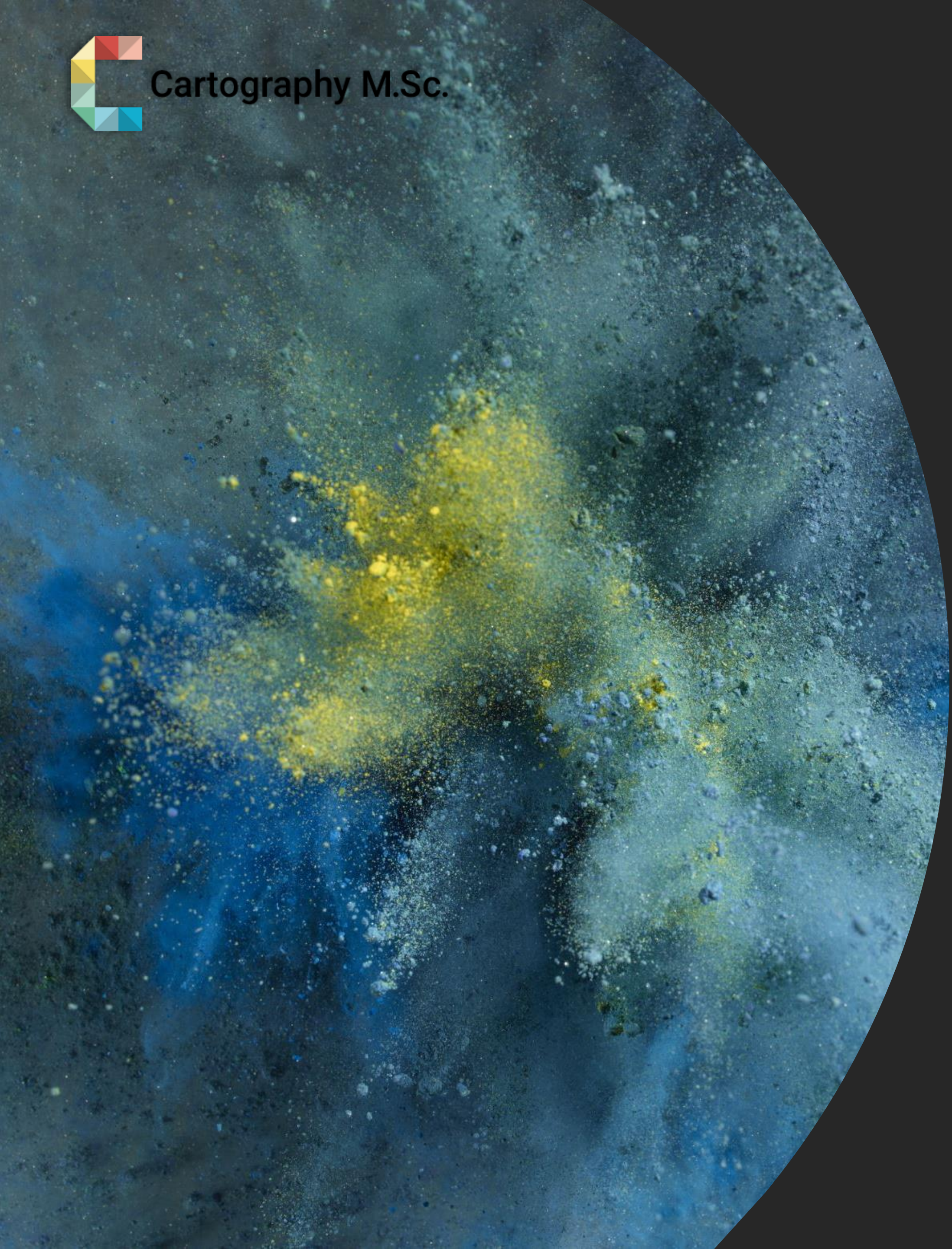

Interactive cartographic visualization of satellite data and their orbits based on user-centered design

Thesis presentation

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29-11-2021

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Reviewer: Dr. Paulo Raposo (University of Twente)

Agenda

Introduction

- The usage of satellites is growing in various fields such as criminology, climate change, aerospace, and cartographic research, thereby increasing the number of satellites.
- The satellites present in space are spatially located, whose representation can be efficiently and effectively done through the means of cartography.
- An interactive application effectively designed can serve the purpose of representing a large amount of data and effortlessly conveying the information to users (Pietsch, 2015).
- In recent times, some organizations have been focusing on designing satellite maps; however, it seems too technical for general map users.
- The general map users having minimum or no knowledge about satellites must be reached out to while developing the application.

