SPARK Program Student Research Project, Summer 2022

Optimized Risk Assessment For Potentially-Hazardous Space Objects

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Outline

1. Motivation

1. Concepts

1. Results

1. Drawbacks and Possible Improvements

1. Conclusion

Motivation

Motivation

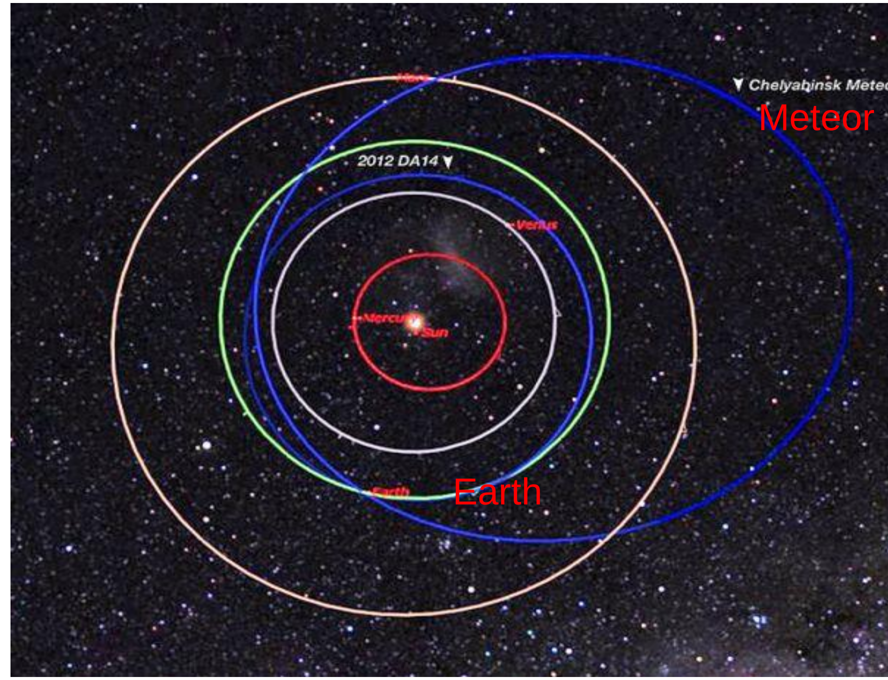
- The 2013 Chelyabinsk Asteroid was a Near-Earth Object(NEO) that was only observed 3 hours AFTER the incident.
- “Per current understanding of the asteroid population, an object like the Chelyabinsk meteor can impact the Earth every 10 to 100 years on average.”(*Phys.org, 2019)*
- The first airburst witnessed by modern humans was in 1908 in the Tunguska River in Siberia where over 500,000 acres of land was flattened by the burst of energy.
- Both instances were resolved by the natural defenses of Earth alone.

An Impact Event, Source: http://en.wikipedia.org/wiki/Impact_event

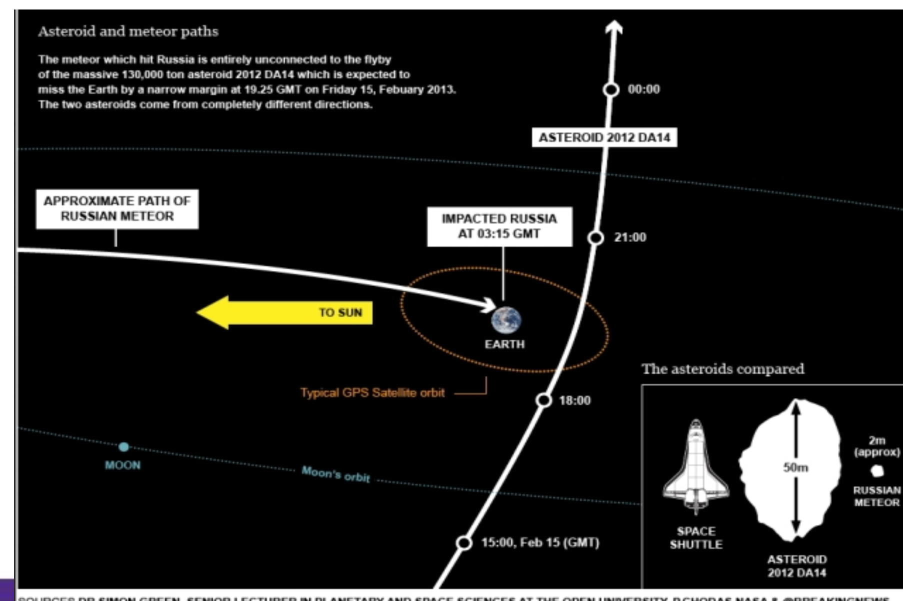
Trees flattened by the intense shock wave created in the atmosphere as the space rock exploded above Tunguska on June 30, 1908. Credit: Wikimedia Commons

