ORBYS

Data Visualization

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Contents

Introduction

This project, named Orbys, aims at visualizing data on asteroids orbiting in the Solar System. It is based on not one but actually three sources of data. The first one comes from Miriade, a tool developed by the Institut de mécanique céleste et de calcul des éphémérides (IMCCE) [1]. This tool allows us to compute positional ephemerides of known solar system bodies in real-time. A dataset retrieved from JPL Small-Body Database [2] is also use to have more physical information on displayed asteroids. A sample of some features from this dataset that are used in this project is presented in table 1 .

feature	description
diameter	body diameter in km
albedo	geometric albedo
rot_per	rotation period in hours
GM	standard gravitational parameter: product of the gravitational constant G and the mass M
n_obs_used	number of observations (all types) used in fit

Table 1: Example of features used from JPL Small-Body Database

All these features are not available for every asteroid. For instance, the GM value is often missing. Finally, we use 3D models of asteroids from the 3D Asteroid Catalogue [3].

Using these three sources of information, Orbys display two different views. A Solar System view, presented in 1, as well as a detailed view, presented in 2. This detailed view shows specific information for each asteroid, especially on their physical parameters.

Acknowledgements

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1 Solar System view

The Solar System view is a map of planets and asteroids in our solar system, in real-time. This map is a "plan view" of the planets and the asteroids laid out in the plane of the ecliptic. It should be realised that asteroids often rise far above and below the plane of the ecliptic. This is because their orbital planes are tilted with respect to the ecliptic - by more than 40 degrees in some cases. Therefore, it should be noted that just because the view may show a planet and an asteroid to be very close to each other in the plan view, they may, in fact, be separated by a large perpendicular distance.

1.1 Orbital Position

To have the orbital position of the bodies of our solar system, Orbys uses the web-service named Miriade as stated in introduction. The code to make the requests to the web-service and then compute the corresponding positions on the SVG comes from the Sanctuary project, more specifically the Sanctuary Calendar [4]. If the web-service is not available, an offline dataset is also provided. An example of the view is presented in figure 1.

