0 in the NAC grid coordinates represents its longitude coordinate and the second 0 represents its latitude coordinate. The second level of the NAC grid is formed by dividing the cell of a first level grid uniformly into 30 subdivisions in both longitudinal and latitudinal directions, each of which is assigned one NAC character as the relative coordinate in both directions respectively, so is the third and other grid levels. This definition of the Universal Map Grid System is equivalent to the algorithm in the definition of the Natural Area Coding System.

These grids can be applied to all maps such as a world map, country map, province map, city map, local community map, and maps for specific purposes. The resulted grid coordinates are universal, simple (an eight-character NAC specifically for a less than 25 by 50 meter area anywhere in the world) and of multiple uses. So, the grid coordinates are Natural Area Codes that can be an important part of an address and everybody will like to keep them as part of addresses.

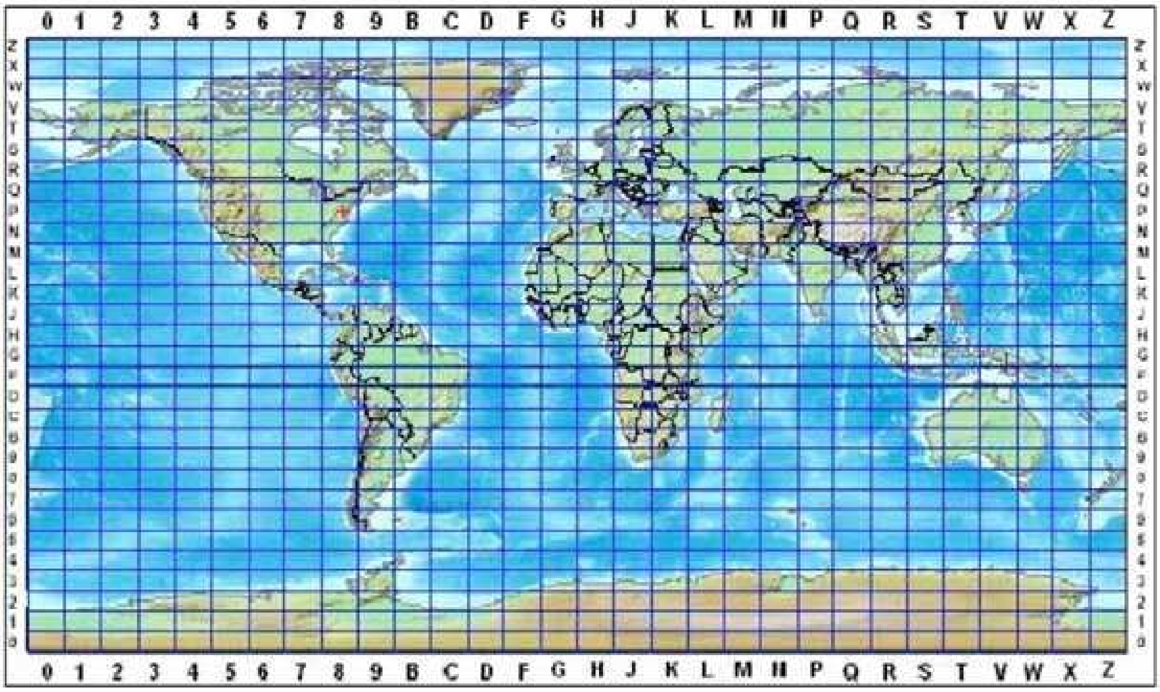


Figure 6. Universal Map Grid on the World Map