Research objectives

RO1.
*To **design** a prototype of an **interactive** web-based application to **visualize satellites and their orbits**.*

RQ1.1 What are the available sources to extract the satellite data for visualization?

RQ1.2 What platforms are being used for designing satellite visualization interfaces?

RQ1.3 How is the interactive application designed considering the requirements of users?

Research objectives

RO2.
To ***explore*** *the various* ***satellite visualization*** *aspects in the designed application.*

RQ2.1 How can the satellites be represented effectively in the interactive web-based map?

RQ2.2 Are 2D or 3D maps more effective for displaying satellites on an interactive web-based map?

RQ2.3 What color or other graphic variable choices must be studied for designing a customizable interface? Does the user prefer a customizable or fixed interface?

RQ2.4 How can two or more user-selected satellites be visualized together for a comparison?

Research objectives

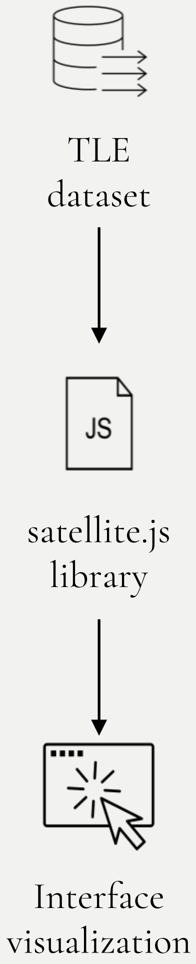
RO3.
*To **evaluate** the designed application.*

RQ3.1 How can the utility of the interface be evaluated?

RQ3.2 How can the usability of the interface be evaluated?

RQ3.3 How is the effectiveness of the interface evaluated?