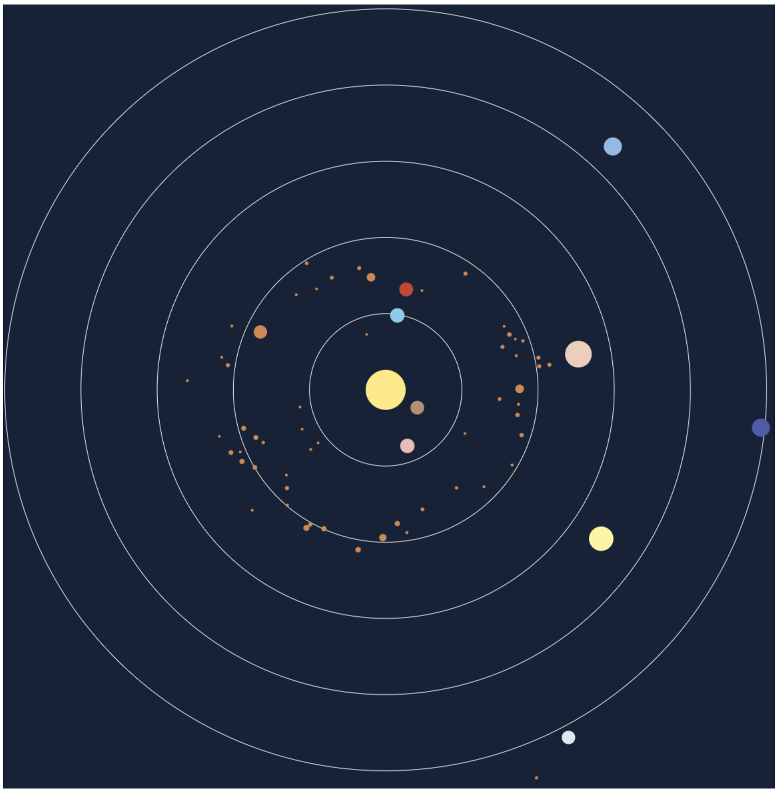


Figure 1: Solar System View

The view distinguishes between two categories of bodies: planets and asteroids. Planets are displayed as circles of different color. Each planet has a color close to the common mental representation associated with the planet. For instance, Earth is blue while Mars is red. On the other hands, asteroids are displayed in brown. The radius of each boy is interesting question. It cannot be too small, in order for the body to be visible, and it cannot be too big, to avoid overlapping. Therefore, a map at full scale is not a option. Orbys uses two different linear scales to define the radius of the circle displayed based on the true diameter of the body. For the asteroids, the domain goes from the smallest asteroid in the dataset (Itokawa in our case) to the biggest one (Ceres) while the range goes from 2 to 10. For the planets, the ranges goes from 10 to 20. Finally, the sun is displayed with a radius of 30. Therefore, the map is not at scale but the order of size is respected. Each body has a tooltip attached, showing the name of the body when the mouse is over it.

I choose to not use a pure black color for the background. Indeed, a pure black sky may be our mental picture of deep space, but it does not represent reality and will tend to look unnatural and over processed. Instead, I choose a dark shade of blue that looks natural but also looks better with the representation of celestial bodies as simple circles.

Finally, the view indludes concentric white circles whose radius are integral multiple of Earth-Sun distance. These radius help the user to get a sense of distances in the Solar System.

1.2 Highlight feature