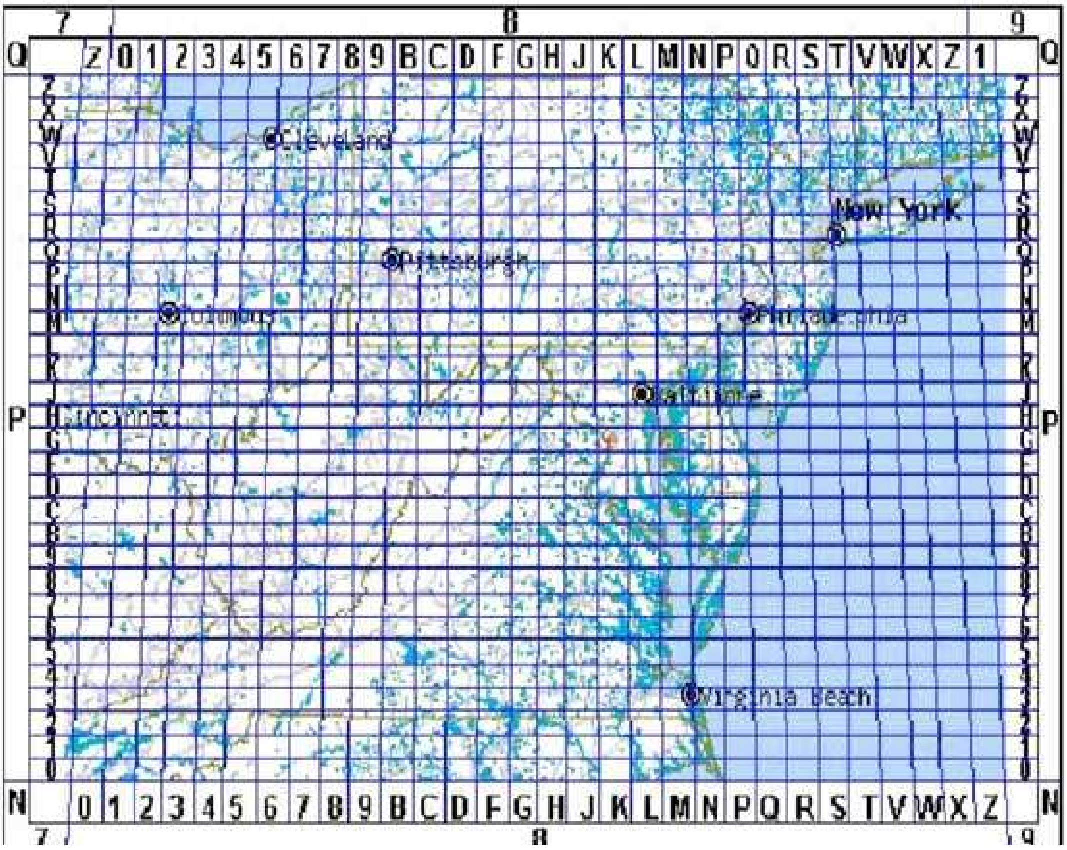


Figure 7. Universal Map Grids on a Regional Map

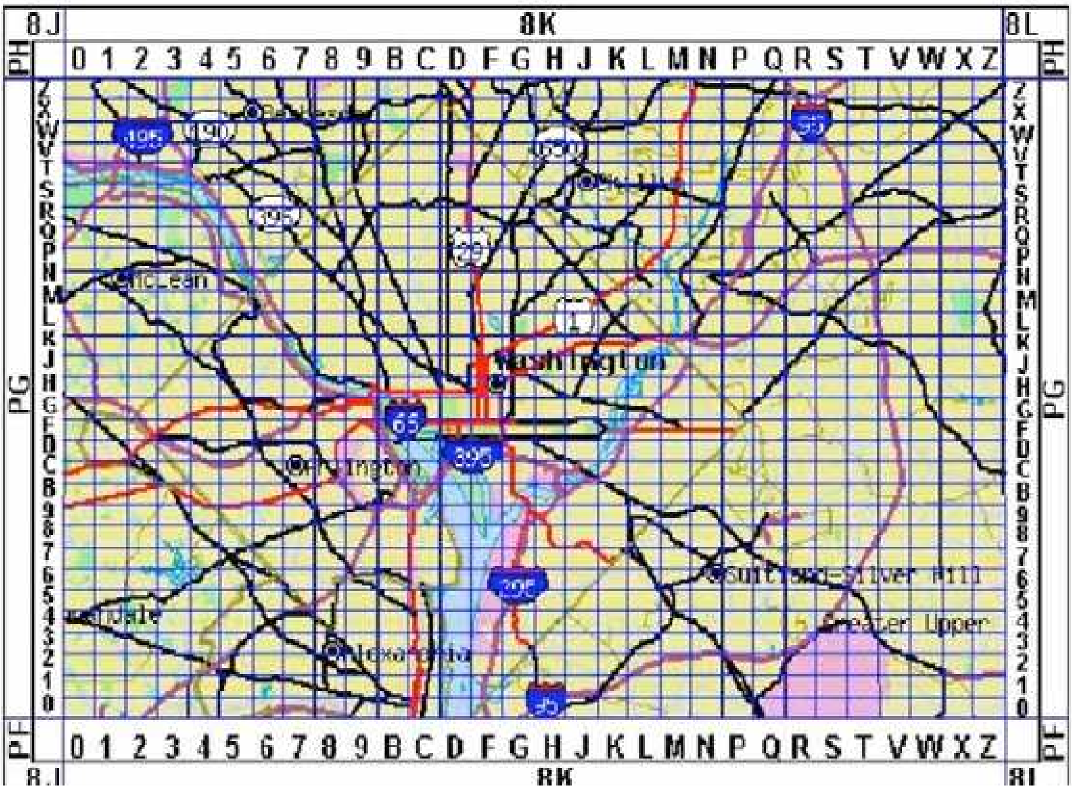


Figure 8. Universal Map Grids on a City Map

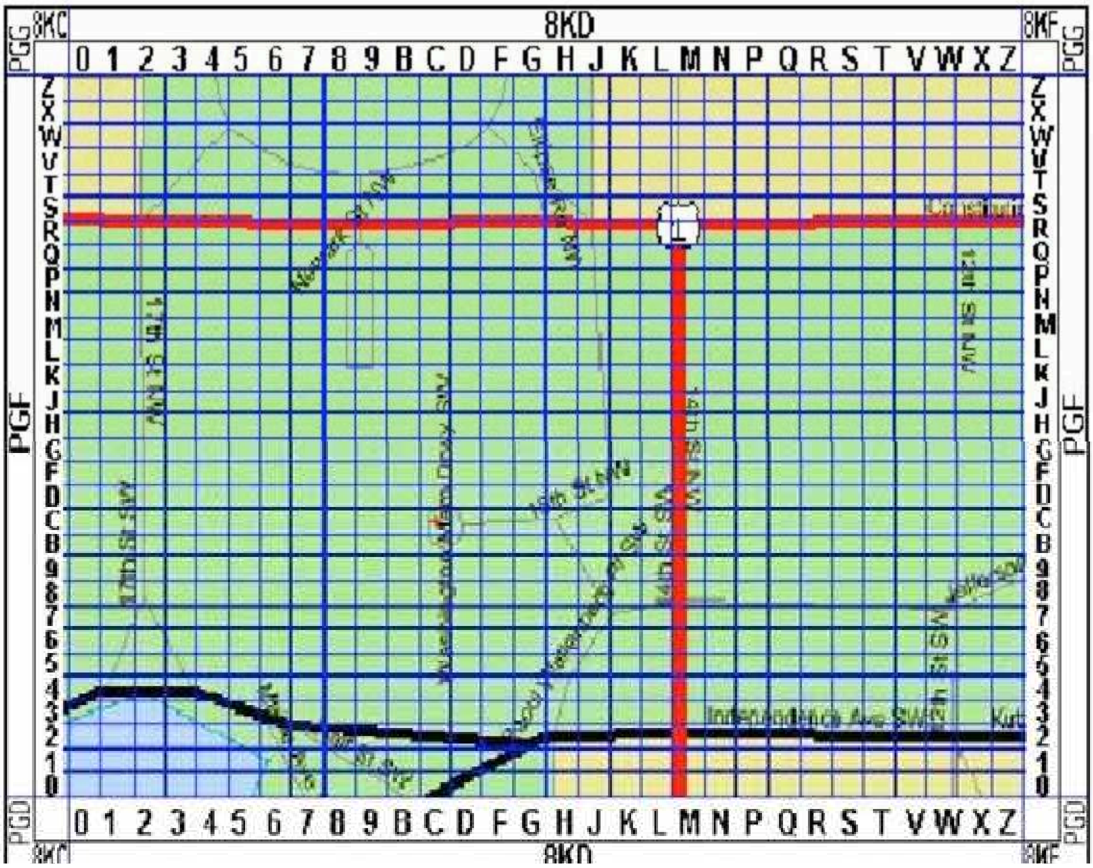


Figure 9. Universal Map Grids on a Local Street Block Map

With this grid system, a map can be efficiently used to pinpoint any Universal Addresses without the needs to look up the street name list, locate the cell on a local map grid, scan all streets in the cell to find the street and estimate the location of the street number along the street.

