An Automatic Tool of Cleaning Space Debris by Improved Debris Evolution Model

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Abstract. Through consulting relevant literature, during the current solution for space junk, the relatively perfect theories are the following kinds, laser removal technology, satellite debris collector, space garbage trucks, suicide satellite, and resistance-increase device. we proposed An Automatic Tool of Cleaning Space Debris by Improved Debris Evolution Model

Introduction

With the continuous development of aerospace science and technology, mankind has developed the history of the space time and time again. However, the space junk, meanwhile, is growing over time. If we don't control or adopt measures to remove timely, the situation will become more dangerous. Through consulting relevant literature, during the current solution for space junk, the relatively perfect theories are the following kinds, laser removal technology, satellite debris collector, space garbage trucks, suicide satellite, and resistance-increase device.

Improved Debris Evolution Model Based on Genetic Iteration

Synthesizing sub-models listed above, after a certain simplifying assumptions, through the research for the movement of explosion, the distribution of the collision debriss and considering the influence of atmospheric perturbation for the debris orbit, we eventually get the debris' distribution in orbit.

The Orbit Distribution Transfer of Debris Caused by Explosion and Collision

Location of each fracture debris in the rupture of vertical distribution is unknown, so for the determination of debris distribution evolution not unique. We can take advantage of the motion law to analysis by iteration to get the optimal solution.

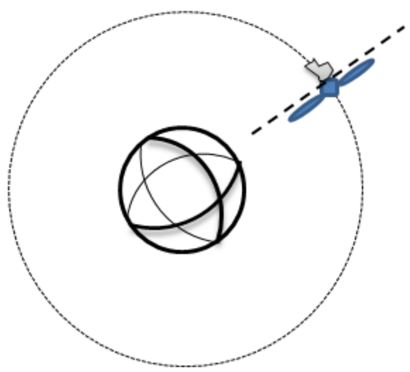

Figure.1 The principle diagram of the debris distribution

First we use $N(m)$ to represent the total number of space debris after exploding, considering $N_\theta(m)$ on the vertical Angle to represent the number of distribution of space debris.

Then depend on the motion law

We can get the following equation

According to the law of universal gravitation formula:

$$F = \frac{GmM}{r^2}$$

Atmospheric drag formula:

$$f = \frac{1}{2}c\rho s v^2$$

where c represents atmospheric drag coefficient, ρ stands for atmospheric density, s is the area and v means relative motion velocity.

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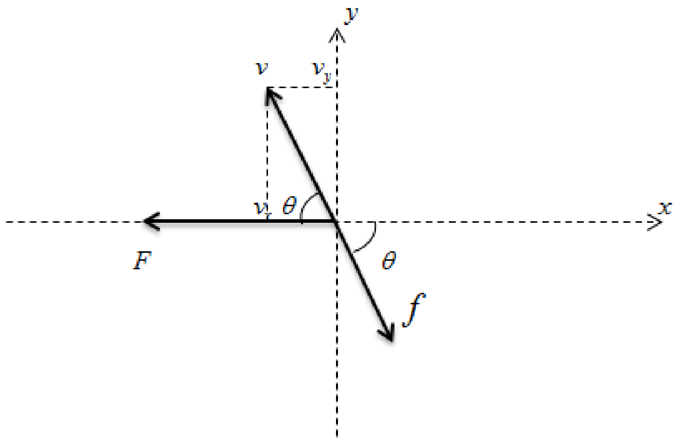

Figure.2 Motion law

Each θ space debris on the equation of motion:

$$\begin{cases} \frac{a_m}{r^2} - \frac{f}{m}\cos\theta = a_x & \Delta x = v_x t + \frac{1}{2}a_x t^2 \\ \frac{f}{m}\sin\theta = a_y & \Delta y = v_y t - \frac{1}{2}a_y t^2 \end{cases}$$

When v_x to slow down to zero , the debris will stop movement. In order to study the spatial distribution of the space debris, we adopt the geocentric equatorial coordinate system .

