An Evaluation of Location Encoding Systems

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Abstract

Many parts of the world, and probably a majority of the world's population, lack street addresses [1]. The falling prices of smartphones, and their increasing adoption, could provide a solution that would allow GPS location signals to be made visible and usable as addresses. To do this, there needs to be a way for the location information to be encoded so that people are able to communicate locations to each other. This document explains the attributes that we feel are important to such an encoding system, and evaluates a number of existing encoding systems against the requirements.

Desired Attributes

We spent some time debating what attributes a location code should have. The list we came up with was, in no particular order:

- Codes should be short enough that they can be memorised;
- A code should be sufficient on it's own, not requiring additional information such as country name;
- To prevent confusion, a place should have only one code.
- Codes should not include easily confused characters (e.g., 0 and O, 8 and B etc);
- Codes should not include profanity, or preferably, any words in any language;
- It should be possible to look at two codes and tell if they are close together and even the direction. This will help people find their way and make the codes more usable;
- Codes should represent an area, not a point, where the size of the area is variable;
- Shortening a code should represent a larger area that contains the original location. A side affect of this is that nearby codes will have a common prefix;
- The code for a place should be deterministically generated, not requiring any setup or application;
- Codes should be able to be generated and decoded offline. Mobile data networks may not be ubiquitous or cheap;
- Codes should not depend on any one provider, so that there is no risk that they will stop working if one company goes out of business;

- The algorithm should be published publicly and be free to use;

Latitude and longitude

Latitude and longitude are signed numbers with different ranges. The order in which they are used matters - if reversed, they will represent a different location.

To express a location to roughly 10 meter accuracy (five decimal places), latitude and longitude require between 15 and 20 text characters ("0.39122,9.45225" to "-43.95134,-176.55053"). This is around double the length of a typical telephone number.

Latitude and longitude express a point location, and there is no universally accepted way to provide a location of something that is not a point, such as a football field, park or lake, other than by providing multiple points to enclose an area. Truncation of latitude and longitude doesn't make any real sense, since it just moves the location.

Cheap GPS devices have existed for at least 14 years [2], and yet latitude and longitude coordinates are still not widely used by people to specify locations. We think that this shows latitude and longitude have too many disadvantages to be adopted for a street addressing solution.

Geohash (geohash.org)

Geohash codes were designed to be used in short URLs to identify locations [3]. They use 32 characters in their symbol set made up of 0-9A-Z excluding "A", "I", "L" and "O". This means that Geohash codes can include vowels (and the digits "0" and "1" with a similar appearance to "O" and "I"). Geohash can generate codes that include words ("DRUGGED"), almost words ("ZUR1CH") and profanity. It also includes some easily confused characters, such as both "8" and "B".

Geohash codes are points. Truncating a code changes the location.

The length of a Geohash code depends on the number of decimal places of the coordinates. This can result in two codes, near each other, having differing lengths and this could be confusing in a street addressing context.

Geohash uses a binary algorithm that is quite elegant, but it results in five discontinuities (places where nearby locations have dissimilar Geohash codes) at longitude 180, longitude 0, the equator, and at the north and south poles. Longitude 180 and the poles are acceptable due to the low populations but the equator and longitude 0 have multiple population centers along them .

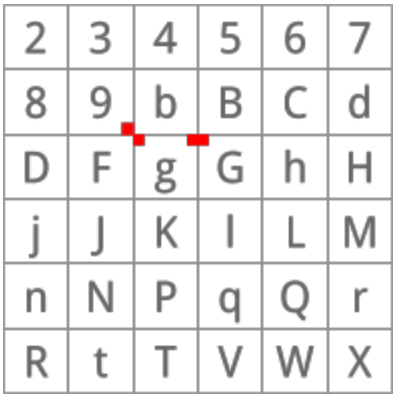
A single location can have more than one code, depending on the input values, and multiple different codes can decode to the same value. For example, "c216ne", "c216ne4" and "c216new" (and others) all decode to the same coordinates (45.37 -121.7).

Geohash-36

Geohash-36 codes are designed for URLs and electronic storage and communication rather than human memory and conversation [4].

Geohash-36 does not include vowels but does include both lower- and upper-case versions of some letters ("b" and "B"). It also includes characters that can be easily confused ("6" and "b", "8" and "B").