Just above the Solar System visualization, a few buttons allow the user to interact with the view. First, a research field allows to research any asteroid by name. I have implemented an auto-complete system to make the research easier for the user. After typing the name of the asteroid or selecting it from the drop-down list, the user can either click on "Search" or press enter. This action will highlight the corresponding body.

The highlight action has been carefully considered. First, all others bodies besides the Sun are go to an opacity of 0.2. The highlighted body keeps its opacity of 1 and get a white stroke of width 3 around it. This operation is visually smoothed by using a D3 transition. The result can be seen in figure 2. However, for the smallest asteroids, it could still take several seconds for the user to visually find the highlighted body which is not very user-friendly. My idea to improve it was to make the white stroke as a very big ring coming from far away that decrease in size until it fits the highlighted body. This visual transition catch the eye of the user and allows to find immediately the position of the highlighted body even if it is very small. With a linear transition, the rendering was not really satisfying. Therefore, I used D3 *easePolyOut* function, which is a reverse exponential easing transition. This easing transition gives the white ring a high speed at the beginning, to catch the eye, and slow down at the arrival to make it easier to follow and obtain the final localisation. This slowing down movement also seems more natural as in the end the ring stop and stay still around the object, hence it is more satisfying to watch.

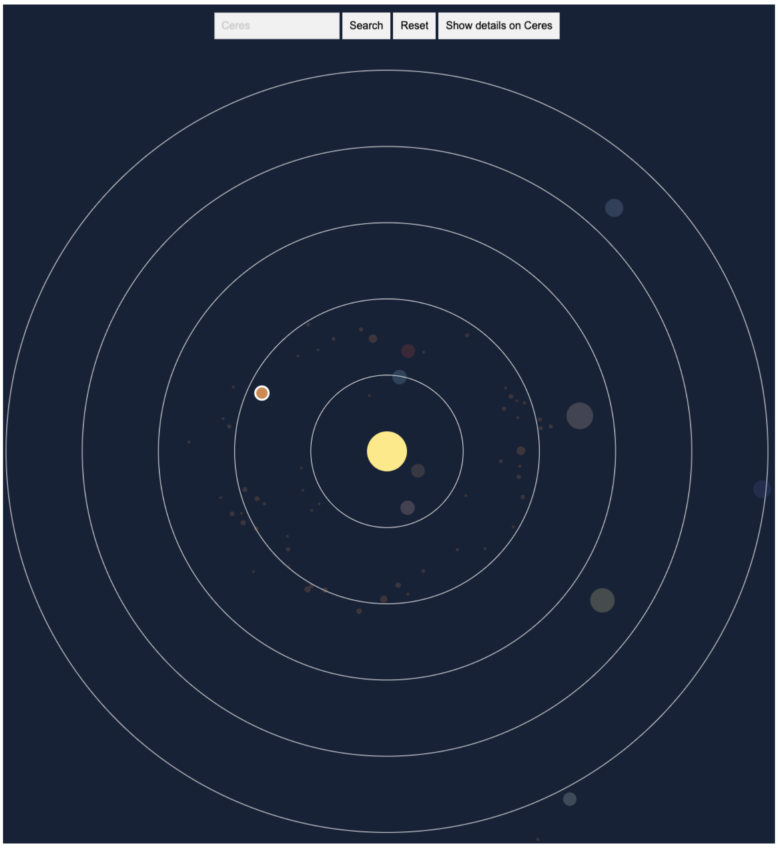


Figure 2: Solar System View - Highlight system

It is also possible to simply click on any given body to highlight it. It will automatically fill the research field with the body name. It can be interesting when you want to highlight a body you found on the map but you do not want to have to copy the tooltip into the research field manually.