Motivation

- Since 2013, NASA has developed a program to find new asteroids and categorize their probability of impact
- NASA's NEO Database uses the Palermo scale(a mix of energy yield and impact probability) alongside 40 other parameters to conduct their classification. Due to extensive distance of these meteors, it isn't too conclusive for drastic scenarios.
- Objective: To optimize the classification of NEOs based on relevant parameters in mapping drastic instances to envision potential events in the future.



http://blogs.nasa.gov/cm/blog/Watch%20the%20Skies/posts/post_1361037562855.html



Concept

Airbursts: Meteors that have combusted due to an influx of wind resistance and friction that causes gradual disintegration of the rocky material.

Some detonate into airbursts high above the ground. These explosions create shockwaves strong enough to break windows.

Credit:https://www.businessinsider.in/slideshows/miscellaneous/how-large-asteroids-must-be-to-destroy-a-city-state-country-or-the-planet/slidelist/64806811.cms#slideid=64806826

This Equation determines the height of burst of an entering meteoroid into an airburst from its density, volume, and velocity.

$$z_{b,1\%} = 13 - 6.04\log_{10}E_{Mt} - 0.88\left(\log_{10}E_{Mt}\right)^2$$

$$z_{b,50\%} = 25.7 - 7.83\log_{10}E_{Mt} - 0.31\left(\log_{10}E_{Mt}\right)^2$$

$$z_{b,99\%} = 47.9 - 8.43\log_{10}E_{Mt} - 0.03\left(\log_{10}E_{Mt}\right)^2$$

Credit: ***A numerical assessment of simple airblast models of impact airbursts* - Gareth S. Collins,Elliot Lynch,Ronan McAdam,Thomas M. Davison**

Concept

$$E_{mt} = 1/2(p \times V) \times v^2$$

Emt= Energy in Megatons(1J= 2.39x10^-16) , p=3400 kg/m^3, V= 4/3 *pi*(r)^3
All in terms of Meters

My Calculations(y):

Chelyabinsk(2013):
Emt = ~0.681Mt
Altitude = ~26.9 km

Tunguska(1908):
Emt = ~24.5Mt
Altitude = ~14.22 km

Actual Measurements(y*):

