Immersive Trajectory Design Framework Using Augmented Reality

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Introduction

- The field of astrodynamics currently relies on highly specialized tools for spacecraft trajectory design, resulting in intricate trajectories sometimes difficult to visualize on 2D screens
- **Augmented Reality (AR)** allows users to visualize real-time space travel in 3D and collaborate using devices such as the **HoloLens 2**

This study reports on an academic collaboration between the Human Factors (HF) Research in User eXperience Lab (RUX) and Space Trajectories and Applications Research (STAR) Lab to develop an easy-to-use AR system for space mission planning

Methodology

- Incorporating a user-centered approach to develop the AR prototype enhances collaboration, ease-of-use, and visualization techniques
- Using a Hohmann transfer, a mission was set up and completed in STK (see figure 1) and in the developed AR prototype (see figure 2) to compare and test efficiency, time execution, and usability for the purposes of trajectory design
- The following methods were used to create a suitable prototype for the AR Trajectory App:
  - **Contextual Inquiry:** Data collection method that requires interviews and observations to understand how tasks are completed
  - **Hierarchical (HTA) & Tabular Task Analysis (TTA) & Task Decomposition (TD):** Major tasks are identified and broken down into steps/sub-steps for easier processing
  - **SHERPA:** Method used to predict and reduce human error within operations
  - **Wireframing:** Form of prototyping used to help visualize interface structure and functionality
  - **Process Charting:** Charting method that shows linear sequential flow of activities within a process (see figures 3 & 4)
  - **Keystroke Level Model (KLM):** HF performance analysis method that focuses on time execution when completing a task (see figures 5 & 6)

Preliminary Results

CI, HTA, TTA, Task Decomposition, and SHERPA Results:

- Eight main steps identified, with three to five sub-steps in range
- Revealed system requirements, with tools and gestures needed for each step; tutorials and examples are needed for novice users
- Errors primarily related to users entering parameters incorrectly

Keystroke Level Model Results:

- Task performance with AR prototype was predicted to be faster than STK. Most of the trajectory calculations required in STK were automated in the AR application , ensuring more efficiency, less errors and higher inclusivity for non-expert users

