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Global location coding
(Universal Geographical Indicator System)

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Abstract: In today's globalised society, where more and more of the goods and services are being routed automatically, there is a growing necessity to use a global location coding system. The longitude and the latitude are global indicators of dimensionless points on the sphere, but, in reality, most locations of practical interest could be considered as areas covering a definite surface. It may be argued that a point within that surface may be used as a location indicator, but this indicator is not unique. The other issue with the geographical coordinates is that to the coordinate of any particular point of interest a tolerance interval need be included. Thus, location indication through area codes is natural and more useful. In this work, the authors propose a global system for indicating geographic areas through limited sequences of decimal digits. Each such sequence of a certain length indicate in a unique manner a definite geographic area. Sequences of increasing lengths indicate the smaller areas, i.e. with a narrower tolerance. This method for location coding is achieved by dividing recursively the surface of the Earth in sections, and then recursively into smaller and smaller subsections, with each new division encoded by a single digit. E.g. a twelve digit sequence indicates an area of about 50 m in diameter. Using such global coding system for geographic locations may substantially simplify the delivery of goods and services, direct and focus a remedial effort in emergencies, or be used advantageously for planning and improvement of city management.

Keywords: location coding, geographic information system, smart city area numbers, smart city, mail delivery routing, goods and services delivery, land monitoring

1 INTRODUCTION

1.1 Geographical coordinate system

In the globalised world of today, it may be of some profit to be able to determine the location of an object in an unambiguous manner. In addition, it would be convenient if this unambiguous determining expression for the location of an object be universally understandable and easy to interpret.

The universal rational interpretation of the planet Earth is spherical, thus, it is the spherical coordinate system that is most naturally being used to denote location on it. For this, two angles are used, the longitude, λ_{LON} , which determines the coordinates in East - West direction, and the latitude, λ_{LAT} , which determines the coordinates in North - South direction. Whilst this is indeed the most natural interpretation of coordinates on a sphere, there are several issues with how these coordinates are used. Firstly, these coordinates, as they are currently used, are expressed in angular degrees, minutes, and seconds, with one angular degree having 60 angular minutes, and one angular minute having 60 angular seconds. That is, the hexagesimal number system is being used for expressing fractions of one angular degree, which may be quite inconvenient for performing computations with angles. More recently, the angles λ_{LON} and λ_{LAT} are being expressed in angular degrees written as decimal fractional numbers, which somewhat resolves this issue. Secondly, the angles λ_{LON} and λ_{LAT} can have positive and negative values :

$$-180^o < \lambda_{\text{LON}} < +180^o \quad , \quad -90^o < \lambda_{\text{LAT}} < +90^o$$

Here, again, the need to pay attention to the mathematical signs of the coordinate numbers is mathematically perfectly correct, but may present difficulties to general public with little inclination towards numerical notations. In addition to this, the longitude and the latitude angles are expressed in angular degrees, which is a widely accepted unit of measurement, but it is not an SI standard unit for angles. On the other hand, expressing the angles in radians, which is an SI unit, is an option, but its use would involve computations using π, which is a transcendental number. The use of radians would probably introduce more problems into expressing geographical coordinates than it would solve.

1.2 Geographical locators not based on coordinates

An important problem with mathematically based coordinate systems for geographical locations is that the coordinate systems determine a point, which is a dimensionless object. In reality, a location is always indicating the position of an object, occupying a non-zero area on the ground, and subsequently, on the map. That means, that geographic coordinates ought be expressed as pairs of intervals, and not merely pairs of numbers. This, of course, may be achieved by adjoining tolerance values to conventional geographic coordinates. This, however, induces more of the problems of the same nature as those mentioned before.