Chelyabinsk(2013):
Emt = ~0.5Mt(*Collins,2017)*
Altitude = ~27.6 km

Tunguska(1908):
Emt = ~15Mt(*Collins,2017)*
Altitude = ~14.48 km

Reasons for Error

- Spherical Volume
- Generalized Densities

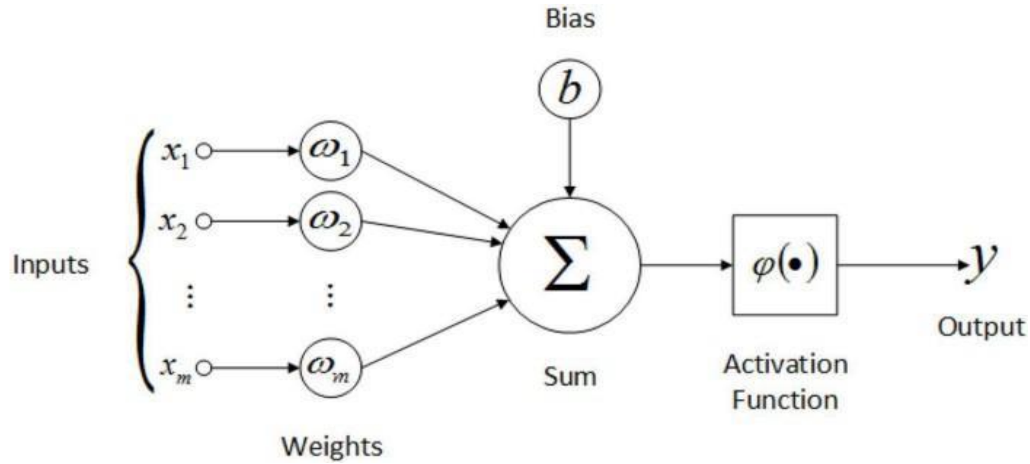
Neural Network Concept

- Derives ‘Hazardous’ status(0 or 1) from 3 parameters: Diameter, Velocity, and Burst Altitude.

- Normalized the data for the parameters and the target value and minimized loss in every interaction.

- Simply, introducing burst altitude as a parameter reconfigured the weights of the activation function to achieve the desired status.

Name	Absolute Magnit	Est Dia in KM(m	Close Approach	Epoch Date Clos	Relative Velocity	Miss Dist.(Astror
3703080	21.6	0.1272198785	1995-01-01	788947200000	6.115834389	0.4194825299
3723955	21.3	0.1460679643	1995-01-01	788947200000	18.11398503	0.3830144627
2446862	20.3	0.2315021222	1995-01-08	789552000000	7.590711162	0.0509560159
3092506	27.4	0.0088014652	1995-01-15	790156800000	11.1738745	0.2853223297
3514799	21.6	0.1272198785	1995-01-15	790156800000	9.840831054	0.4078321707
3671135	19.6	0.3195618867	1995-01-15	790156800000	10.80884396	0.3927847844
2495323	19.6	0.3195618867	1995-01-15	790156800000	10.80884159	0.392783196
2153315	19.2	0.3841978911	1995-01-22	790761600000	24.42188399	0.1291791611
2162463	17.8	0.7320739893	1995-01-22	790761600000	17.37378384	0.3582829267
2306383	21.5	0.1332155667	1995-01-22	790761600000	12.89960972	0.1518057418
3444370	22.4	0.0880146521	1995-01-22	790761600000	22.42136631	0.2010399884
3448992	25.8	0.0183888672	1995-01-22	790761600000	17.27461146	0.4310155871
3611400	25	0.02658	1995-01-22	790761600000	12.11850995	0.3598014121
2162854	19.1	0.4023045798	1995-02-08	792230400000	10.82992629	0.4306559914
3446396	18.8	0.4619074603	1995-02-08	792230400000	39.60532791	0.3009631412
3764806	25.2	0.0242412481	1995-02-08	792230400000	25.21128858	0.4959739922
3314405	20	0.2658	1995-02-15	792835200000	3.089003929	0.2388244997
3426410	21	0.1677084622	1995-02-15	792835200000	20.01924193	0.4780869949
3666785	22.3	0.0921626549	1995-02-15	792835200000	8.526320844	0.4612592433
3702321	22.7	0.0766575574	1995-02-15	792835200000	7.919524045	0.1072710745
3719196	26.1	0.0160160338	1995-02-15	792835200000	4.655478593	0.2554883015



Cite:https://medium.com/analytics-vidhya/feed-forward-neural-networks-intuition-on-forward-propagation-f77468fad625