All information obtained from different maps can be easily correlated by the NAC grid coordinates and people will not have problems to link two maps of neighboring cities.

The NACs of two addresses anywhere in the world can be used to calculate their distance and their natural time difference and determine their relative locations.

Maps of the NAC cells can be named by their Natural Area Codes and stored systematically in a map library according to the NAC character order, which may give people great convenience to find maps.
Tourist maps may include the list of hotels, restaurants, railway stations, airports, tourist information centers, parks, historic sites, shopping malls, and museums with their Universal Addresses, which will be very useful to tourists.

2.7 The Universal Property Identity Code System

The Natural Area Coding System has also produced an ideal property identity code system called the universal property identifier (UPID). A UPID is a ten-character NAC representing a 0.8 by 1.6 meter reference area of a property such as the main entrance door of a building, defined by the owner of the building. In very special cases, a 12-character NAC may be used as the UPID of a property, which represents a 5 by 2.5 cm reference area of the property. The advantages of the system are:

1. the UPID is recognized universally. People do not need to mention any other address such as street, city, country of a property when the UPID is known;
2. the UPID is permanently attached to the property and never change, which can save a lot of work when the political boundary changes;
3. the UPID can be directly pinpointed on all maps which include the property no matter what kind of scales they are;
4. the natural order and natural layers of the UPID can greatly simplify the databases of property registration information, significantly reduce the storage size and efficiently retrieve the information;
5. the UPID can also be used for other purposes such as postal services and emergency services due to its accurate information;

The UPID does not need to be assigned by government but can be found by owners themselves, which can save huge amount of cost for the government.

3. Photographies des TC à Toronto

Source : F. Kuhn

Station du métro automatique de Scarborough, l'entrevoie pour le moteur linéaire

Source : F. Kuhn

Station du métro automatique de Scarborough avec une zone particulièrement surveillée la DWA[13]

[13] DWA : Designated Waiting Area

Source : F. Kühn

Viaduc supportant les voies du métro automatique

Source : F. Kühn

Une avenue de Scarborough : on remarque le piétonnier et la bande engazonnée sous laquelle se trouve les réseaux de concessionnaires

