SCUDEM 2019

---Movement Of An Object In Micrograviy Environments

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OUR TOPIC

Landing a probe in a microgravity environment

1). Closest location to predesignated point
2). Smallest dimensions of asteroid
3). Least amount of energy consumed to go to new location

Apollo 11 Lander

Step 1

Assumption I

-Rotating with respect to only one axis (assume z-axis)

-the angular velocity ω is time-invariant about this axis.

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$$\ddot{r} = \frac{1}{m}(-\nabla U(r) + F_{other}(r))$$

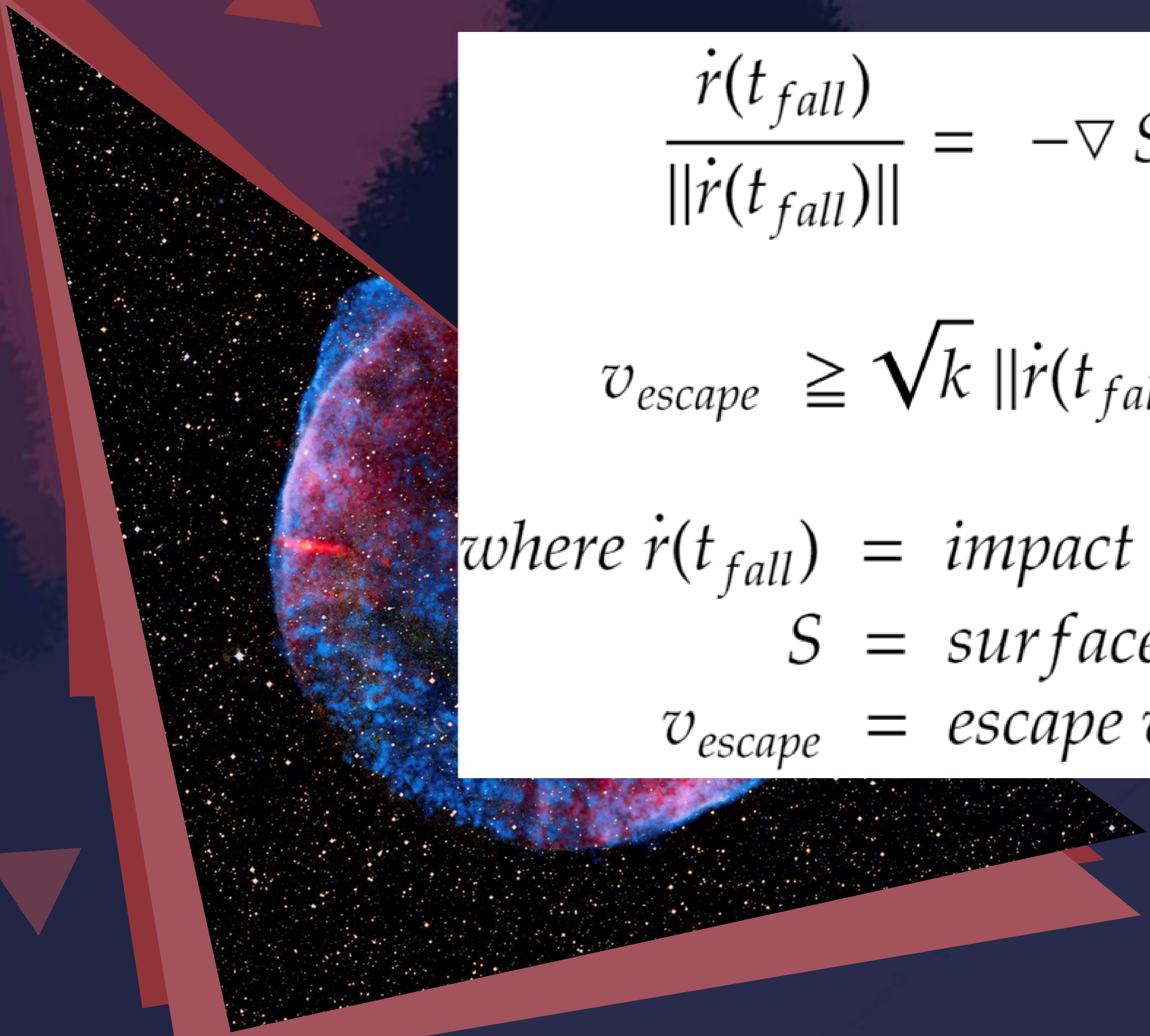
$$S_{new} = R_z(\omega t) \times S_{initial}$$

$$R_z(\omega t) = \begin{bmatrix} cos(\omega t) & -sin(\omega t) & 0 \\ sin(\omega t) & cos(\omega t) & 0 \\ 0 & 0 & 1 \end{bmatrix} (rotation\ about\ z - axis)$$

$$r(t,\ v_i) = x_{new} = R_z(\omega t) \times x_{old}$$

Our variables:

