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Quantification of Near-Earth Objects Between 1990-2021: An Overview

Osuji Emmanuel Uchenna, Ugwu Monday, Aernan Andofa, Ojima Ocheni, Aneke Ukpabi, Wash Albert, Madike Emeka Michael, Justus Chukwunonyerem, Okolo Obinna, Okoro Emmanuel Chineche, Okpara Richard Tobechi, Vincent Osinachi Ezinwa, Ekechukwu Uzoamaka, Obasi Rita Chioma, Ezenwukwa Nnenna Dorathy

National Space Research and Development Agency-Center for Basic Space Science, University of Nigeria, Enugu, Nigeria

Email address:
chukwujus@gmail.com (Justus Chukwunonyerem)

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Abstract: In this work, the quantification of Near-Earth Object (NEO) has been carried out between 1990 to 2021. The emphasis is to examine the total number NEO discovered, the relationship between them and the earth-orbit especially with respect to their magnitude and distance (objects, aphelion and perihelion). Three categories of data (Amors, Apollos and Atens) were sourced from Minor Planet Center data repository (minorplanetcenter.net//iau/lists/Unusual.html), based on their orbital revolution and the pattern. Exploratory data analysis (EDA) of 5700 NEOs samples using python analytics was carried out and the result shows the average distribution of minimum distance between earth-orbit and NEOs. The result also shows yearly distribution of mean distance and magnitude. Furthermore, out of the 5700 NEOs analyzed, 22.9% were found to be potentially hazardous asteroids (PHAs) with higher possibility of an encounter with the earth, found at 0.01AU distance from the earth-orbit.

Keywords: Quantification, Near-Earth Object, Earth-Orbit, Asteroids

1. Introduction

The study of NEOs furthers the understanding of the initial conditions in the proto-solar nebula and sets important constraints on the formation of the solar system in an era when exoplanet discoveries seem to have complicated the classical scenario of planetary formation [1]. Further-more, NEOs can help us answer fundamental questions about the presence of water and organics on the early Earth as well as life itself. Recent astro-biological studies suggest that it is plausible that comets and NEOs are responsible for the delivery of organic and pre-biotic molecules to the Earth [2]. The study of the physical characteristics of NEOs is also compelling in view of the potential hazard posed to our planet [3]. NEOs are linked with all kinds of meteorite falls, from the recent Chelyabinsk event [4] to the occasional catastrophic impact events (like the K-T event [5].

In case of possible impactors, their physical characterization is crucial to defining successful mitigation strategies [6]. Unfortunately, more than 85% of the ~18.000 known NEOs still lack a compositional characterization, and their increasing discovery rate (currently 1.900 objects year) makes the situation progressively worse.

A broad range of diversity in terms of composition and spectral properties is also present among the NEO population. All the taxonomic classes in the main belt, the predominant source region for NEOs, are represented in the distribution of NEOs taxonomic types. However, the S-complex is by far the most common type of NEOs observed, while at the moment the C-complex objects only account for 15% of the taxonomic distribution [7]. The underrepresentation of the C-complex and generally of low albedo NEOs is even more un-usual considering that they represent the majority of the main belt population [8].

There is growing evidence that this could be due to an observational bias among taxonomic types which favours the discovery of small and bright silicate asteroids rather than big and dark carbonaceous asteroids [9]. Thermal infrared surveys, like NEOWISE, suggest that 35% of all NEOs discovered have low albedos [8]. Furthermore, it has been shown in [10, 11] that even thermal fragmentation can destroy preferentially dark bodies, reducing faint, and dark carbonaceous material to a size limit below which they are no longer detectable.

Near-Earth Chronology list (2021) publication from NASA asserts that, for an object to be classified as potential hazardous asteroid (PHA) it must be within the near-earth object perimeter and also have magnitude (diameter) of H < 22mag and its orbit most come within < 0.04 or less [12, 13].

NEOs below a few hundred metres, deserve attention since they greatly outnumber the larger objects, thus increasing their chances of impact with the Earth. An object that is a few hundred meters in diameter, is capable of causing severe regional damage [14]. Because of the potential threat to human civilization posed by NEOs, several space agencies and international organizations are currently studying how to plan in advance, possible countermeasures that could mitigate NEO impact [15, 16]. In view of this, this research is aimed at studying the total number of objects that are found within and close to the earth orbit from 1990 to 2021.