Either clicking on the ”Reset” button or pressing escape will reset the map to its original states.

After highlighting a body, the button ”Show Details” will be available for the corresponding body. This is not available for planets and is reserved for asteroids. Clicking on this button will switch to the detailed view, presented in section 2.

2 Detailed view

After selecting an asteroid in the Solar System view, you can click on the *Show Details* button to switch to the detailed view on this specific asteroid. This view provide different graphics and plots to display physical data on the asteroid. The name of the asteroid is also displayed. An overview of the page is presented in figure 3. Clicking on reset allows the user to go back to the Solar System view.

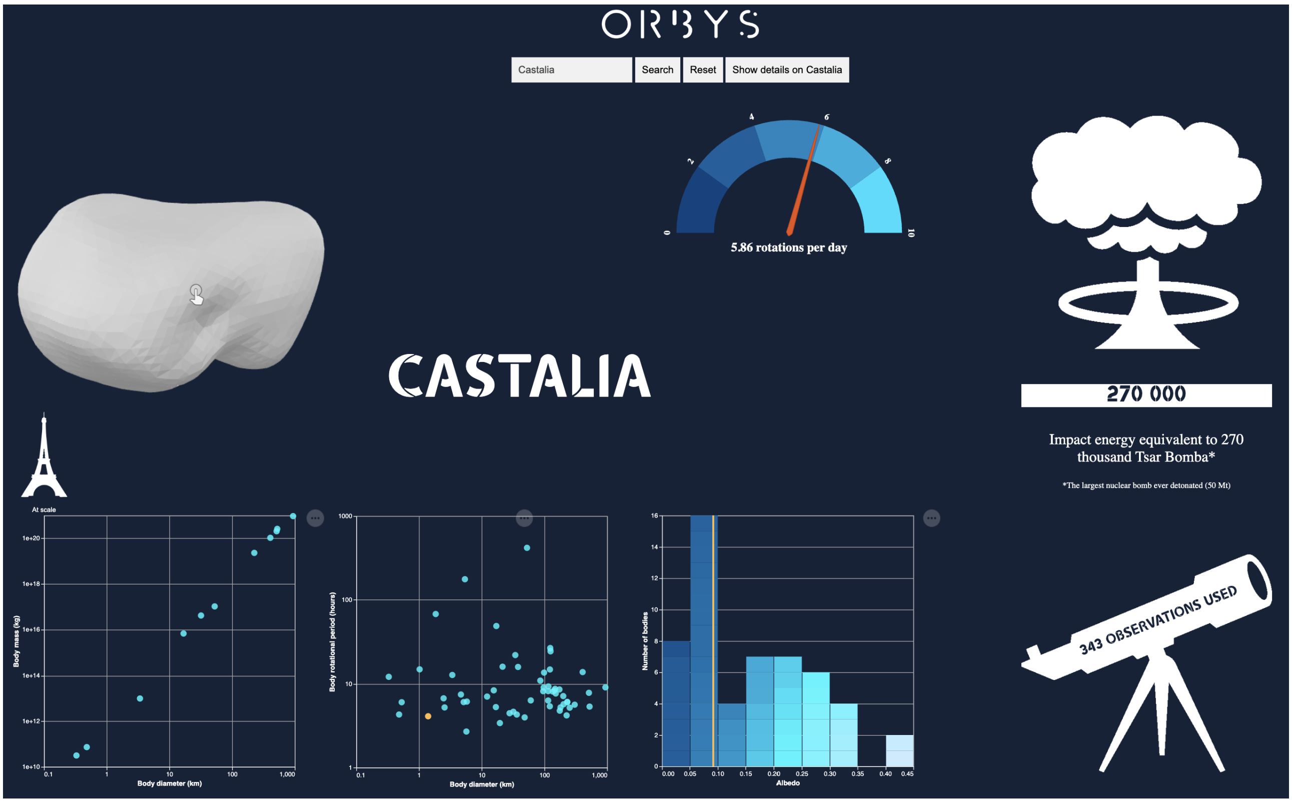


Figure 3: Detailed view

2.1 3D model

The first panel, on the left of the view, displays a 3D model of the asteroid. This is done using 3D shape models, derived from lightcurve inversion, radar measurements or spacecraft imagery. The models by the 3D asteroid catalogue mentioned in introduction were in a .obj format. To achieve a better performance when displaying it, I used a python script to convert them to a .gltf format. Then, the model is displayed using model-viewer, a web component that renders interactive 3D models [5]. The displayed 3D model of the asteroid can be rotated using the mouse, to observe it from every angle. Without user interaction, it will auto-rotate slowly. It is to be noted that the quality of the 3D model may vary depending on the asteroid. Indeed, 3D models created from spacecraft imagery are better than those created from radar measurements, which are themselves better than those using lightcurve inversion. A number of objects such as Eros, Itokawa, Vesta or c67P (Churyumov-Gerasimenko) have been visited by space probes, resulting in a large amount of high-resolution photography and measurements, thus allowing scientists to create very precise models of these objects.

2.2 Adaptive scale

The 3D model display offers an appealing view for the user. However, as all 3D models are displayed in a square box 600px wide, it can be difficult to have an idea of the size of the asteroid just by looking at it. Therefore, I created an adaptive scale for size comparison. When a 3D model of an asteroid is displayed, the silhouette of a well-known object is also displayed in the bottom-left corner, at scale. Depending on which asteroid is displayed, the system will automatically choose the best object to display for scale from a list of references. I created a list of references ranging for the french Triumphal Arch (50m) to France (1000 km). Most of the references are associated with Paris and its region but some such as Mount Fuji or Mount Everest were inspired by *Universcale*, a web content created by Nikon that provides objects to scale from the proton to the size of the observable Universe [6]. In the eventuality that a user do no know the reference or cannot remember it's size, a tooltip is attached to the scale reference providing its name and height. An example of the scale reference alongside the 3D model is presented in figure 4.