Results

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Truly hazardous by the neural network is:
0.30168551312139963
Not hazardous is:
0.6983144868786004
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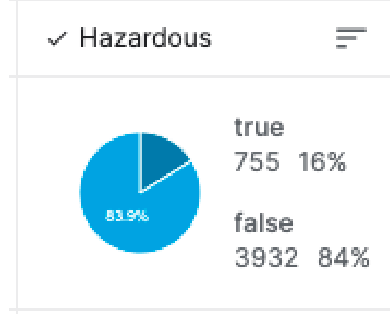

- The hazard levels with the sole parameters of velocity, diameter and burst altitude were 30% and 70%.
- The target values were 16% and 84%
- Despite the changes, this proves interesting results.
- When compared to Chelyabinsk, these hazard percentages showed.
- Most optimal epoch was 5 after many runs that led to a close, but still a bad fit

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Chance of being a hazard:
0.7606144655429913
Chance of not:
0.2393855344570872
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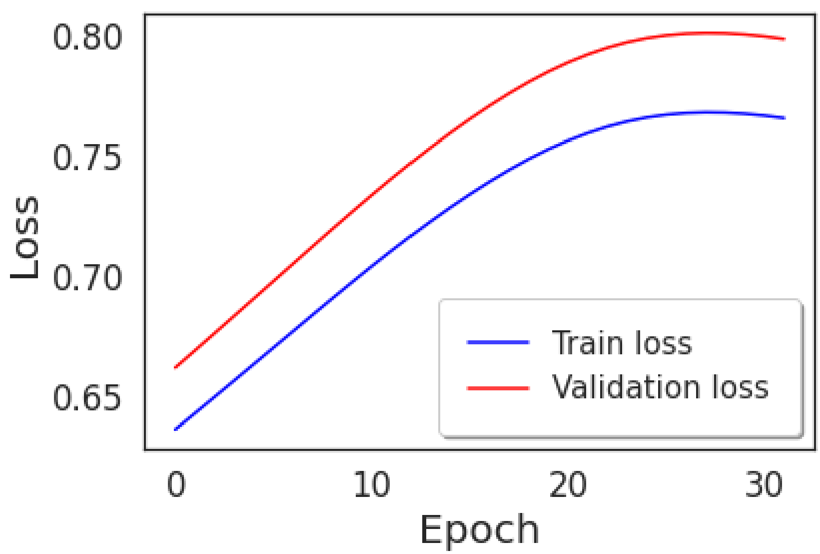
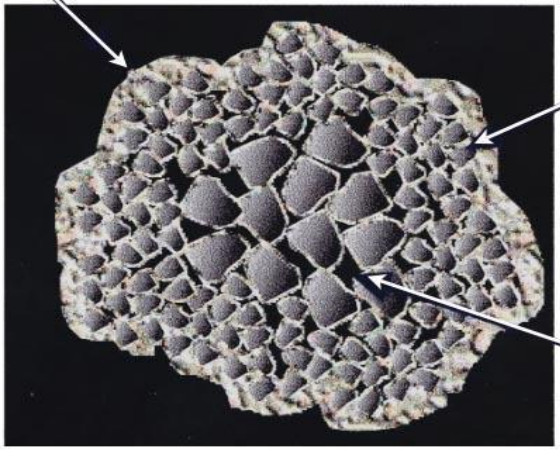


Possible Drawbacks

- Generalized features of Meteors(density, volume, and composition)
- Additional factors(dispersion rate, air density, porosity)
- Limited correlation between model and data

An illustration of an asteroid in space. Credit: NASA/JPL/Caltech

Impacts break down surface into regolith



Friction keeps smaller material closer to the surface (prevents from moving further down)

Largest voids typically found towards center of asteroid

https://skyfallmeteorites.com/education-research/glossary/rubble-pile-asteroid/

Future Suggestions

- Correlate model with data that is solely dependent on the parameters chosen.
- Experiment with a combination of multiple other parameters aside from the three chosen.
- Classify asteroids based on composite material to better understand density, porosity and volume of meteors.
- Establish a special criterion for drastic scenarios over using pre-established results

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Questions?