As an early attempt to circumvent some of the problems with geographic coordinates in practical everyday situations, postal codes have been invented. Postal codes have been used to denote geographical locations or routes without using mathematical notation. Usually, postal codes are short strings of numbers or combined numbers and letters. They indicate geographic areas, such as towns or city suburbs, sometimes streets, sometimes post-office facilities, and sometimes mail delivery paths. Some postal codes are even allocated to vehicles, vessels, or to mobile entities, e.g. to military or rescue units. Some jurisdictions use no postal codes, and amongst those that do use them, there is a great variety of forms and usages. In addition, postal codes are allocated nearly exclusively to inhabited places. There have been attempts to employ complex alphanumerical strings to indicate intended locations with great precision. These systems usually require access to a data-base mapping the strings into locations and vice versa. In today's interconnected world, a round-the-clock access to such a data-base is possible, but the throughput capacity of the communication interface can almost certainly be a serious limiting factor. Finally, postal codes are nearly universally decreed by legislative or executive powers that be. Nearly universally, because, nowadays a large part of mail and parcel delivery, especially those destined for rapid delivery, is effectuated by private courier enterprises. Thus, sometimes, private, proprietary delivery codes are being used, which are not widely known or described to the wide public. Taking all this into account, postal codes cannot be seen as global nor universal locators, firstly due to the variety of forms and usages, and also due to the limits of their application.

Thus, at this moment, there is no system for global determination of geographic locations that could be accepted and used by everyone. In this interconnected global world, in which most banal activities rely on information and communication technologies, in a world that purports to be "smart", there is a great need for a universal, accurate, yet simple system for coding geographic locations.

2 UNIVERSAL LOCATION INDICATORS

2.1 Maidenhead square system and USNG

A very worthy idea for resolving the issues mentioned above is to use so called locator grids. The world is thus divided into rectangular areas, where each area is coded by an alphanumerical string.

Maidenhead square system has been derived from an older grid locator system, the QRA. It has been intended for denoting locations of radio transmitters for VHF communication, and has been and still is in use, manly by amateur radio operators. This grid locator system divides the world into a grid of 18 by 18 fields, each of which is divided into 10 by 10 squares, with each square further being divided into 24 by 24 sub-squares. Thus, the coding string for the Maidenhead squares is composed from 2 latin letters, from A to R, then 2 digits, from 0 to 9, then another 2 latin letters, from A to X. An example of the Maidenhead code (MHC) for the premises of Alfa University has been presented here, together with its geographic coordinates :

$$\lambda_{\mathrm{LON}}(\mathrm{ALFA}) = +20^{o}24'54'' = +20.415^{o}$$
$$\lambda_{\mathrm{LAT}}(\mathrm{ALFA}) = +44^{o}18'40'' = +44.311^{o}$$

$$\mathrm{MHC(ALFA)} = \mathrm{KN04ET}$$

The Maidenhead square system in its original form has limited precision, but an extension has been proposed. Thus, the sub-squares may be divided even more, with each division adding two more digits, and then two more letters to the locator code, and so interleaved on. All in all, there is a lot of merit in the Maidenhead square grid locator system.

Another well developed grid location system is the American grid locator system, the USNG (United States National Grid). On the top level, it is very similar to the Maidenhead squares, but it differs significantly as to the sub-divisions of the top level grid fields. USNG system is intended for civilian use, whereas the American military uses an almost identical system, the MGRS (Military Grid Reference System). Both of these American grid encoding systems divide the world map into 60 by 22 squares, with polar areas subdivided separately. These top level squares are then being recursively subdivided into smaller squares up to final resolution of about 1 m. The location is encoded by an ASCII alphanumerical string, i.e. by Latin letters and digits, whose length depends on the required precision. The maximum precision is thus encoded by a string of 15 characters. There are, in fact, two slightly different versions of codes, NAD 83 and NAD 27. This is due to the different reference points used for determining exact geographic coordinates. Thus, the USNG code for the Alfa University is (in both versions) :

(NAD 83) 34TDQ5334306594
(NAD 27) 34TDQ5334206378

The resolution of these codes is about 1 m. Shorter codes, comprising nine characters, locate the University premises within a square the length of a side is about 100 m : 34TDQ5334. Here the locator code is the same for both reference points.

