Voyager's Journey: an interactive visualization of NASA's mission through the solar system

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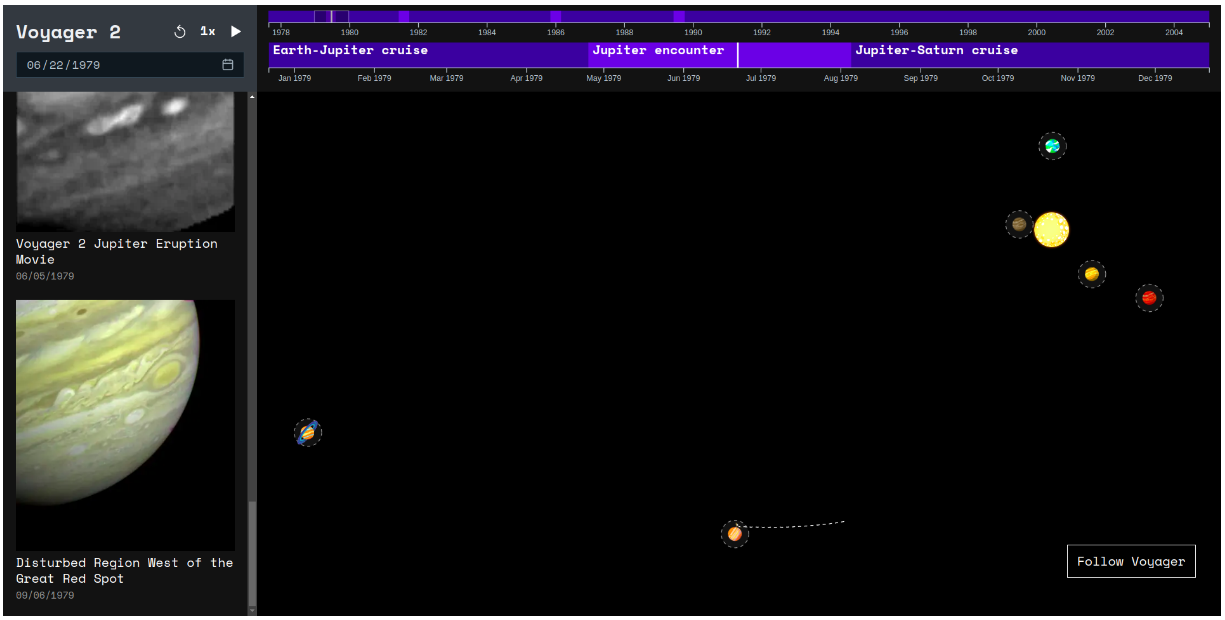

Figure 1: Visualization screen.

Abstract

This article presents an interactive visualization using web technologies of the Voyager program by showing, for each probe, a simulation of the Solar System, containing the probe's position for each day, the main events of the mission inside a timeline and a gallery of images captured by them. The visualization is controllable by a player, which offers the option to play, pause, change the speed and reset the whole visualization.

1 Introduction

In this project, we build an interactive web visualization of the achievements of the Voyager program, showing useful data and the trajectory through the Solar System of both spacecrafts, with the help of a timeline.

Each probe can be visualized separately based on their data. The visualization of both probes is divided into four main sections:

1. the player, where the user can play, pause, change the speed and resetting the whole visualization;

2. the timeline, where the events are displayed, and the user can select any point in the mission history;

3. the gallery, where all the images released by NASA until the current simulation time is displayed; and

4. the Solar System simulation, where the sun, the planets and the position of the selected spacecraft are displayed.

It works by showing the state of the mission for each of day of the available timespan with the corresponding data. The idea of animation is created by iterating through the days at least 30 times per second.

The website was created with Svelte, a JavaScript framework for developing front-end web applications. Some components, like the timeline and the Solar System simulation, were built with D3.js.

Other than having a personal interest in this subject, we were motivated by the lack of a simple and accessible representation of the aforementioned missions, so we tried to create an intersection of the raw data, the visual media and interaction in a web page.

2 Data

The data for the visualizations comes mostly from data.nasa.gov, the official NASA website for datasets related to their programs. For the position of both probes, NASA offers two datasets [3] [4] with the daily information. Both datasets contain the heliocentric range (au), solar ecliptic latitude (deg) and longitude (deg), and solar heliographic latitude (deg) and longitude (deg).

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The images presented with the visualization come entirely from the press releases of the Voyager mission provided by NASA Planetary Data System, and contain images dating from the launches of both spacecrafts.

3 VISUALIZATION

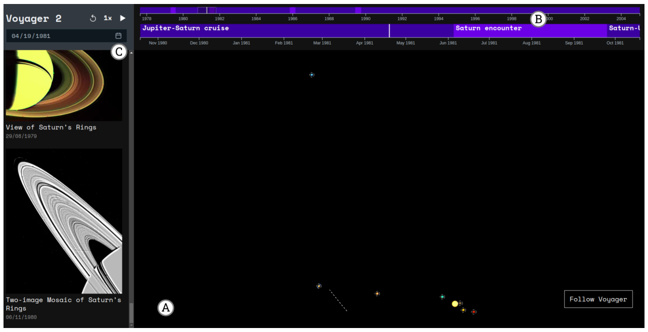

Figure 2: Our visualization at whole. A - Solar System Simulation. B - Interactive Timeline. C - Real-time photo gallery.

3.1 Solar System simulation

The orbit mechanics of the planets are known since Johannes Kepler propose its laws about the planetary motion in the 17h century. Unfortunately, trying to simulate the Solar System is not simple. In fact, a simulation of a gravitational system with more than 2 bodies depends on numerical methods to be calculated [6] and are often chaotic [2].