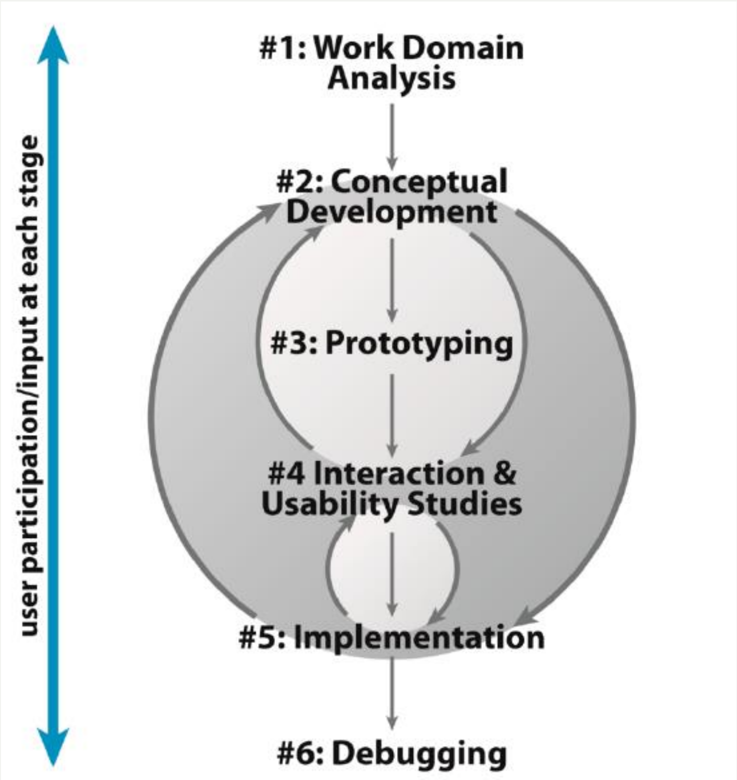
Background information



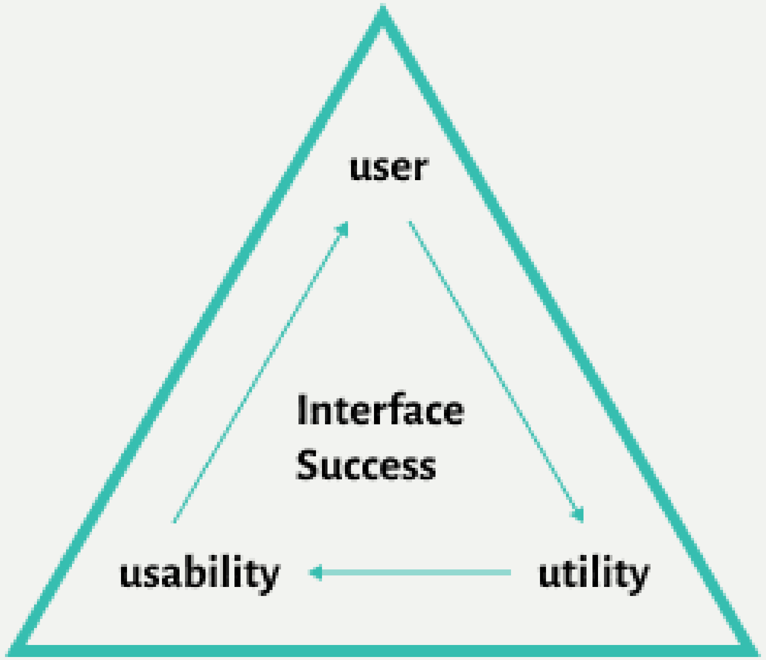
The TLE dataset for these three applications is extracted from ***space-track.org***, and the ***satellite.js*** JavaScript library is used for the calculation of satellite position.

	Representation	Interaction
Satvis.space **(Ahmed, n.d.)**	Built with CesiumJS, Satellite.js, Vue.js, Workbox. 3D virtual globe representation is found with the possibility to change into 2D. A single color dot symbolic representation of satellites is observed.	Pan, zoom, retrieve, filter, overlay
Satellite map - Esri **(Esri, n.d.)**	It is built with ArcGIS API for JavaScript, Bootstrap, jQuery. 3D virtual globe representation is found. A single color dot symbolic representation of satellites is observed.	Pan, zoom, retrieve, filter
Stuffin.space **(Stuff in Space, n.d.)**	Built with WebGL. 3D virtual globe representation is found. Multiple color dot symbolic representation, which classifies space objects based on their types (satellites, rocket bodies, and debris), is noticed.	Pan, zoom, retrieve, filter, search