Both the Maidenhead squares and USNG are global in extend, and can indicate the location of any object or region on the globe. Similar grid coordinate systems exist, and nearly every country has defined one, for military, surveying, or other purposes. Still, they are mostly mutually incompatible, and cannot be used globally.

2.2 Universal geographical indicator system

In this work, the authors propose a new, universal geographical, truly global, indicator system for a grid based geographic coordinates. It has been inspired mainly by the Maidenhead squares, but there are significant differences.

In this Universal Geographical Indicator system, the locations are coded as strings comprising only digits from 1 to 9. Thus the reading of the code is not so much culturally biased as is the case for the previous two systems, which use also Latin letters.

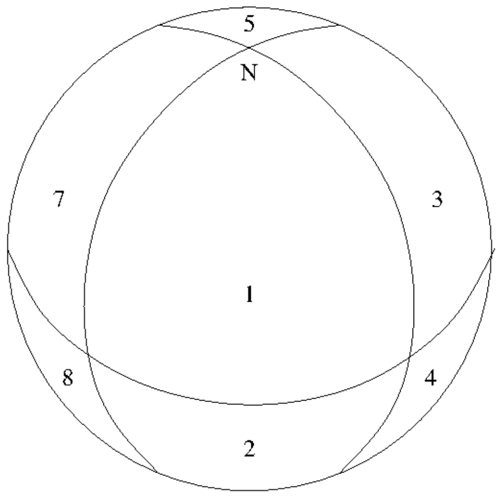

Figure 1 The numbering of the globe octants

This new geographic locator system has been conceived to be extremely simple to interpret and to use.

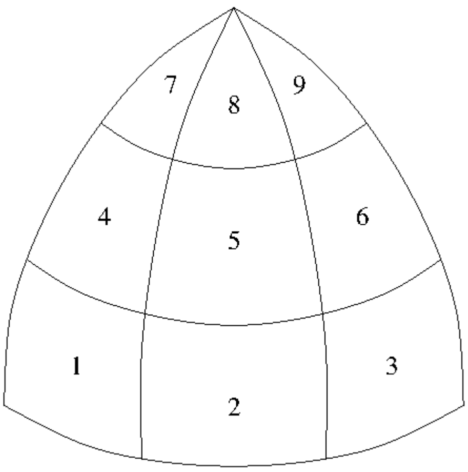

Figure 2 The numbering of sub-divisions of one octant

The globe has been divided into eight octants, encoded by digits from 1 to 8 (Figure 1). This is the first symbol of the proposed geographic locator code. On a world map (in cylindrical projection) the octants appear as squares or rectangles (Figure 7).

Table 1 The limiting square dimensions at number of locator code digits

Number of code digits	Angular size [^{o}]	North - South length	East - West length at $\lambda_{\mathrm{LAT}} = 0^o$	East - West length at $\lambda_{\mathrm{LAT}} = \pm 60^o$
1	90	10010 km	10010 km	5005 km
2	30	3337 km	3337 km	1668 km
3	10	1112 km	1112 km	556 km
4	3.33333	371 km	371 km	185 km
5	1.11111	123 km	123 km	65 km
6	0.37037	41.2 km	41.2 km	20.6 km
7	0.12346	13.7 km	13.7 km	6.76 km
8	0.041152	4.57 km	4.57 km	2.29 km
9	0.013717	1.53 km	1.53 km	763 m
10	0.004573	508 m	508 m	254 m
11	0.001524	169 m	169 m	84.8 m
12	0.00051	56.5 m	56.5 m	28.3 m
13	0.00017	18.8 m	18.8 m	9.42 m
14	0.000056	6.28 m	6.28 m	3.14 m
15	0.000019	2.09 m	2.09 m	1.05 m

Each octant has been further divided into nine fields of equal angular dimensions i.e. 30^o (Figure 2). These nine fields are being coded by digits from 1 to 9. This is the second symbol in the proposed locator code. Again, on a map in cylindrical projection, the fields obtained by sub-division may be seen as squares (Figure 8).