Source : F. Kühn

Un parc de Scarborough

Source : F. Kühn

Une publicité de la TTC pour attirer les clients

Source : F. Kühn

Une station du métro de Toronto

Source : F. Kühn

Arrivée d'une rame en station

Source : F. Kühn

Une rame automatique au départ d'une station de Scarborough

Source : F. Kühn

Une rame automatique à l'arrivée en station de Scarborough

Source : F. Kühn

Vue sur les voies en bout de station de Scarborough

Source : F. Kühn

Vue sur une voie en station de Scarborough

Source : F. Kühn

Vue sur une voie en station de Scarborough

Source : F. Kühn

Les voies du métro à moteur linéaire de Scarborough

Source : F. Kühn

Les voies du métro à moteur linéaire de Scarborough

Source : F. Kühn

Les voies du métro à moteur linéaire de Scarborough

Source : F. Kühn

Les voies du métro à moteur linéaire de Scarborough au sol

Source : F. Kühn

Les voies du métro à moteur linéaire de Scarborough au sol

Source : F. Kühn

Accès aux voies du métro à moteur linéaire de Scarborough

Source : F. Kühn

Bout des quais en entrée de stationde Scarborough

Source : F. Kühn

Vue intérieure du véhicule UTDC du métro de Scarborough

Source : F. Kühn

Borne d'appel en bout de quai d'une station

Source : F. Kühn

Détails de la voie du métro automatique

Source : F. Kühn

Plaque commémorative de la mise en service de l'ALRT

Source : F. Kühn

L'entrée du Parc de Guildwood surplombant le Lac d'Ontario

Source : F. Kühn

Les falaises d'argile (Bluffs) surplombant le Lac d'Ontario

Source : F. Kühn

The Bluffs

Source : F. Kühn

Ancien Hôtel du Parc fermé n'étant plus adapté à la clientèle

Source : F. Kühn

L'ancien Hôtel du Parc fermé racheté par la Ville de Toronto

Source : F. Kühn

Plaque commémorative d'une des premières cabanes de l'Ontario 1795

Source : F. Kühn

La première maison de Scarborough 1795

Source : F. Kühn

Un volant d'inertie (flywheel) industriel déposé dans le Parc de la Guild

Source : F. Kühn

Le Parc de la Guild à Guildwood in Scarborough

Source : F. Kühn

L'église de Guildwood et salle de jeux pour les jeunes en sous-sol à Scarborough

Source : F. Kühn

Panneau indiquant que cette voie est réservée aux autobus, aux véhicules avec plusieurs passagers, HOV, aux cyclistes, à certaines heures

Source : F. Kühn

Train de banlieue à étages de GO Transit

Source : F. Kühn

Sortie de métro et tramway de surface

Source : F. Kühn

Tramway de surface par temps neigeux

Source : F. Kühn

Un quartier sous la neige

Source : F. Kühn

Visite avec une architecte de la TCC vers la nouvelle ligne Sheppard

Source : F. Kühn

Un quartier de Toronto

Source : F. Kühn

Rabattement du tramway sur une station de Métro

Source : F. Kühn

En visite vers Sheppard

Source : F. Kühn

Visite de la station Don Mills à Sheppard

Source : F. Kühn

Equipement d'arrêt en station sur la nouvelle voie de Sheppard

Source : F. Kühn

Visite de la station Don Mills sur Sheppard

Source : F. Kühn

Visite de la station Don Mills sur Sheppard

Source : F. Kühn

Visite de la station Don Mills sur Sheppard

Source : F. Kühn

Equipements d'information des voyageurs en station

Source : F. Kühn

Nez de quai en station Don Mills et voie posée sur béton et blocs élastiques

Source : F. Kühn

Vue intérieure d'une rame de métro en heures creuses

Source : F. Kühn

L'architecte de la TCC qui a assuré la maîtrise d'œuvre de la ligne Sheppard

Source : F. Kühn

L'Art en station

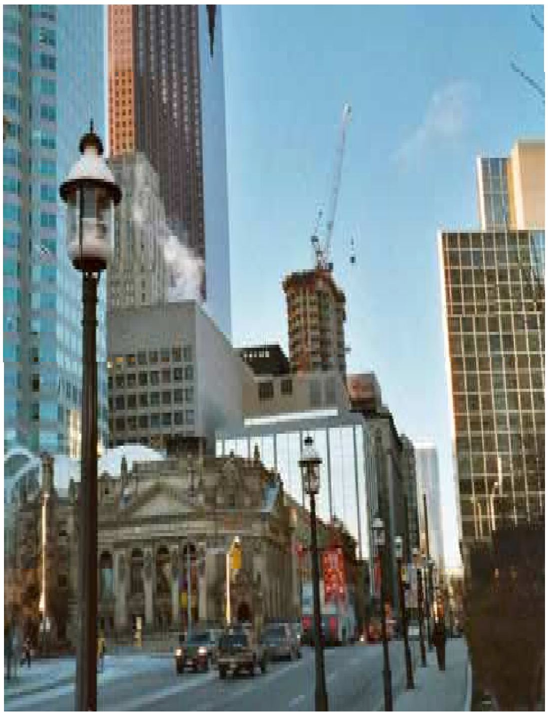
Source : F. Kühn

L'Art en station

Source : F. Kühn

Une rame PCC en attente près d'une station de métro

Source



F. Kühn

Le centre ville de Toronto

F. Kühn

L'Hôtel de Ville de Toronto

F. Kühn

L'Hôtel de Ville de Toronto

F. Kühn

Le Centre Ville de Toronto

F. Kühn

Le Centre Ville de Toronto

F. Kühn

Arrêt du tramway sous circulation

F. Kühn

Entrée d'un shopping center

F. Kühn

Remise en état des voies du tramway

F. Kühn

Remise en état des voies du tramway

F. Kühn

Remise en état des voies du tramway

F. Kühn

Remise en état des voies du tramway

F. Kühn

Remise en état des voies du tramway

F. Kühn

Remise en état des voies du tramway