2. Methodology

The data for this research was sourced from minorplanetcenter.net//iau/lists/Unusual.html (Minor Planet Center, 2021). The minor planet center (MPC) web page is part of International Astronomy Union (IAU) and collaboration with National Aeronautics and Space Administration (NASA) planetary defense coordination. The data from this web page used in this research are Amors, Apollos and Atens. These three categories of data are based on their orbital revolution and the pattern created by the movement (MPC, 2021).

According to MPC (2021), Amors - whose orbits advancing however do not pass Earth orbit, and whose orbits are far from the Sun than Earth's orbit. Many have orbits which are living absolutely among Earth and Mars. Some of those are economically appealing in close term. Apollos -- whose orbits crosses Earth's orbit. Apollos spend maximum of their time out of the Earth orbit. Many of these are economically appealing in near term. Technically, they have wider orbits than Earth; while, Aten -- whose orbits also crosses Earth's orbit, however in contrast to Apollos, Atens spend maximum of their time inside Earth orbit. A greater percent of discovered Atens were economically attractive in near term.

Using Python and exploratory data analysis (EDA) method, the total number, mean distance, median of distance and standard deviation of all the object closer to the earth’s orbit was found. The results of the study are presented with tools such as histogram, graph, tables, asteroids estimator (center for near earth objects study, 2022), correlation matrix and scatter plot. Histogram was used to highlight the distribution pattern of those objects from 1990-2022. Tables and Bar graph were utilized to present the mean distribution between the earth orbit and the objects, magnitude of the objects, aphelion distance, perihelion distance, the number of objects discovered each year and their percentages. The largest and the smallest object, in terms of its magnitude, that made the closest approach were also considered- conversion from magnitude to kilometre was done using an online calculator and albedo estimate of 0.05 gotten from center for near earth objects study (Canoes, 2022). The conversion of astronomy unit (AU) to Kilometre (Km), that 1AU=149597870.691KM, was used in computing the result. The correlations of all the variables were also analysed using correlation matrix. Scattered plot was used to point out the distribution pattern of perihelion distance and the eccentricity of the near-earth object. Regression model was carried out using supervised machine learning to establish nature of the association between aphelion distance and perihelion distance.

3. Results and Discussion

A total of 28,836 data objects/samples were found and downloaded. These number of objects includes; Amors, Apollos and Atens from 13th August 1898 to April 27th 2022.

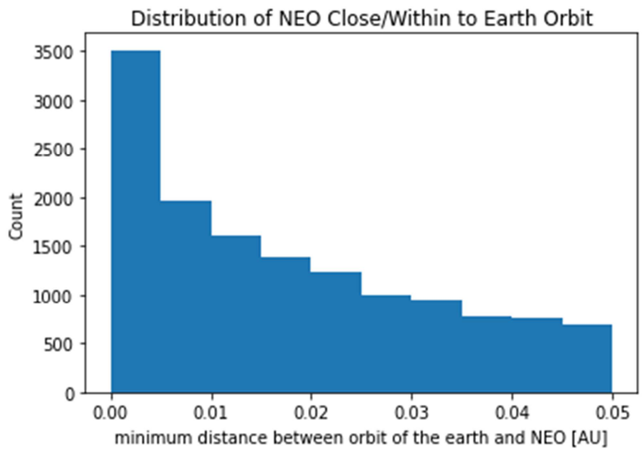

Figure 1. *Histogram showing the NEO distribution.*

Out of the 27643 raw data downloaded, 5700 objects satisfied the criteria for near-earth objects. The data shows that about 50% of such objects are found within 0.00AU to 0.02AU- the distance between the earth orbit and the NEO.

Figure 1 above shows that 39.7$^{o}/_{o}$ of the NEO are within 0.00 to 0.01 astronomy unit (AU). The objects within this space includes- meteors, comets, asteroids, and auras of different shapes and sizes.

The summary statistics of the distance of NEOs from the earth orbit:

Mean distance = 0.016987;

Median = 0.027192, and

Standard deviation of distance = 0.014185.