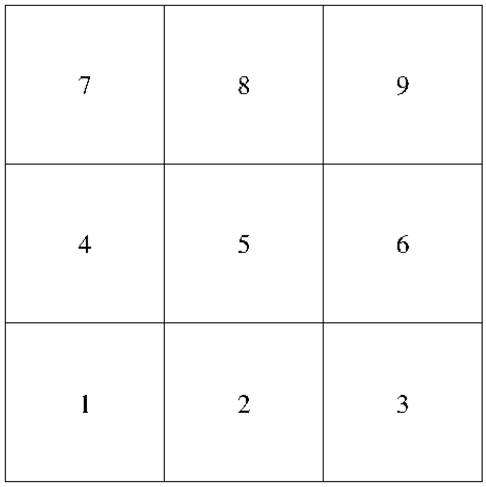

Figure 3 The numbering of sub-divisions of one locator square

Of course, on each level of sub-divisions the actual form of the locator square is not a true planar square but rather a trapeze on the surface on a sphere (Figure 5). As the recursive sub-divisions progress, the curvature of the sphere is of diminishing importance, and the form of the locator area approaches a planar square, or a rectangle. The dimensions, both angular and linear, of a sub-division square are presented in Table 1. It should be noted that, as a consequence of the sphere geometry, whilst the angular dimension of a locator square is the same for both dimensions on one level, the longitudinal linear dimension becomes shorter as the position of the square becomes closer to the poles.

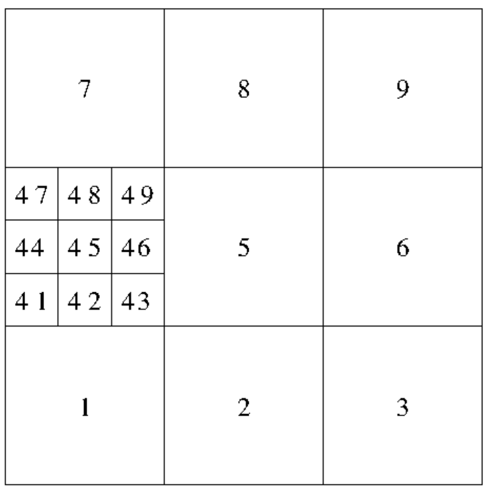

Figure 4 An example of numbering of two levels of sub-divisions of a locator square

Each such locator "square" is being divided into nine divisions of equal angular size. The nine sub-divisions are, again, denoted by digits from 1 to 9 (Figure 3). This is the third digit in the locator code. These sub-divisions are continued recursively, until the size of the locator square of a required size has been reached. The same pattern of allocating digits to sub-squares is applied on each level sub-divisions (Figure 4).

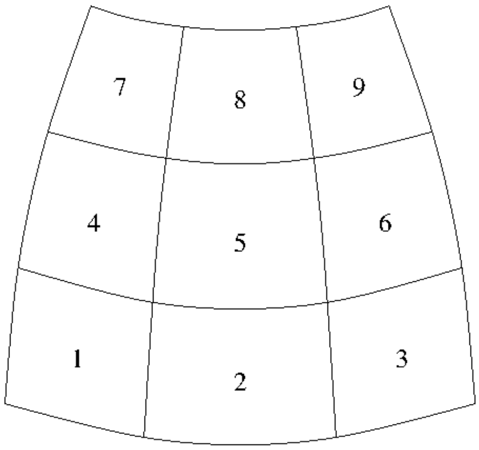

Figure 5 Thenumbering of a primary, curvilinear, locator square

Another particular issue of the geometry of the divisions is that the locator "squares" that are nearest to the poles in reality of triangular shape, even if approximately flat (Figure 6). Still, the same scheme for allocating digits to sub-divisions remains in use.

