Original Method: Optimization-Based Pathfinding and Fuel Management in the Elite Dangerous Galaxy

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***Abstract*—This project proposes an optimization-based navigation and fuel management framework for interstellar travel within the *Elite Dangerous*[1] simulated galaxy. The aim is to model ship FTL jump sequences between stars, constrained by jump range and fuel consumption per jump, and to develop efficient algorithms for minimizing total fuel cost and maximizing reachable destinations under realistic in-game constraints. The possibility to refuel the ship at a given star type will be considered, based on the jump destination. The project will integrate constrained multi-objective optimization, and graph-based pathfinding based on Dijkstra to demonstrate an original computational approach to large-scale route optimization.**

***Index Terms*—Optimization, pathfinding, simulation, Elite Dangerous, graph algorithms**

I. Motivation

Elite Dangerous is the latest incarnation of a game that was first released in 1984 [2]. It is the fourth iteration of the game, having been released in 2014 [3], with an expansion released in 2021. The game consists of pilots, with their own spaceships, able to act as traders, mercenaries, or explorers, utilizing a faster-than-light drive to "jump" between stars and navigating the galaxy. In the latest version of the game, the galaxy in which players navigate is based on some actual star position data, and current cosmological science, simulated in what is called the Stellar Forge simulation. The Stellar Forge creates stars and systems in scientifically agreed probabilistic locations [4]. The Elite Dangerous galaxy provides players a realistic, procedurally generated model of over 91 million star systems (the number of stars currently mapped by players in the game, out of an estimated 400 billion possible).

The motivation for this project is to explore and formalize navigation strategies inspired by optimization theory, particularly shortest-path and trust-region methods, within a nontraditional domain. By treating interstellar FTL jump travel as an optimization problem, we bridge theoretical concepts with applied computational science. I seek to build an algorithm that can provide a route from any starting point in the galaxy, to an end point.

[1]https://en.wikipedia.org/wiki/Elite_Dangerous

[2]https://en.wikipedia.org/wiki/Elite_(video_game)

[3]https://en.wikipedia.org/wiki/Elite_Dangerous

[4]Of note, Trappist 1 was found in Elite Dangerous, in nearly the same location in real life https://www.polygon.com/2017/2/25/14737940/elite-dangerous-trappist-1-system-predicted/

II. Expected Contribution

Dijkstra relies on edge weights in the graph. The graph here being the available jumps, based on the ship jump range. The edge weights will be based on fuel consumption. While Dijkstra only relies on fixed edge weights, this project will introduce a variable edge weight, based on the last node visited. Specifically, the last node visited will be a star, that may or may not allow the player to refuel their ship.

The primary contribution will be a complete MATLAB implementation of a route optimizer that integrates distance, jump range, fuel constraints, and refuel points, as mentioned. All code for graph construction, feasible jump set generation, and constrained optimization will be original. Built in MATLAB packages will be used for CSV dataset handling and visualization. The expected outcome is a reusable framework for analyzing large-scale constrained route planning problems under nonlinear cost dynamics. I seek to optimize routes between distant stars better than either the in game routing, or one of several third party routing programs. Eventually, the addition of FTL drive types, ship mass and fuel tank size could easily be added as variable constraints to the resulting algorithm.

The eventual algorithm will identify and return a Pareto Front, with the tradeoffs being fuel consumption vs number of jumps to reach the end point. It is already known that there are some end point stars that require a specific route. These end points will be evaluated in the resulting algorithm, and compared to known routes.

III. Expected Contribution Against Competitive Methods

I do not have access to either the in-game route plotter, nor any of the methods used by third party websites. The only comparison I will be able to make is direct comparisons against sample routes using existing methods. There are some popular routes that players have found, which are not reflected in existing routing implementations, which can also be compared to the results of the proposed algorithm.

I will use the fuel equation below [5]. In the game, there are several other engines, with different fuel equations. A different fuel equation, and different jump range, can easily be integrated into the proposed algorithm.

$$f = r \times \left(d \times \frac{m_{\text{ship}}}{m_{\text{opt}}} \right)^{p} \times 10^{-3}$$

IV. Draft Flowchart or Pseudo-code

Dijkstra's algorithm is based on edge weights. The main change with respect to the classic formulation is that a jump is only feasible if the ship has enough fuel according to the nonlinear fuel equation, and some stars allow the ship to fully refuel when reached. The edge weights will need to be adjusted in every step of the Dijkstra algorithm. This leads to an adaptive optimization constraint.

V. Code

The implementation will be written in MATLAB, leveraging matrix-based operations and vectorization for speed. Reusable code will handle distance calculations, feasible jump graph generation, and optimization loops. If published (which I haven't been able to find yet, despite extensive searches), the fuel used per jump will be cited. I've reached out to Frontier Development to see if they will share the specifics of the fuel use calculations, but have not heard back yet. In the absence of a specific formula, I will use a generic exponential equation, where the fuel use increases exponentially with the jump length, which matches my observations in the game. All code and data sets will be published on GitHub, for peer review and reproducibility.