- F_other= External
- m = the mass of the probe]
- S_(initial) = initial surface estimation



$$\frac{\dot{r}(t_{fall})}{\|\dot{r}(t_{fall})\|} = -\nabla S$$

$$v_{escape} \geqq \sqrt{k}\, \|\dot{r}(t_{fall})\|$$

$$\begin{aligned} \text{where } \dot{r}(t_{fall}) &= \text{impact velocity} \\ S &= surface \\ v_{escape} &= \text{escape velocity} \end{aligned}$$

Asteroid Dimensions

Assumptions II

- Landing procedure is consistent throughout all asteroids
- Density of the asteroid is uniform throughout
- The radius of any given asteroid is the average of the highest and lowest point
- All the other forces oppose microgravity

Model II

01

Variables Introduced:

-asteroid density

G -gravitational constant (dependent on asteroid)

V -volume

$$V_{imp} = V_{esc}$$

$$V_{esc}^2 = \frac{2GM_{ast}}{R}$$

$$V_{imp}^2 = V_{esc}^2 = \frac{2GM}{R_{av}}$$

$$M_{Ast} = \rho * V$$

$$V = \frac{4}{3}\pi R^3$$

$$V_{imp}^2 = \frac{2G\rho\frac{4}{3}\pi R^3}{R} = \frac{8}{3}G\rho\pi R^2$$

$$R = \sqrt{\frac{3V_{imp}^2}{8\pi G\rho}}$$

$$M = \rho\left(\frac{4}{3}\pi\left(\sqrt{\frac{3V_{imp}^2}{8\pi G\rho}}\right)^2\right)$$

Step 3

Bouncing and using the least amount of energy

Assumptions III

- **Our model is in 2-D**
- **The path of bouncing can be tracked as a straight line;**
- **Micrograveity: gravity of the asteroid is the prominent factor for ballistic motion on the asteroid's surface.**

$$KE_i = k * KE_{i-1} \text{ where } k \in (0, 1)$$

$$\theta_i = \theta_{i-1}$$

$$R_i = \frac{v_i^2 \sin(2\theta_i)}{g} = \frac{k^{i-1} v_1^2 \sin(2\theta_1)}{g}$$

$$\text{After } n \text{ bounces, } R_n = \sum_{i=1}^{n} R_i = \sum_{i=1}^{n} \frac{k^{i-1} v_1^2 \sin(2\theta_1)}{g} = \frac{v_1^2 \sin(2\theta_1)}{g} * \frac{1-k^n}{1-k}$$

$$\text{After coming to rest, } R_{total} = \lim_{n \to \infty} R_n = \frac{v_1^2 \sin(2\theta_1)}{g(1-k)}$$

- K -coeffiction that reduces energy after each bounce
- Θ -the angel in each bounce
- R_1 -horizontal distance after each bounces

$$R_{total} - R_n = Error_{margin}$$

$$n = \frac{1}{\ln k} * \ln\left(1 - Error_{margin} \times \frac{g\,(1 - k)}{v_1^2\, sin\,(2\theta_1)}\right)$$

Additional Info

02

What role does the size and shape of the asteroid play in your model? If the size of the asteroid changes what impact does that have on your prediction?

- Unsymmetrical Shape of asteroid → Change in position of center of mass
- The position of center mass → magnitude and direction of microgravitional field
- Microgravitional potential → the escape velocity at any point
- Escape velocity → hopping and landing

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- The shape of the asteroid may allow high grounds around the predesignated point, which can interact with our probe's path before the probe lands on the target.

03

Thank you

Resources:

02

https://hackaday.com/2018/10/16/the-science-of-landing-on-an-asteroid/

https://www.krdo.com/news/national-world/japans-hayabusa-asteroid-rovers-send-back-first-footage/800522364

https://www.space.com/41941-hayabusa2-asteroid-rovers-hopping-tech.html

https://www.youtube.com/watch?v=nXKgL7XCkkE

https://www.youtube.com/watch?v=8H4aZX_8hMA