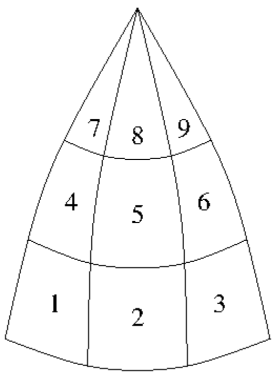

Figure 6 The numbering of a locator triangle, with its apex at the geographic pole

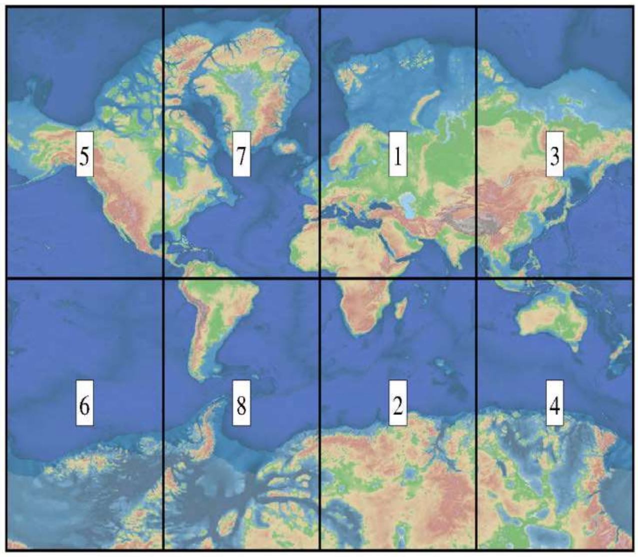

Figure 7 The world map divided into octants

In summary, advantages and disadvantages of the Universal Global Locator Indicator system have been listed:

There are several significant advantages :

The Universal Global Locator Indicator covers the whole surface of the earth.

The location is encoded using only digits from 1 to 8 at the first place, and then digits from 1 to 9.

The production and the interpretation of the code is simple and straight forward, and does not require complicated computations nor extensive use of data bases.

It is adaptable, whereby longer codes are used for greater precision of location determination.

The code may be adapted for other purposes, e.g. digit 9 at the first place may be used to indicate locations mobile units.

The length of location codes may be significantly shortened if used regionally, for which purpose the prefix digits may be completely omitted.

There are, however, some disadvantages:

The tolerances of location indication is non uniform, the East - West tolerances are reduced for locations closer to the poles.

There may be some difficulties of interpreting locations of objects which straddle the grid lines.

However, these and other disadvantages may be overcome with some modifications. In particular, digit 0 is so far unused, and some interpretations of the location codes may be made different for codes containing digit 0.

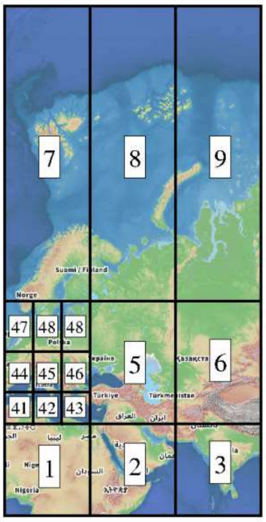

Figure 8 The numbering of the first and second level sub-divisions of the first octant shown on the world map

3 UNIVERSAL GEOGRAPHICAL LOCATION INDICATOR FOR ALFA UNIVERSITY PREMISES

In this section, the Universal Geographical Location Indicator code has been derived for the Alfa University premises. The global location indicator code has been determined to the length of 12 digits. The code is

$$\mathrm{UGI(ALFA)} = 146\text{-}445\text{-}124\text{-}168$$

The maximal width of the containing square i.e. rectangle determined by this code is about 56 m. This length is in the direction North - South, whereas the length in direction East - West is about 39 m. The reasons for this have been explained in the previous section. That means, that the maximal tolerance of location is about 28 meters, which is deemed to be sufficient for the establishing a correct location of a building of this size.