VI. Dataset Requirements

The dataset will consist of real in-game star coordinate data (x, y, z positions, star types, refueling flags). Data will be collected from existing *Elite Dangerous* community databases (EDSM https://www.edsm.net/en/nightly-dumps). In this case of simple constrained optimization, there is no need for training or test data sets. Start and end points of the route will be selected and run through the algorithm, and then compared to existing models (in-game routing, third party routing, player routes) and evaluated for distance, fuel, number of jumps, etc.

VII. Evaluation Method

As mentioned, several routes will be selected, and the resulting routing will be compared to existing models for efficiency.

VIII. Method Validation Metrics

The algorithm, when given a start and end point, will provide a route through the galaxy, within the provided EDSM database. The resulting route can be compared against existing metrics, to compare the number of jumps, the needed fuel, the required fuel stops. Further comparisons can be made against the existing route plotting solutions (in game, spansh.com) to compare the required time to find said routes.

Some routes cannot be found with existing methods. Those routes, if found by the proposed algorithm, will be compared to those found by the player base. The player discovered routes clearly can't be evaluated for computation time, and will be evaluated on fuel and number of jumps.

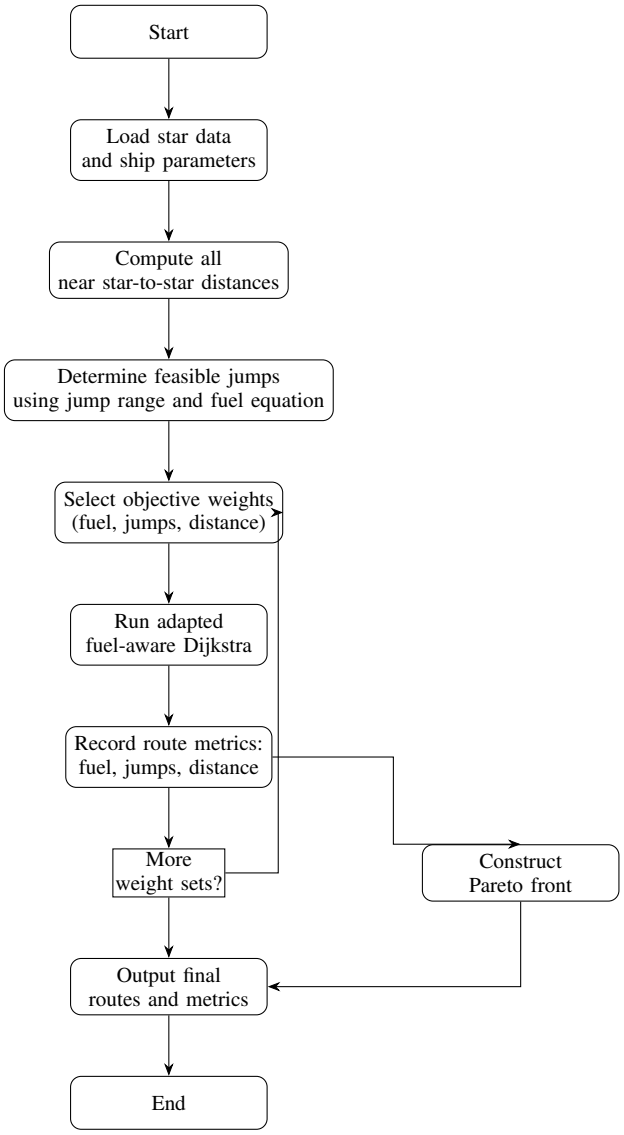

Fig. 1. Draft flowchart for fuel-constrained pathfinding and multi-objective evaluation.

IX. Bibliography Justification

The Reddit documentation on the Elite Dangerous hyperspace fuel equation will serve as a data foundation, though it is as of this writing 11 years old. EDSM.net has nightly releases of the star systems discovered by players. When tests of the algorithm are run, the date of the nightly dumps will be noted, and a link and relevant data CSV included in the GitHub implementation.

[5] Credit to "Joe Cool" on the Frontier forums

X. Bibliography Links

[1] "The Hyperspace Fuel Equation," Reddit Technical Documentation, 2015. Available at: https://www.reddit.com/r/EliteDangerous/comments/30nx4u/the_hyperspace_fuel_equation_documented/

[2] "EDSM Nightly Dump." The EDSM nightly dumps are added to continuously, the data set used will be included in the GitHub repo, and date stamped. Available at: https://www.edsm.net/en/nightly-dumps

Acknowledgment

The author thanks the *Elite Dangerous* community for maintaining public datasets such as EDSM and the subreddit r/EliteDangerous. The author also wishes to thank members of the Fleet Comm in-game private group and Discord server, and the organizers of the Distant Worlds 2 Expedition, where the idea for this project first took root.

Portions of this document were formatted with the assistance of ChatGPT (OpenAI) to ensure IEEE LaTeX compliance; all technical content, data sources, and writing are original.

Lastly, I want to acknowledge my cat, Demi. She has made this entire process unbearable. To anyone reading this, I'll give her a belly rub, just for you. She has found the optimal time to get a belly rub. And that time is exactly when I needed to write this proposal.