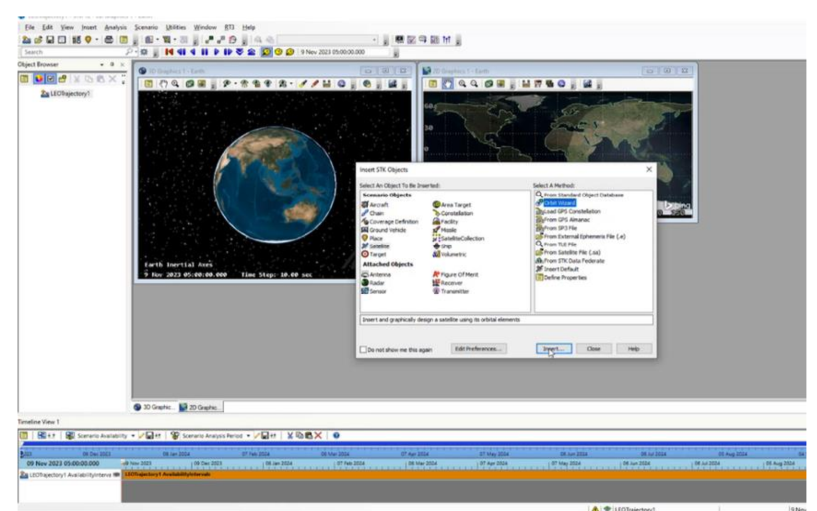


Figure 1. Current STK Interface

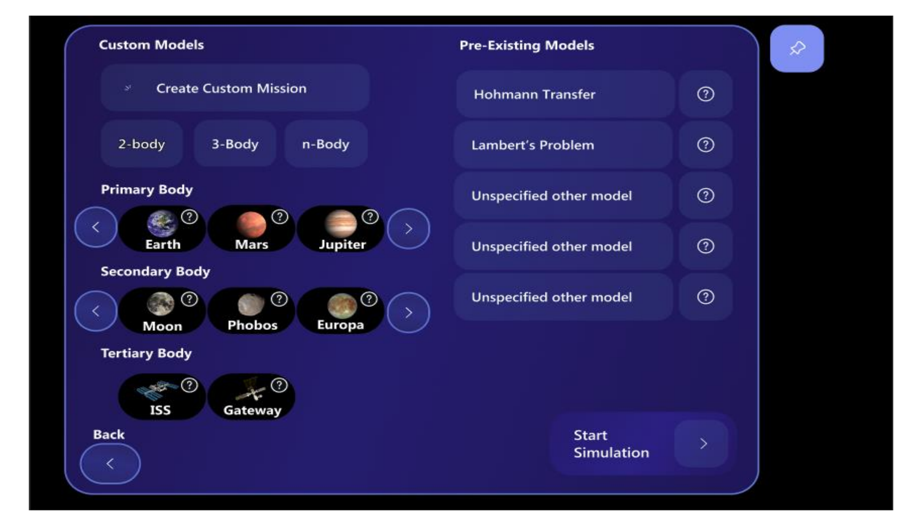


Figure 2. AR Prototype Interface

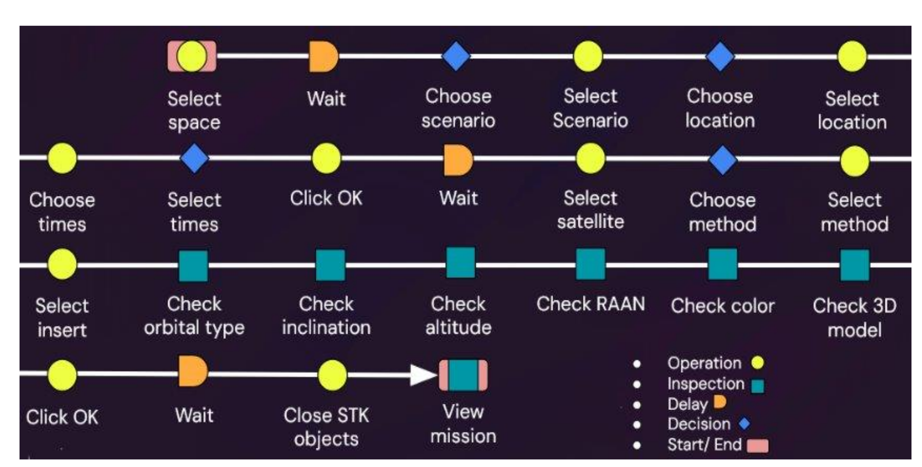


Figure 3. Process Chart for STK Interface

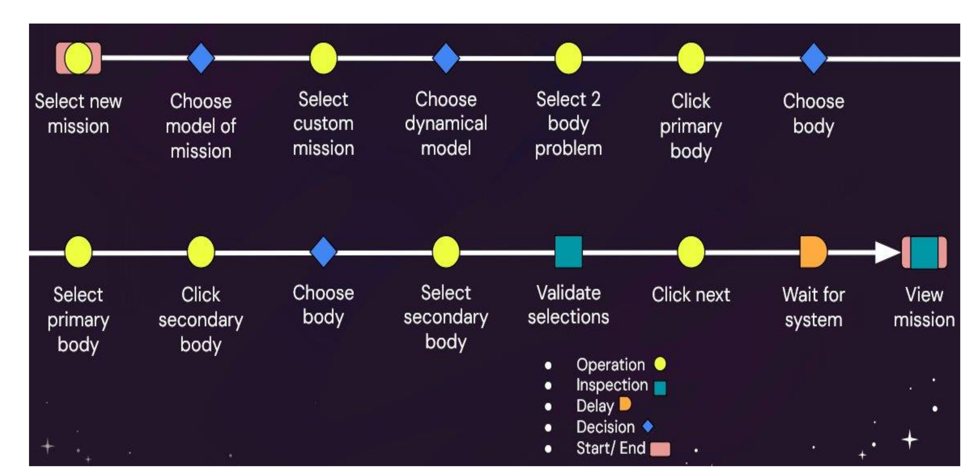


Figure 4. Process Chart for AR Prototype

Steps	Operators	Response Time [s]	Execution Time [s]
Select STK Premium Space	M + P + 2B + R	15	18.65
Select Create Scenario	M + P + 2B		2.65
Select location	M + P + 2B + S + 4B + R	1	8.01
Create start and stop times	M + 16B + 8P		11.751
Click OK	P + 2B + R		1.3
Insert STK objects loads		14	14
Select satellite	M + P + 2B		2.65
Select method	M + P + 2B		2.65
Click insert	P + 2B + R	2	3.3
Change/ validate orbital type, inclination, altitude, RAAN, color, 3D model	6M		8.1
Click OK	P + 2B + R	1	2.3
Close STK objects	P + 2B		1.3
			76.66