Geohash-36 is based on a 6x6 grid where each cell is identified by a character. This causes codes over a boundary to be dissimilar even though they may be neighbours:



9x, g2, g7 and G2 code locations compared.

With just two levels, we can see that the cell "g2" (red, upper left of the cell marked g) is next to the cell 9X, but further from g7 (which is next to G2). Using real Geohash-36 codes, "bdg345476Q" is next to "bdbtTVTXWB" but several kilometers from "bdg3Hhg4Xd".

Geohash-36 codes may be one character shorter than full Open Location Codes for similar accuracies.

The Geohash-36 definition includes an optional altitude specification, and an optional checksum, neither of which are provided by Open Location Code.

MapCode (mapcode.com)

MapCodes can be defined globally or within a containing territory [5]. The global

codes are a similar length to Open Location Codes, but codes defined within a territory are shorter than full Open Location Codes, and a similar length to short Open Location Codes.

To decode the identifiers, a data file needs to be maintained and distributed. The identifiers are mostly ISO-3166 codes for the territory names which can lead to issues in disputed areas. Not all territory names are unique and the recommendation is to use a country-state (e.g., "US-AL") identifier in these cases.

MapCode codes represent points and cannot be truncated (although the territory identifier may be omitted within the territory). This can get codes as short as four characters, something Open Location Code can do but only within very small areas.

A single location can have multiple different codes. For example, Schiphol Airport in Amsterdam has the code (without a territory identifier) "VHWK5.G7YB", and codes (with territory identifiers) "NLD 8G.262", "NLD DCC.J5H", and "NLD N3V5.4PZ".

MapCode supports a variety of different character sets, e.g., Hindi, Cyrillic, Greek. This increases usability in non-latin countries but causes challenges distinguishing visually similar codes such as "HH.HH" from the cyrillic "**НН**.**НН**". Open Location Code currently only supports a Latin character set.

Open Post Code (openpostcode.org)

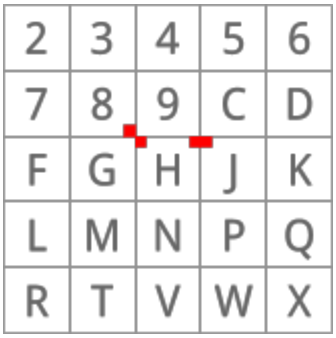
Open Post Codes can be defined globally or within a containing country [6]. The global codes are a similar length to Open Location Codes, but codes defined within a country are shorter than full Open Location Codes, and a similar length to short Open Location Codes.

Four countries are defined: Ireland, Hong Kong, Yemen and India.

Every location on the planet has a global code. Locations within the countries where Open Post Code has been defined also have a local code. These codes are completely dissimilar. For example, the global code 942G85NLMX is the same place as the Ireland code JKQQQXPG. If a global code is mistakenly entered as a country code, it will be valid but decode to a different location, and vice versa. The area and aspect ratio of a global code is not the same as the local code for the same coordinates, or a local code in another country, since it is a result of the aspect ratio used to enclose the country.

Open Post Codes decode to an area, and when truncated, expand the area. Open Post Codes can be truncated a single character at a time.

Open Post Codes use a 5x5 grid, meaning that two different codes may be closer together than two highly similar codes:



8x, H2, H7 and J2 code locations compared.

With just two levels , we can see that the cell "H2" (red, upper left of the cell marked "H") is next to the cell "8X", but comparatively far from "H7" (which is next to "J2").

Using Open Post Codes for Ireland, "KFLLLRFT" is the house next to "JKQQQXPG", but the more similar code "KFPLPX24" is a couple of kilometers away.

Open Post Codes have an optional checksum that can be used to distinguish the country a code was generated for.

Natural Area Code (nacgeo.com)

Natural Area Code is a proprietary system that requires licenses to use [7]. The codes are made up of up to three parts, the first provides the latitude, the second the longitude and an optional third part the altitude as the arctangent of the altitude relative to the Earth's radius in a suffix to a code [8]

Natural Area Codes do not support truncating. Although shorter codes represent larger areas, they do not necessarily share a prefix with the codes inside them. "J3 RQ" covers the city of Berlin, Germany, and the code "J39NL RQLLB" is contained within it.

