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AUTO-ID CENTER

TECHNICAL MEMO

The Graticule Coordinate Code

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ABSTRACT

The graticule coordinate system specifies the location of an object relative to the surface of the earth. This paper describes the graticule coordinate system and presents the Graticule Coordinate Code, a compact 104 bit representation of the graticule coordinate system that is capable of accurately representing the location of an object relative to the surface of the earth.

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Biography

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Daniel W. Engels received his B.S. from the University at Buffalo, his M.S. from the University of California, Berkeley, and his Ph.D. from the Massachusetts Institute of Technology all in Electrical Engineering and Computer Science. His master's thesis is in the area of computer-aided design for electronic systems, and his doctoral thesis is in the field of theoretical computer science. Dr. Engels joined the Auto-ID Center after obtaining his doctoral degree where he leads the day-to-day research activities of the Center. Dr. Engels' research interests include scheduling theory and applications, real-time system design, distributed and mobile computing, and computer-aided design for embedded systems.

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Contents

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1. INTRODUCTION

Uniquely identifying every location on earth requires a world wide geographic coordinate system. One such coordinate system used by mapmakers is the **graticule**. The graticule is the network of lines of latitude and longitude upon which a map is drawn [grab]. The graticule uniquely identifies every location on the surface of the earth; however, it does not uniquely identify locations above or below the surface of the earth.

The deficiency of the graticule is overcome with the addition of an altitude coordinate to form the **Graticule Coordinate System**. The Graticule Coordinate System is a geographic coordinate system used for locating places relative to the surface of the earth. The Graticule Coordinate System consists of three coordinates, latitude, longitude, and altitude.

Figure 1: The graticule. Figure reproduced from GeoSystems [graa]

THE THREE COORDINATES OF THE GRATICULE COORDINATE SYSTEM

1.1. Latitude

The equator is an imaginary line around the earth that is exactly midway between the poles. The equator divides the earth into the Northern Hemisphere and the Southern Hemisphere. **Latitude** is the angular measurement of a place expressed in degrees North or South of the equator. The equator is a line of latitude. The other lines of latitude are lines north and south of the equator that run east-west around the globe parallel to the equator. Consequently, lines of latitude are also referred to as **parallels**.

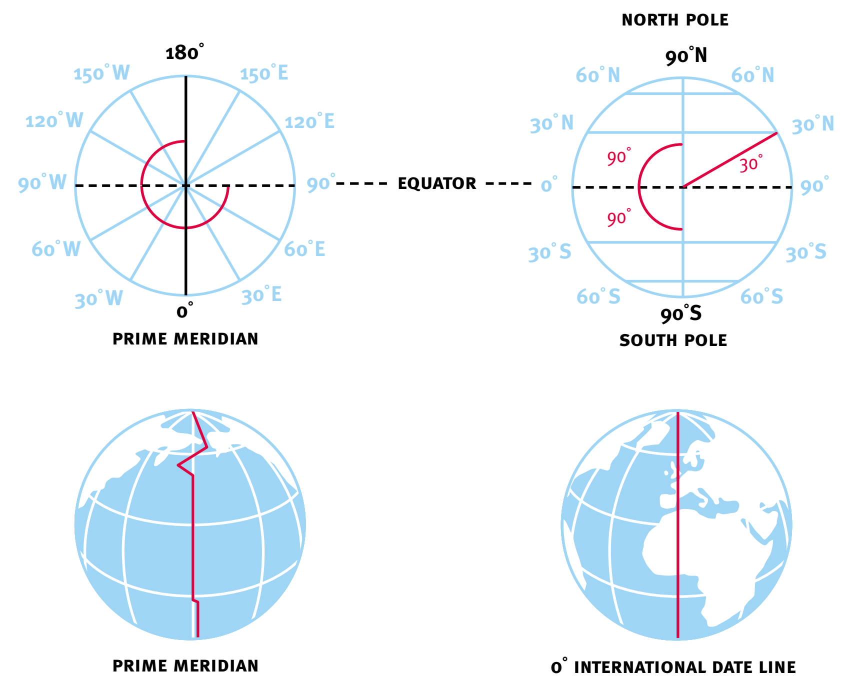
Latitude values are measured in degrees from the equator. Thus, the equator is at 0 degrees latitude. The distance from the equator to the North Pole is one fourth the distance around the earth. The earth, as a circle, is divided into 360 degrees; therefore, the North Pole is at 90 degrees north latitude. Similarly, the South Pole is at 90 degrees south latitude.