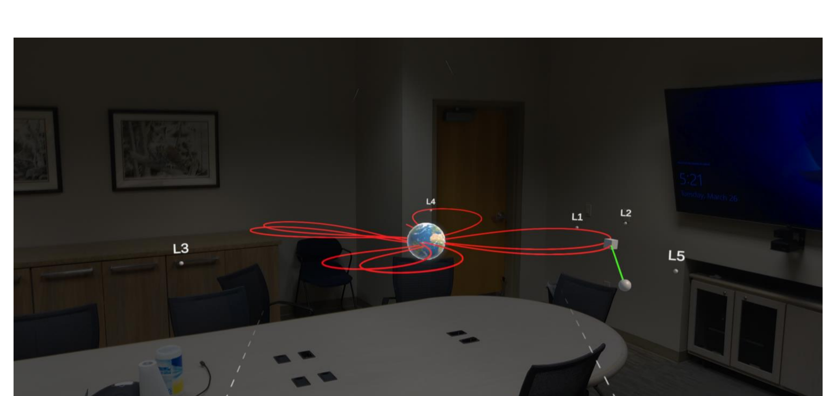
Figure 5. KLM Chart for STK Interface

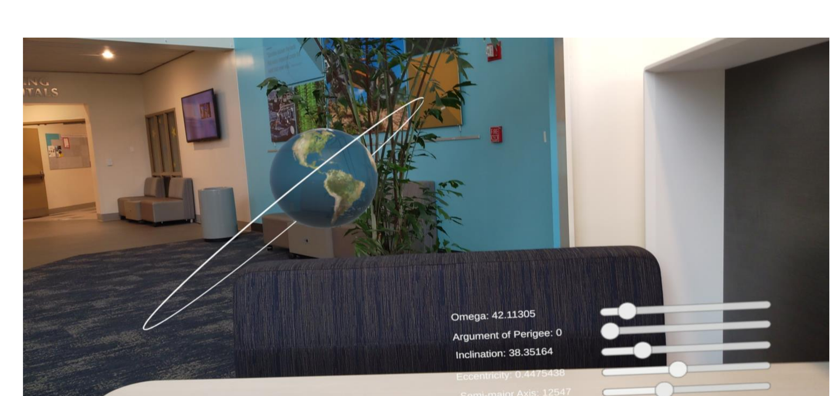
Steps	Operators	Execution Time [s]
Select new mission	Rh + At	1.05
Select custom mission	M + At	1.77
Select 2 body problem	M + At	1.77
Click primary body	M + At	1.77
Select primary body	Php + M + At	2.19
Click secondary body	Php + At	0.846
Select secondary body	Php + M + At	2.19
Click next	At	0.427
		12.046

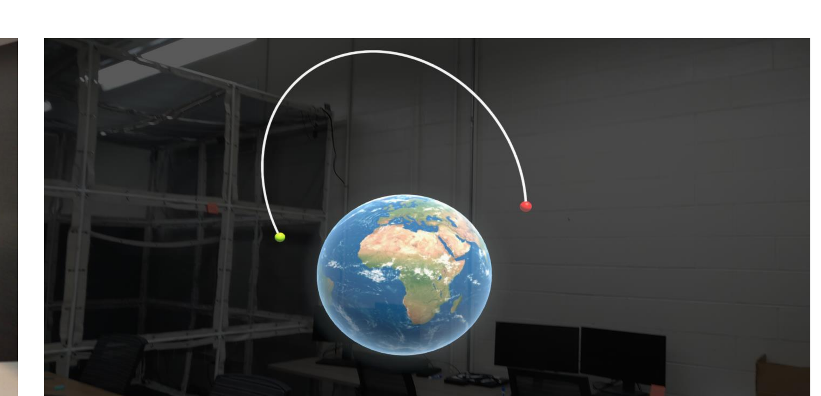
Figure 6. KLM Chart for AR Prototype

Prototype Results:

- A database has been created with accurate data for all celestial objects in our Solar System and a database with live two-line element satellite data, which will be used for surveillance purposes and to ensure collision avoidance when completing the trajectory design process
- Several models have been created for modeling orbits in the cislunar region by leveraging the circular-restricted three-body problem, visualizing orbital parameter changes, and using a Lambert solver for two-body problem trajectories







Future Work

- As the prototype evolves, heuristic evaluations will be conducted on the different body problem scenarios using a heuristic checklist designed specifically for AR applications and devices (Derby, 2023)
- Prototypes will continue to be refined and tested with users with varying knowledge of astrodynamics
- The research results hope to inform the design of similar applications and to guide future research on usability and efficiency in space mission planning tools
- More mission scenarios will be modeled, and ultimately, the user will be able to create their own mission, using AI to aid in the design process

Takeaways

- A comprehensive foundation for the development of an AR application prototype for space mission planning was developed through collaboration of HF and AE
- User experience, collaboration, and user interaction with the virtual model are predicted to improve with the implemented AR prototype
- The prototype has been tested for accuracy and reliability; further testing will be performed with users to understand its use for higher fidelity astrodynamics problems

References

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