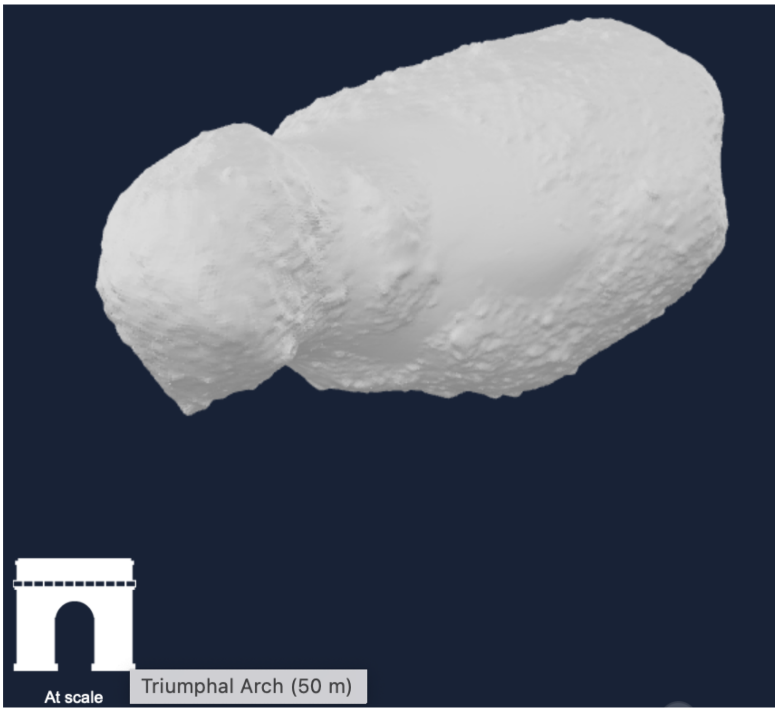


Figure 4: 3D Model along a reference

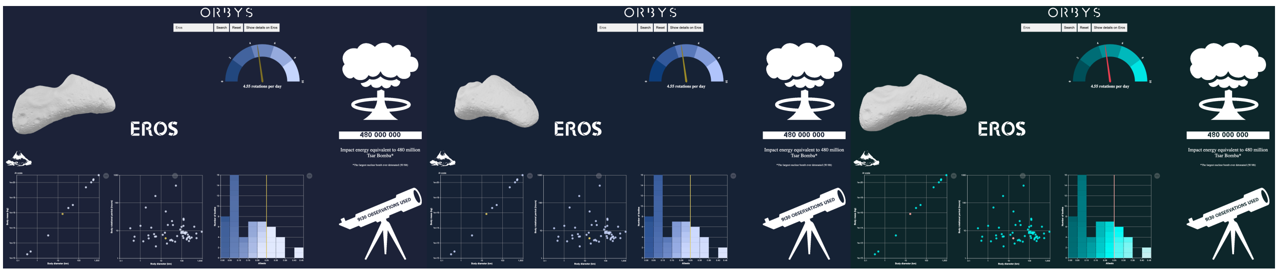
2.3 Plots

Several graphs are plotted under the 3D model to display information on asteroids physical data provided by the dataset. They are created using vega-lite. The first graph plots the body mass as a function of the diameter for all asteroids, if the corresponding data is available for them. The points are filled with an electric blue color that is used as well in other graphical elements to keep a design consistency. Only the dot of the asteroid currently selected appears in bright orange for better distinction. The point may not appear, if no mass data is available for the selected asteroid. Each dot has a tooltip to display the name of the corresponding asteroid as well as the exact values of mass and diameter. Both axis use a log scale due to the high range of values in the dataset.

A similar graph presents the body rotational period in function of the diameter. The same conventions for colors and tooltips are used. As we can see from these two graphics, diameter and mass are more or less correlated, as asteroids density are quite close, while the rotational period is not really correlated with diameter. Most asteroids seems to have a rotational period around 7-10 hours while a few outliers have a period above 50 hours, probably due to specific events such as collisions.

Finally, a histogram shows the number of asteroids per interval of geometric albedo. The visual information about the albedo is not only conveyed by the x axis but also by a sequential color scale on brightness, based on the same electric blue used in others element. The albedo of the selected asteroid is displayed using an orange vertical line. Finally, each part of the histogram has a tooltip with the name of the correspoding asteroid.

The color theme, mainly blue, has been tested to be colorblind-friendly. Using Google Chrome devtools, you can emulate the view as it was seen by a colorblind-person. All element are still distinguishable with Protanopia, Deuteranopia or Tritanopia. The emulated views are shown in figure 5.



(a) Protanopia (b) Deuteranopia (c) Tritanopia

Figure 5: Emulated views with colorblindness

2.4 Infographic elements

Finally, the detailed view also displays infographic elements. First, a speed gauge shows the rotational speed of the selected asteroid. Using a speed gauge, a tool that most people are very familiar with, makes it easy to read and understand. Also, the unit for rotational speed has not been chosen at random. Indeed, is is well known that the Earth rotates once in a day (well actually almost a day). Therefore, the number of rotations per day is easy to understand and compare. Again, we use the same color scale for the segments of the speed gauge.

An infographic element shows the kinetic energy that an impact of the selected asteroid on Earth would have. It is to be noted that this is a very approximate information based on the body diameter. Still, it is an appealing visual information and is often display on asteroids infographic presentations. The energy is expressed by comparison with the explosion of the Tsar Bomba, the largest nuclear bomb ever detonated (50 Mt). The full number is printed, to give and idea of how many zeros it contains. It is also written with words, easier to read and to use for comparison.
Finally, the number of observations that were used to collect the data presented in every part of Orbys is shown in the bottom-left of the view. The number is printed over a telescope, so that the user understand more easily what observation means in this context.

Conclusion

Orbys is a visualization for asteroids of the Solar System. It has two main views. The Solar System view displays the orbital positions of planets and some asteroids of the solar system. A highlight system allows the user to find any specific asteroid. Then, the user can switch to a detailed view with more physical information on the selected asteroid. This view displays several plots, infographic elements and a 3D interactive model alongside an adaptive scale system.

Future improvements of Orbys could include for instance more physicial data on asteroids. The possibility to have a detailed view for planet could also be added with their own 3D models. However, if the planets were to be added, the plots considering the masses and/or the diameters should probably be independent from the equivalent plots for asteroids, as the values for the planets would disrupt the scale.

References

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