Table 2 Twelve digit numerical global location code for Alfa University premises

Digit	Numerical code	Location tolerance
1	1	5005 km
2	4	1668 km
3	6	556 km
4	4	185 km
5	4	62 km
6	5	20.6 km
7	1	6.7 km
8	2	2.3 km
9	4	763 m
10	1	254 m
11	6	84.8 m
12	8	28.3 m

The digits of the Universal Geographical Indicator code with the maximal tolerances of location of the corresponding code length are presented in Table 2.

In the rest of this section, several images have been presented, which show the location of the Alfa University on the world map, and the extent of the encompassing rectangles containing this location.

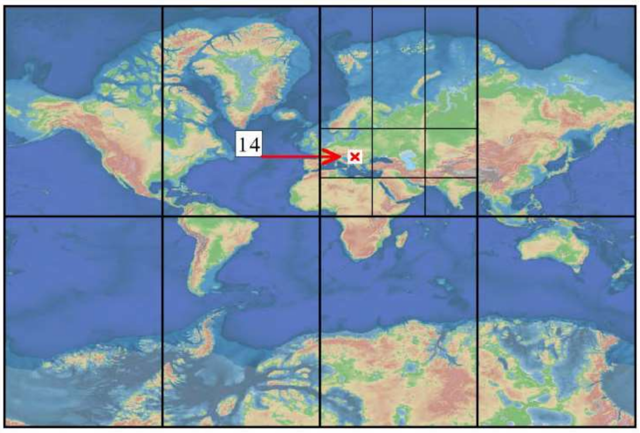

Figure 9 Determination of the locator of ALFA University, digits 1 and 2

Figure 10 Determination of the locator of ALFA University, digits 4 and 5

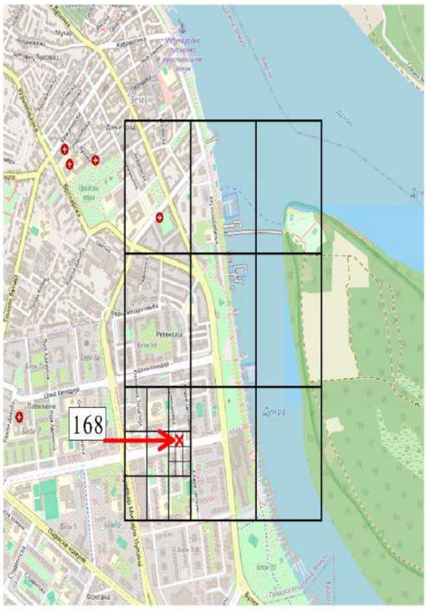

Figure 11 Determination of the locator of ALFA University, digits 10, 11, 12

4 CONCLUSIONS

In this work, a new version of a grid-based system of geographic coordinates has been presented. The principal idea is that the top level division of the surface of the globe is in 8 octants, and all subsequent sub-divisions are performed uniformly and recursively. The indicator code comprises only digits, the first digit being one from 1 to 8, and all subsequent digits being from 1 to 9. The system has some significant advantages over some similar existing grid coordinate systems. The Universal Geographical Location Indicator is truly global, it covers the surface of the whole earth. The length of the universal global indicator code depends on the required tolerance of location determination, and is freely adaptable according to the required precision. Also, the code is purely numerical, an as such it may be considered to be appropriate and understandable globally. The spectrum of uses of this geographic locator codes is wide, from their being used as postal codes, over the use in emergency and rescue operations, to surveillance of territories and water bodies. It is unambiguous, universal, simple to interpret, and as such may be integrated into various information technology systems pertaining to smart cities, and to smart land and water management.

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