1.2. Longitude

The Prime Meridian is an imaginary line that runs along the surface of the earth from the North Pole to the South Pole through the original site of the Royal Observatory. The Prime Meridian is also known as the Greenwich Meridian since the original site of the Royal Observatory was located at Greenwich,

Figure 2: Latitude and longitude lines defined. Figure reproduced from GeoSystems [graa]

LATITUDE AND LONGITUDE LINES DEFINED

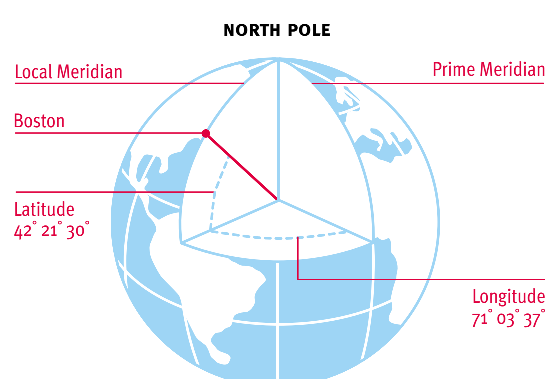


just outside of London, England. **Longitude** is the angular measurement of a location East or West of the Prime Meridian. The Prime Meridian is a line of longitude. The other lines of longitude are imaginary lines that run from the North Pole to the South Pole along the surface of the earth. Lines of longitude are also referred to as **meridians**.

Each meridian travels halfway around the earth. Along this imaginary journey it crosses each line of latitude exactly once. These intersections mark a unique location for every point on the surface of the earth.

Figure 3: Calculating the degrees for latitude and longitude. The place located at 42°21'30"N71°03'37"W is city center, Boston, Massachusetts, U.S.A. Figure reproduced from GeoSystems [graa]

CALCULATING THE DEGREES FOR LATIDUE & LONGITUDE



Longitude values are measured in degrees east and west from the Prime Meridian. Thus, the Prime Meridian is at 0 degrees longitude. The distance from the Prime Meridian to the meridian on the opposite side of the earth from the Prime Meridian is one half the distance around the earth traveling east or west. Therefore, the meridian opposite the Prime Meridian is located at 180 degrees east longitude. Equivalently, it is located at 180 degrees west longitude. The International Date Line follows the 180 degree meridian, making a few jogs to avoid cutting through land areas. Lines of longitude meet at the poles only. Thus, lines of longitude are furthest apart at the equator.

1.3. Altitude

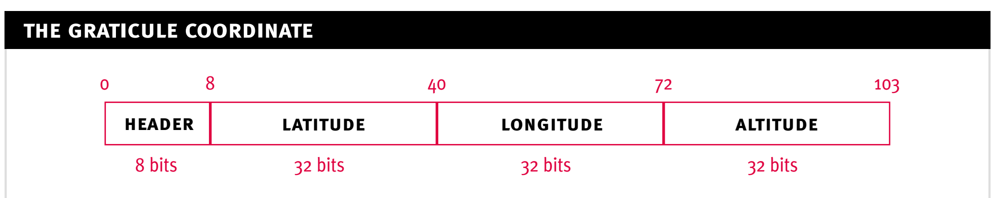
The **sea level** is an imaginary sphere, centered at the center of the earth, with a radius of 6378 km. The surface of the sea level sphere corresponds to the mean level of the oceans on earth. **Altitude** is the vertical measurement of a location above or below the sea level of the earth. The sea level is a sphere of altitude. The other spheres of altitude are imaginary spheres, centered at the center of the earth, with minimum radius of 0 meters.