The graph in Figure 2 shows the distribution of yearly NEO discovery within the year in study. The increase in the yearly number of NEO discovered is not far-fetched from the advancement and sophisticated modern instrument used in dictating NEO. A greater number of NEOs were discovered in the last decade and much more discovery should be expected in the coming years. The year with least number of discoveries is 1992, whereas, the highest discovery was made in the year 2021.

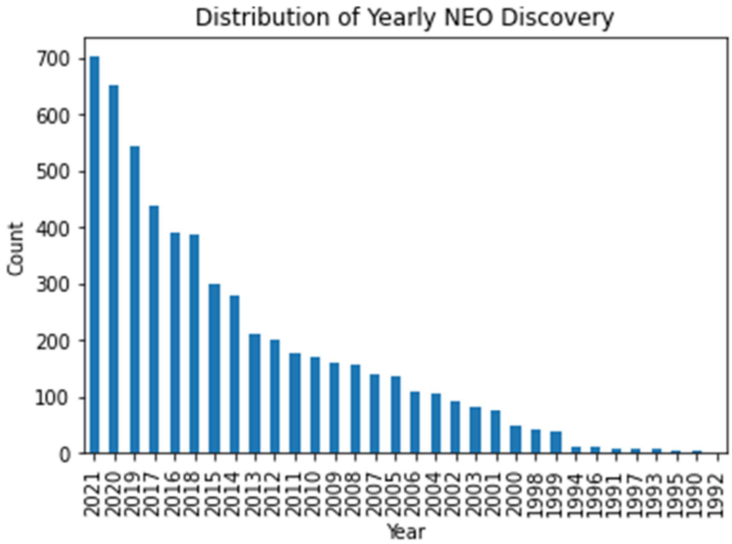

Figure 2. *Distribution of yearly NEO discovery.*

Table 1. *The mean distance distribution of minimum distance between earth orbit and NEO [AU], Aphelion Distance, Perihelion Distance with the total number discovered each year.*

S/N	Discovery Year	minimum distance b/w earth orbit and NEO [AU]	Mean Aphelion Distance [AU]	Mean Perihelion Distance [AU]	NEO Number discovered	NEO Number discovered [%]
1	1990	0.155228	2.757440	0.919560	8	0.06
2	1991	0.109672	2.548350	0.855200	19	0.14
3	1992	0.147022	2.400333	1.008100	6	0.04
4	1993	0.117479	2.478575	0.961350	14	0.10
5	1994	0.116071	2.840170	0.940894	22	0.16
6	1995	0.150788	3.041394	0.881758	7	0.05
7	1996	0.095259	2.627578	0.876089	22	0.16
8	1997	0.121925	2.801075	0.907868	18	0.13
9	1998	0.126613	2.652716	0.893417	74	0.52
10	1999	0.138770	2.789326	0.923630	70	0.51
11	2000	0.140413	2.719623	0.911174	120	0.87
12	2001	0.125736	2.685179	0.918088	156	1.13
13	2002	0.123312	2.698270	0.896421	180	1.30
14	2003	0.120603	2.772690	0.906364	168	1.21
15	2004	0.105577	2.593944	0.873382	256	1.85
16	2005	0.106022	2.716730	0.895740	273	1.97
17	2006	0.104819	2.681547	0.908451	276	1.99
18	2007	0.098177	2.662677	0.900298	309	2.23
19	2008	0.094722	2.615816	0.905275	373	2.69
20	2009	0.091223	2.664072	0.913777	380	2.74
21	2010	0.099346	2.613242	0.909954	415	2.99
22	2011	0.097108	2.673369	0.919561	403	2.91
23	2012	0.091928	2.623722	0.928254	467	3.37
24	2013	0.096263	2.667655	0.914851	477	3.44
25	2014	0.100564	2.674734	0.943880	662	4.78
26	2015	0.096424	2.579901	0.923273	714	5.15
27	2016	0.091203	2.593258	0.922871	943	6.80
28	2017	0.080679	2.863884	0.915335	1107	7.99
29	2018	0.074455	2.528653	0.920907	1047	7.56
30	2019	0.077728	2.639545	0.913816	1369	9.88
31	2020	0.075540	2.531738	0.913201	1669	12.04
32	2021	0.068682	2.473099	0.913818	1836	13.25

Table 1 shows the average distribution of minimum distance between earth orbit and NEOs, aphelion distance, perihelion distance and the number or percentage of objects found within the earth orbit. The year with the most discoveries is 2021, having $13.25^{o}/_{o}$ (1836 objects discovered) of the total number of discoveries between 1990 to 2021. The year 2021 has the average minimum distance 0f 0.068682AU, 1995 has the farthest aphelion distance of 3.041394, while 1991 has the least average perihelion distance of 0.855200.