Because of this, the Solar System simulation used on the visualization is based on an approximation of the position of the planets between the years of 1800 and 2050 [5]. To approximate the position of the planets for this time period, the base value and the century variation for each of the Keplerian elements is needed (for each planet):

- a_0, $\dot{a}$: semi-major axis (au, au/century);
- e_0, $\dot{e}$: eccentricity;
- I_0, $\dot{I}$: inclination (deg, deg/century);
- L_0, $\dot{L}$: mean longitude (deg, deg/century);
- ϖ_0, $\dot{\varpi}$: longitude of perihelion (deg, deg/century);
- Ω_0, $\dot{\Omega}$: longitude of the ascending node (deg, deg/century).

The values for each information can be found in Standish and Williams book (or in the JPL website [1] with small adaptations). We also find the steps to calculate the coordinates of each planet based on the J2000 ecliptic plane:

1. Compute each value of the planet's six elements (e.g.: $a = a_0 + \dot{a}T$, where T is the number of centuries past J2000;
2. Compute the argument of perihelion $\omega = \varpi - \Omega$ and the mean anomaly $M = L - \varpi$;
3. Modulus the mean anomaly so that $-180° \leq M \leq +180°$;
4. Obtain the eccentric anomaly E by solving the Kepler's equation $M = E - e^{\star} \sin E$, where $e^{\star} = \frac{180}{\pi} e$;
5. Compute the planet's heliocentric coordinates: $x' = a(\cos E - e)$ and $y' = a\sqrt{1-e^2}\sin E$.
6. Compute the coordinates in the J2000 ecliptic plane, with the x-axis aligned toward the equinox:
   - $x_{\text{ecl}} = (\cos\omega\cos\Omega - \sin\omega\sin\Omega\cos I)x' + (-\sin\omega\cos\Omega - \cos\omega\sin\Omega\cos I)y'$;
   - $y_{\text{ecl}} = (\cos\omega\sin\Omega - \sin\omega\cos\Omega\cos I)x' + (-\sin\omega\sin\Omega + \cos\omega\cos\Omega\cos I)y'$.

Because our visualization is 2D, we only calculate the x and y coordinates.

3.2 Voyager spacecrafts' position

The solar ecliptic coordinates for the voyager spacecrafts are also needed to be calculated. Hopefully, the following data from the daily position datasets can be used for this task: heliocentric range, solar ecliptic latitude and longitude. Naming them r, θ_{lat} and θ_{lon}, respectively, we can do

- $x_{\text{ecl}} = r\cos\theta_{\text{lat}}\cos\theta_{\text{lon}}$;
- $y_{\text{ecl}} = r\cos\theta_{\text{lat}}\sin\theta_{\text{lon}}$.

3.3 Timeline

The timeline is displayed at the top of the screen, with the timespan being the same as the data of the position of each spacecraft. It shows the main events of the mission, like the launch (at the start of the timeline), planet approximations, etc.

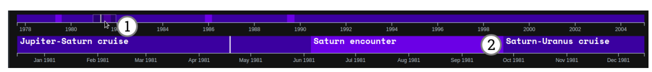

Figure 3: Timeline with important events. 1 - Main timeline. 2 - Secondary timeline.

It is divided in two smaller timelines, where the top one shows the whole timespan and the bottom one shows at most a period of one year. Both are clickable, moving the current time to where the click event happened.

3.4 Gallery

The gallery is displayed inside a sidebar at the left of the screen. The main objective of this component is showing the last images captured by the probe, giving the user more context about the state of the mission.

The images are showed in ascending order of capture date, but always focused on the last content available. It contains the title of the image and the capture date. The title is clickable, and redirects the user to the page of the image, that contains more information about it (description, release date, etc.).

4 RELATED WORK

A visualization by NASA of the solar system in a 3D immersive app, featuring the most relevant missions. With their trajectory data, it is possible to check past and present positions of the tracked objects. Eyes on the Solar System is a beautiful and inspiring way to visualize the trajectory of both the Voyager missions, but our work focuses on simplicity and clarity, avoiding the text cluttering and using 2D instead.

A visualization of minute details of Apollo missions and probably our main source of inspiration, Apollo in Real Time provides a timeline in different levels with matching media regarding the missions.

5 DISCUSSION

The visualization helped us gain some insight concerning the trajectory of the Voyager mission probes, such as the gravity assist or slingshot maneuver, which happens when a large gravitational body causes an orbiting spacecraft to follow an elliptical path around it. It is possible to understand why those dates were chosen for the launch, with the planets aligned in a way that would facilitate the probes' navigation around the solar system.

Our solar system simulation is a good stand-alone representation of the orbits of the planets and helps understand the magnitude of the distances between represented objects.

6 CONCLUSION

In this paper, we present a problem in the form of visualizing data related to a specific topic and propose our solution. We were able to achieve most of our goals with this project, as well as make improvements based on user feedback. Despite this, we believe further modifications would benefit the visualization.

6.1 Limitations

One of the key limitations when building this visualization was finding good data. NASA's official data website offers a lot of useful datasets for scientists and researchers, but lacks to offer datasets with clean data for broader purposes.

Most of the initial work focused on finding, parsing and transforming the datasets NASA offers into something useful. For example, all the images for the gallery had to be scraped from NASA Planetary Data System press releases.

6.2 Future work

We believe the gallery could be more responsive to user interaction and have a better interaction with other components of the visualization, as it is mostly static currently.

It should also be possible to show more of the publicly available data on the probes, for instance their magnetic field and particle measurements.

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