Altitude values are measured in meters from the sea level. Thus, the sea level is at 0 meters altitude. The center of the earth has an altitude of – 6378000 meters. The beginning of the Thermosphere has an altitude of 200000 meters.

2. THE GRATICULE COORDINATE CODE

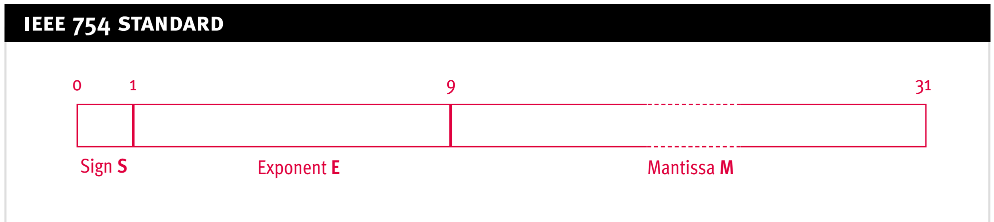
The **Graticule Coordinate Code** is a compact 104-bit representation of the graticule coordinate system. The Graticule Coordinate Code consists of four partitions: header, latitude, longitude, and altitude as shown in Figure 4. The header corresponds to the 8 left most bits of the Graticule Coordinate Code. The header is used to indicate the version number of the Code. The latitude, longitude, and altitude partitions consist of 32 bits each, with the latitude corresponding to the bits adjacent to the header, and the altitude corresponding to the 32 right most bits of the Code.

Figure 4: The Graticule Coordinate Code bit layout.



Each of the coordinates is represented with a 32-bit floating point number. The 32-bit floating point numbers are represented using the IEEE 754 32-bit floating point standard [IEE85] illustrated in Figure 5. The 754 standard comprises a 23-bit mantissa field **M**, an 8-bit exponent field **E**, and a sign bit **S**. The base B for the number is 2. The sign bit **S** occupies the leftmost bit position. The sign bit **S** and the mantissa **M** form a sign-magnitude binary number. The magnitude part of the 754 number is normalized such that it does not contain any insignificant leading bits. Therefore, the magnitude part of a normalized sign-magnitude number always has 1 as its most significant bit. There is no need to store this leading 1 since it is known to exist and may be regenerated easily. Consequently, the complete mantissa in the 754 standard is actually 1.**M**, where the 1 to the left of the binary point is an implicit or ‘hidden’

Figure 5: IEEE 754 standard 32-bit floating point number format.



EXPONENT BIT PATTERN	UNSIGNED VALUE E	SIGNED VALUE BIAS = 127
111 – 11	255	+ 128
111 – 11	254	+ 127
100 – 00	128	+ 1
011 – 11	127	0
011 – 10	126	– 1
000 – 01	1	– 126
000 – 00	0	– 127

leading bit that is not stored with the number. The exponent representation is the 8-bit excess-127 code shown in Figure 6; therefore, the actual exponent value is computed as E – 127.

A 32-bit floating point number conforming to the IEEE 754 standard represents the real number given by the formula

$$N = (-1)^{S}\, 2^{E-127}(1.M)$$

provided $0 < E < 255$.

The Graticule Coordinate Code uses positive and negative numbers to indicate direction for the three coordinates: latitude, longitude, and altitude. The latitude has values that range from – 180 to 180. All negative values correspond to degrees West of the Prime Meridian, and all positive values correspond to degrees East of the Prime Meridian. The longitude has values that range from – 90 at the South Pole to 90 at the North Pole. All negative values correspond to degrees South of the equator, and all positive values correspond to degrees North of the equator. The altitude has values that range from – 6378000 to + ∞. All negative values correspond to meters below sea level, and all positive values correspond to meters above sea level.

The absence of a coordinate value is given when **E** = 255 and $M \neq 0$. The IEEE 754 standard defines this value as NaN, or Not a Number.

3. REFERENCES

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2. **[grab] Merriam-Webster's Collegiate Dictionary.**
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3. **[IEE85] IEEE. IEEE Standard for Binary Floating-Point Arithmetic (ANSI/IEEE Standard 754–1985),**
   August 1985.