In addition to Table 1 above, Figure 3 has shown that the year with minimum distance is 1993 having 0.007 and also, the year with highest diameter with magnitude 17.8 as displayed in Figure 4, Whereas, the year with the mean maximum distance is 1991 with the mean distance of 0.028AU in Figure 3. The year with higher magnitude is 2021, having magnitude = 25.3 in Figure 4.

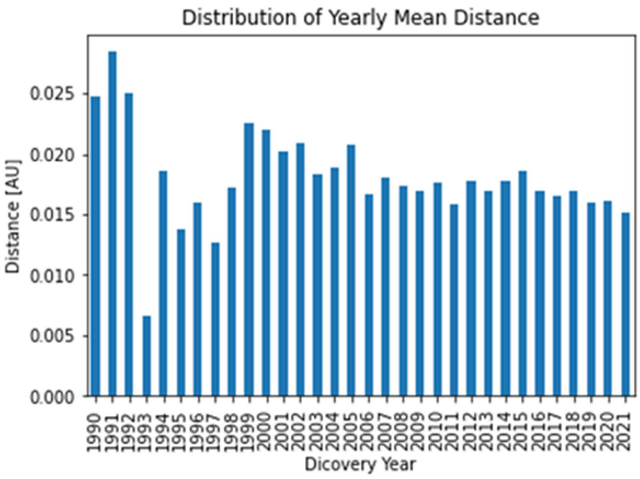

Figure 3. *Distribution of yearly mean Distance.*

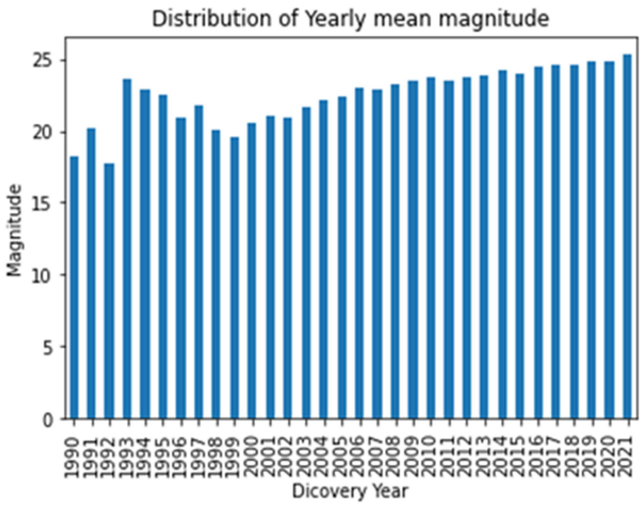

Figure 4. *Distribution of yearly mean magnitude.*

Furthermore, out of the 5700 NEOs, $22.9^{o}/_{o}$ are potential hazardous asteroids (PHAs). The PHAs that have higher possibility of having an encounter with the earth were found at 0.01AU distance from the earth orbit which constitute $9.7^{o}/_{o}$ of the total list of PHAs. The devastation on impact of any of these asteroids that finds its way into earth atmosphere and reaches to the surface would be disastrous to life and properties on the earth surface. Amongst the risk list, 1993 EA is found to be the closest (distance = 13463.81Km) and with high approximate diameter (4.4Km), more details about 1993 EA characteristics are found in Table 2 below, while the smallest of the objects that made the closest approach is 1990 UN, also see table 2 below.

