Project 2 – Comets and asteroids

METHODS AND DATA ANALYTICS FOR RISK ASSESSMENT

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Summary

1 Abstract

The aim of this report is to explain and justify the hazard conditions caused by comets and asteroids exploiting the properties of Bayesian Networks.

2 Types of nodes

In our model there are 8 nodes that capture the characteristic of the impactor and its level of risk:

- Technology development (ranked with 5 states): it expresses with the accuracy of human's tools;
- Actual frequency (ranked with 5 states): represents the probability for an object of a certain size to impact with the Earth in a given number of years represented by the ranks;
- Object frequency (ranked with 5 states): represents the frequency of object detected thanks to the available technology;
- Observed number of objects per intervals (ranked with 6 states): represents the frequency of the observed craters dimension[1];
- Impact magnitude (ranked with 6 states): node that deals with the size and speed of the object[2];
- Distribution crater dimension (integer interval partitioned expression of a normal): it is a continuous interval representing the probability distribution of craters;
- Distribution diameter size (integer interval T-normal): it is a continuous interval of the distribution of the probable dimension of the diameter of the object given the crater size; roughly, we divided crater size by 20;[3]
- Risk object impact (labelled with 6 states): it is the risk of the event;

Then there are 12 nodes that aim explaining the consequence of an impact on the planet:

- Generated dust time in weeks (continuous interval): node that analyses the dust generated after the impact of the object[4];
- Period climate change in years (continuous interval with arithmetic expression): represents how long the effects of the dust last on earth;
- Dust quantity (labelled with 6 states): this node represents the quantity of dust generated after the impact;
- Earthquake (labelled with 3 states): it deals with the probability of the occurrence of an earthquake of a certain magnitude;
- Tsunami (labelled with 4 states): it deals with the probability of the occurrence of a tsunami of a certain magnitude;
- Natural disaster (integer interval): this node agglomerates the data of tsunami and earthquake;
- Impact climate change (labelled with 4 states): represents the variation of temperature depending on dust quantity;
- Impact winter distribution (continuous interval with a partitioned expression of a Chi squared);

[1] All rights reserved (2020). "Meteoroids – a proposed classification by size" <https://www.spaceacademy.net.au/watch/debris/mdsclass.htm>
[2] All rights reserved (2011). "Speed of a Meteor" <https://www.mathscinotes.com/2011/07/speed-of-a-meteor/> © Mathscinotes
[3] All rights reserved (2020). "Earth impact database" <http://www.passc.net/EarthImpactDatabase/New%20website_05-2018/World.html>
[4] Toon, O. B. et all. (1990). Environmental perturbations caused by asteroid impacts. In Gehrels, T. (ed.), Hazards Due to Comets and Asteroids, p. 7 9 1 (Tucson: University of Arizona).

- Impact winter (Boolean): node representing the probability of occurrence of an impact winter[5];
- Flora and fauna percentage extinction (continuous interval):it depends on the climate change and on the Climate mitigation efficiency, it tries to express mathematically the percentage of flora and fauna extinction after the impact[6];
- Natural disaster impact on the economy (integer interval with a partitioned expression of a normal): it depends on Natural disaster and Natural disaster mitigation efficiency, it tries to express mathematically the percentage global GDP loss after the impact;
- Human losses (continuous interval of an expression type arithmetic): percentage of human losses due to an impact

Finally, there are 5 nodes that mitigate the impact:
- Anti-climate change technology and Anti-natural disaster technology (both ranked with 5 states): following the Bow-Tie model, they represent the mitigation measures that influence and circumscribe the consequences of the occurrence of the event;
- Climate mitigation efficiency (ranked with 5 states, partitioned expression of a T-normal): node mitigating the climate effects on flora and fauna;
- Natural disaster mitigation efficiency (ranked with 5 states, partitioned expression of a T-normal): node mitigating the natural disaster effects on the economy;
- Object invisibility (ranked with 3 states): it represents the level of reflectivity of the impacting body.

Other information can be found in the notes of our nodes on AgenaRisk.

2.1 Structure of the model & scenarios

The central node of the model is the "risk object impact": a risk metrics considering the object frequency and the impact magnitude (with different level of precision depending on the technology development). This node influences the "generated dust over time", the degree of natural disaster and the climate change on earth. Those nodes try to estimate the percentage of flora and fauna extinction and the disruption of global economy. They are mitigated by two ranked nodes, that try to express the efficiency of our "climate mitigation" and our "natural disaster mitigation".

The scenarios impacted are the following:

1)New geological tools are developed and in consequence the number of confirmed craters with a diameter larger than 10km is increased by 25 percent. What are the consequences for the probability that an impact winter will happen in the next 50 years?

2)Given that an impact winter has come about, what is the average size and standard deviation of the impacting object, according to your model?