The whitespace in the code is significant and removing it results in an invalid code (since it cannot be split into latitude and longitude). The codes do not include vowels, but do include "0" and "1" as well as characters that are easily confused ("8" and "B").

Natural Area Codes have a discontinuity at longitude 180 and at the poles.

Maidenhead Locator System (MLS)

Maidenhead Locator System codes explicitly represent areas, and can be truncated in a similar way to Open Location Codes. The accuracy and length of the codes is similar, but Maidenhead Locator System codes include vowels and so the

generated codes include words [9].

Maidenhead Locator System codes are based on an interleaving of latitude and longitude, and so are truncatable, and nearby locations have similar codes. It is only formally defined to a length of 8 characters.

Web-based services

There are a variety of web-based services that have recently been created, such as MyDoorHandle, What3Words and Zippr.

These sites provide a code that when entered on their site or used in a URL brings up a web page displaying the location. That much is similar to e.g., Geohash, but in contrast to Geohash, codes for a place may not exist until someone applies for them.

The codes may be pseudo-randomly generated and so nearby places may have completely different codes. It may be possible for multiple people to apply for codes for the same location and for different codes to be generated.

Making a mistake with a code may simply display somewhere else - for example, on What3Words, "banana rabbit monkey" is a location in Argentina, "banana monkey rabbit" is in Russia.

Some services charge money either for granting a code, for resolving codes or for allowing users to select their own short code.

These systems do not work offline and have a single provider. They appear to be more targeted towards being business directories, hosting additional information such as contact details, photos etc in addition to the location.

Open Location Code

We felt that the attributes of the above systems didn't sufficiently meet our requirements. As a result, we defined a new coding system and termed it Open Location Code.

Open Location Codes are 10 to 11 characters long. They can also be used in a short form of six to seven characters, similar to telephone numbers and postcodes, within approximately 50km of the original location. Within approximately 2.5km of the original location they can be shortened further, to just four to five characters.

To aid memorisation, we include a separator to break the code into two. To aid recognition, we use a "+" prefix to distinguish Open Location Codes from postcodes. Both of these characters are optional and omitting either or both does not result in an invalid code.

In their short form, Open Location Codes have from four to seven characters. These can be used on their own within 50km of the place, or globally by providing a city or locality within that distance. Full Open Location Codes require no other information to locate them.

There is only one Open Location Code for a given location and accuracy. Because for street addressing there are only two practical lengths, and they only differ by the last letter, we feel it meets this requirement.

The Open Location Code characters exclude easily confused character pairs. There is a risk that "VV" will be confused for "W" in handwritten messages but we consider this to be unlikely, since that would change the length of a code and this should be detected by the user or recipient.

The character set for Open Location Code was selected out of over eight billion possibilities, using a word list of 10,000 words from 30 languages. All possible sets were scored on whether they could spell the test words, and the most promising sets evaluated by hand.

The character set used to form Open Location Codes is not contiguous. This is a result of removing easily confused characters, vowels and some other characters. This does make manually comparing codes difficult, as one has to remember whether there are characters between 9 and C in order to tell if +8FW9 is next to +8FWC. However, we think that this is justified by the improved usability.

Nearby places have similar Open Location Codes. There are three discontinuities, at longitude 180 and the north and south poles, where nearby locations can have very different codes, but due to the low populations in these areas we feel this is an acceptable limitation.

With some practice, it is possible to estimate the direction and even very rough distances between two codes. Due to the way the codes are generated, latitudes are clipped to be greater than or equal to -90 and less than 90 degrees, making representing the exact location of the North Pole impossible although it can be very closely approximated.

Open Location Codes represent areas, and the size of the area depends on the code length. The longer the code, the smaller and more accurate the area.

Truncating an Open Location Code increases the area and contains the original location.

The codes are based on a simple encoding of latitude and longitude. The code for a place can be looked up by anyone and does not require any setup or configuration.

Open Location Codes can be encoded and decoded offline.

Open Location Codes do not depend on any infrastructure, and so are not dependent on any organisation or company for their continued existence or usage.

We are publishing the algorithm and making open source implementations available for anyone to use.

References

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