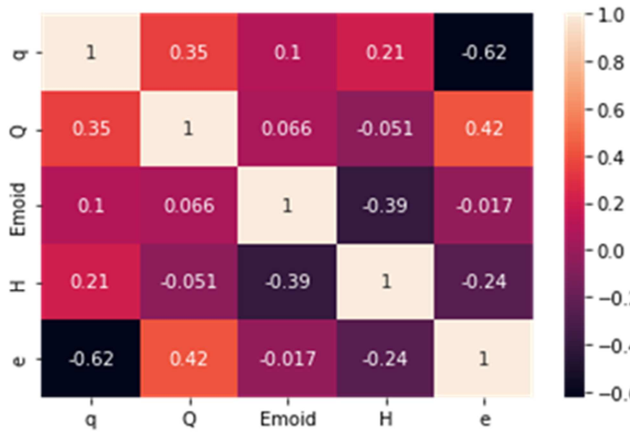

Figure 5. *The correlation matrix.*

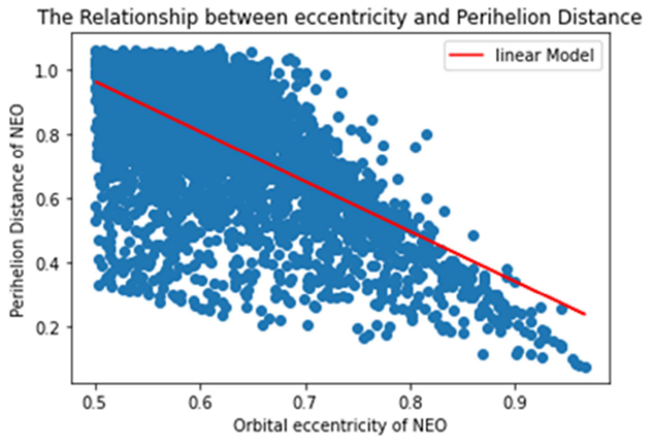

Figure 6. *Linear regression.*

Table 2. *The largest and smallest object closest to the earth orbit.*

S/N	Provisional Designation	Perihelion distance (Km	Aphelion distance (Km)	Distance of NEO from earth orbit (Km)	magnitude
1	1993 EA	27974801.82	182509402.24	13463.81	15.64
2	1990 UN	11519036.04	147503500.50	0.00	22.01

Figure 5 is the 5 × 5 correlation matrix of parameters (Q: aphelion distance, Emoid: distance between NEO and the orbit of earth, H: magnitude of the object in space). The matrix is grounded on spearman's rank correlation coefficient (r_s). from Figure 5, the values of the coefficients range from -0.051 to 0.066 and the variables that are negatively strong associated to each other are q (perihelion distance) and e (eccentricity) which is -0.65 in the correlation matrix, r_s=1 in the figure 5 is the correlation of the variables in question are correlated to itself.

$$y = -1.56x + 1.74 \quad (1)$$

Furthermore, Figure 6 is linear regression model of the association that exist between perihelion distance and eccentricity; the duo linear regression coefficient is -1.56 and 1.74 is the intercept of the linear model equation (see eq 1). What this means is that to every increase in the perihelion distance there is 1.56 decrease in the orbital eccentricity. When the decrease in eccentricity continues, it reaches zero where the perihelion distance is at its peak, which is 1.74; the reverse is also applicable for an increase in eccentricity. The eccentricity is maximum where there is a decrease of 1.56 in the perihelion distance reaches its lowest limit.

In view of the linear regression model, it is uncovered that the eccentricity is a major factor that influences perihelion distance of NEOs from the earth's orbit.

4. Conclusion

The quantification of Near-Earth Object Between 1990 to 2021 with particular emphasis in examining the total number of discoveries of NEO has been carried out. Also found in this work is the relationship between the near-earth objects and the earth-orbit with keen interest in ascertaining the magnitude, distance (objects, aphelion and perihelion) of Near-Earth Object (NEO) from the earth-orbit for the period of 31 years. 5700 NEOs data samples sourced from Minor Planet Center data repository; minorplanetcenter.net//iau/lists/Unusual.html; were analysed using python analytics and exploratory data analysis. The results of the data analysis also show yearly distribution of mean distance and yearly distribution of mean magnitude. Furthermore, out of the 5700 NEOs analysed, 22.9% were found to be potentially hazardous asteroids (PHAs) with higher possibility of an encounter with the earth, found at 0.01AU distance from the earth-orbit.

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