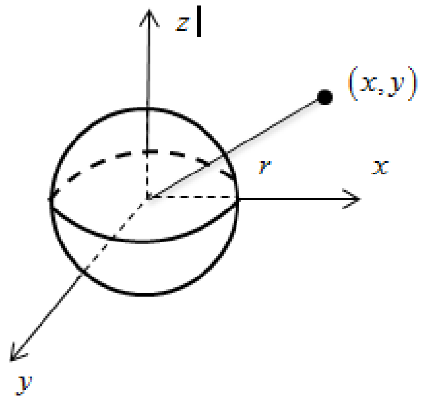

Figure.3 Geocentric coordinate system

We can get,

$$x^{'} = x + \Delta x \text{ , } y = y + \Delta y$$
$$(r, x, \mathrm{y}) \Rightarrow (r^{'}, x^{'}, y^{'})$$

By the following conversion we can get the final location after the evolution of space debris $\Delta N_{\theta}(m)$.

Here we use based on the genetic model of comprehensive evaluation of debris evolution to structure as the objective function

$$\min \; N_n(m) + \Delta N_{\theta}(m) - N_n^{'}(m)$$

$N(m)$ represents the fracture before each orbital debris distribution of $N_{\theta}^{'}(m)$ on behalf of the fracture after each orbital debris distribution of the observations number .

By putting $N_{\theta}(m)$ to be a iteration variable, we get the ideal space debris distribution evolution law eventually.

The Transfer of Debris Orbit's Distribution after Adding Atmosphere Perturbation

Because the atmospheric drag perturbation will only change the space debris orbit between the height of 150 km to 1200 km, through the atmospheric density model and space debris orbit life model, as well as the atmospheric drag perturbation theory, we can conclude the following formula:

$$\frac{da}{dE} = -a^2 k\rho(e + \cos E)^{\frac{2}{3}}(1 - e\cos E)^{-\frac{1}{2}}$$
$$\frac{de}{dE} = -a(1 - e^2)k\rho(1 + e\cos E)^{-\frac{1}{2}}\cos E(1 - e\cos E)^{-\frac{1}{2}} \;)$$

The atmospheric density can be expressed by the model of atmospheric density,

$$\rho = \rho_p \exp\left[-\frac{r - r_p}{H}\right]$$

What we do is integrate with respect to equation6-16， The total calculation time is very long because of step length. Calculation step length is 200 pieces of orbital period, and we calculate the variation quantity of a, e in 200 cycle variation, then we conclude;

$$\Delta a = \int_0^{400\pi} \frac{da}{dE} dE$$

$$= -400\pi a^2 k \rho_0 \exp\left(-\frac{a_0 e_0}{H}\right)\left[I_0 + 2eI_1 + O\left(e^2\right)\right]$$

Where I_1 represents the Bessel function of the first kind of virtual variable,

$$I_n = \frac{1}{400\pi}\int_0^{400\pi} \exp\left(-\frac{a_0 e_0}{H}\right)\cos nE dE$$

Like wise,

$$\Delta e = \int_0^{400\pi} \frac{da}{dE} dE$$

$$= -400\pi a^2 k \rho_p \exp\left(-\frac{a\ e}{H}\right)\left[I_0 + 2eI_1 + O\left(e^2\right)\right]$$

ρ_p stands for the air density at the near earth point, $k = C_D \frac{A}{m}, C_D = 2.2$, A is the cross-sectional area of the debris, m is the quality of the pieces.

We can get the change regulation of $\Delta a, \Delta e$ over time due to the cycle of debris $T = 2\pi\sqrt{\frac{a^3}{\mu}}$

$$\Delta a = \sqrt{a\mu} \cdot k\rho_p \exp\left(-\frac{ae}{H}\right)\left[I_0 + 2eI_1\right]200T$$

$$\Delta e = \sqrt{\frac{\mu}{a}} \cdot k\rho_p \exp\left(-\frac{ae}{H}\right)\left[I_0 + \frac{1}{2}e\left(I_0 + I_2\right)\right]200T$$

Here we don't consider the debris' impact of space distribution of orbital debris when the spacecraft launch. In the evolution model of debris, and we think that the orbit of space debris distribution transfer only depends on the fracture of space debris and atmospheric perturbation directly, by the model above, we can get the orbit distribution of space debris and the transfer of orbit.

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