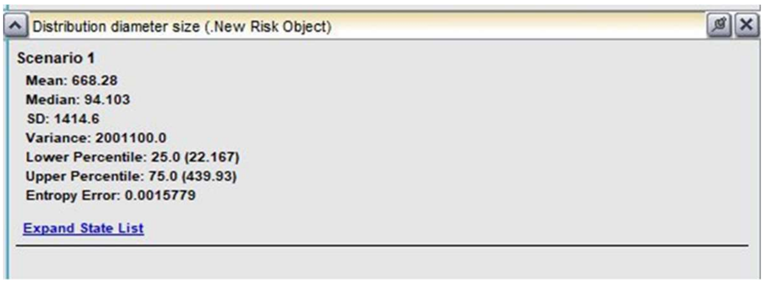
1) We started by considering the probability of an impact winter with a context of a high technology development and our actual crater size probability distribution. The results indicate that the

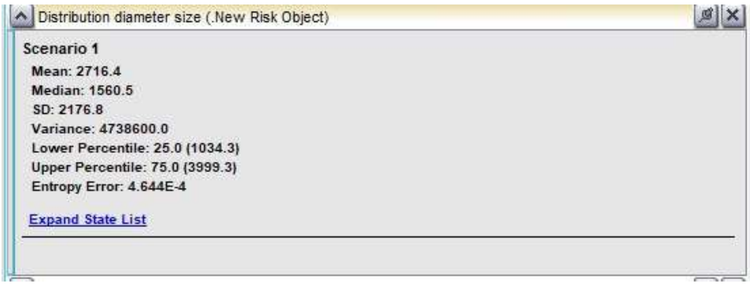
[5] Toon, O. B. et all. (1990). Environmental perturbations caused by asteroid impacts. In Gehrels, T. (ed.), Hazards Due to Comets and Asteroids, p. 7 9 1 (Tucson: University of Arizona).

[6] Anju Agrawal (2011) "Effect of Global Warming on Climate Change, Flora and Fauna" <http://www.informaticsjournals.com/index.php/JEOH/article/view/2261> © CSJM University, Department of Zoology, SN Sen BVPG College, Kanpur, India

probability of impact winter is 6.071%. Whereas, if we consider a 25% increase in the probability of crater with size greater than 10 km, the probability of an impact winter will be increased to 7.059%

2) Given an impact winter, the mean will be 2716.4m with a standard deviation of 2176.8m





3. Results, assumptions and weakness

3.1 Results

Without entering any observation, the risk of an impact of an object with the Earth is “Nothing” and the median value of observing a decrease in flora and fauna is 0.05% while the median value of observing a decrease of global economy due to a natural disaster is 0%. Instead, if we set the “Very High” scenario in the ”Risk object impact” node the median value of flora and fauna extinction is now 92% (mean 97%) while the median value of the impact of natural disaster on the economy is 72% (mean 73%) and the mean value of human loses is 89%.

3.2 Assumptions

There are some important assumptions that characterize our model:

- The crater size of the impactor is 20 times the diameter of the impactor based on consideration made by Napier (2008)
- Technological development increases our ability to consider new factors and variables with more precision (lowering the variance for instance)
- It is easier to mitigate a natural disaster than climate changes
- “Generated dust in weeks” and the impact winter are distributed as a Chi squared based on consideration made in Toon, O.B. et al. (1990)

3.3 Final consideration and weakness of the model

Our model analysed the impact of asteroids and comets only on the earth surface without considering their collision with the ocean, because it is difficult to compute crater dimensions after an impact on the ocean. We considered only dust generated from the impact without considering the one generated from asteroid's fragmentation from the main belt or due to comets going through the earth orbit. This is because it turned out that the effects following these events are minimal for our purposes. For instance, in the worst case scenario of this type, which is the event following a comet going through the earth orbit, there should be an increase in dust quantity from 40k tons a year of dust to 1-2M tons a year of dust, that would entail a dust quantity related to the earth surface equal to $2g/m^2$, which is very low. Finally, we considered object of a certain diameter (400m) since those with a lower diameter typically disintegrate in the atmosphere before even landing on the surface; moreover, given their small dimensions, their effects will not be relevant.

There are few other major weaknesses in the model. One is the fact that when a new research on the number and dimension of cosmic objects is carried out, it must insert manually in the model in the node "Percentage of objects per intervals". For instance, in the first scenario we manually increased the percentage by 25 % (12% in the interval between 8000 and 13000 m). We did not find a clear definition of impact winter, so we assumed that it is possible to refer to an impact winter when the average temperature of a region decreases of 20k (at least). Moreover, most of our distribution are sharply right skewed and the variance is very high. This happens probably because even if most asteroids have a diameter smaller then 650m there are few *outliers* with diameters larger than 6000 m.

4. References

Anju Agrawal (2011) "Effect of Global Warming on Climate Change, Flora and Fauna" <http://www.informaticsjournals.com/index.php/JEOH/article/view/2261> © CSJM University, Department of Zoology, SN Sen BVPG College, Kanpur, India

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