Background information

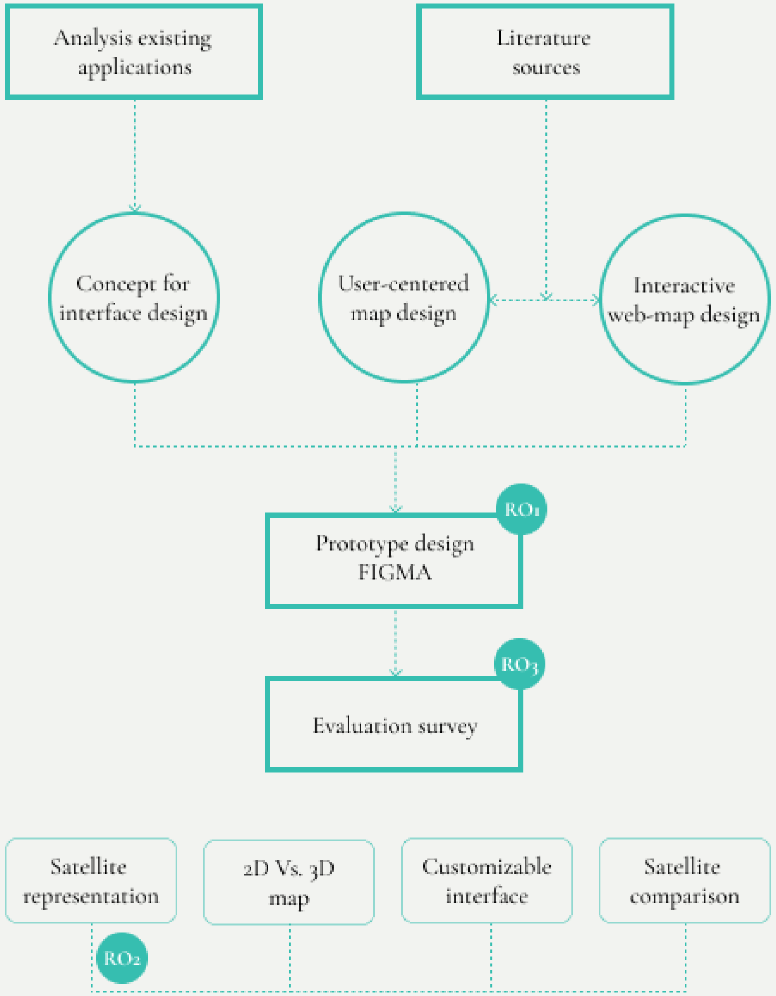


The iterative process of user-centered design adopted from (R. Roth et al., 2015).



Interface success relationship adopted from (R. Roth et al., 2015).

Methodology



Methodology

Prototype design

Data design

- dual sources available for satellite data which are Space-Track and CelesTrak.
- CelesTrak data is chosen because it does not require authorization.

Expected outcome

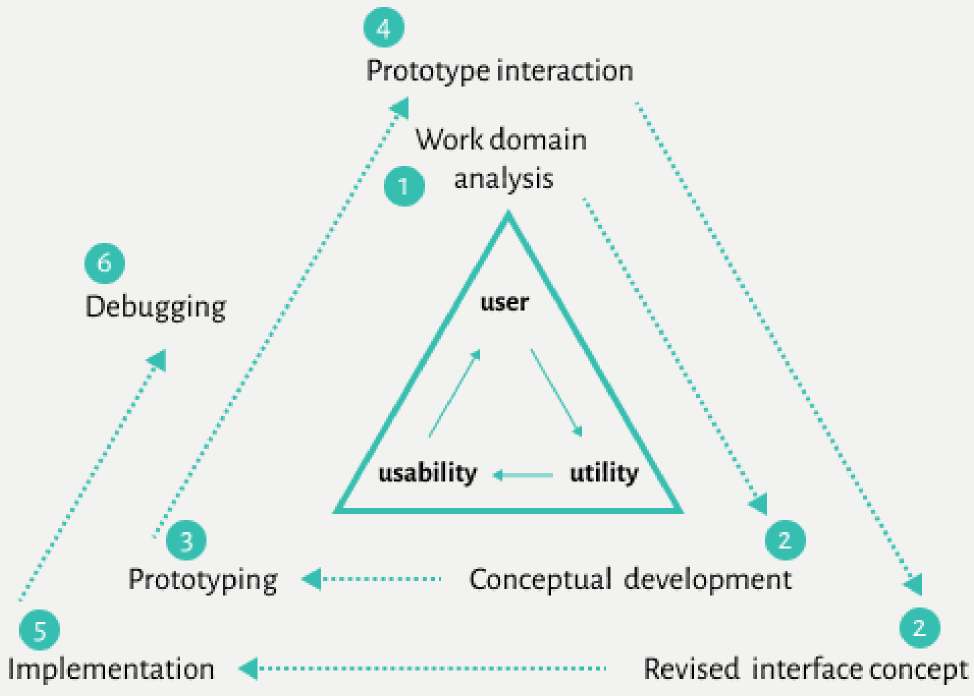
- simple navigation menu design
- search function and filter option
- 2D and 3D globe representations
- comparison window

User-centered interface design

- prototype interface is designed considering the UCD workflow
- FIGMA

Methodology

Prototype design



User-centered design workflow

work domain analysis (1) and prototype interaction (4) check the interface with the perspective of **users**;

conceptual development and revised interface concept (2) examine the application based on the **utility**;

prototyping (3) and implementation (5) evaluate the **usability** of the interface.

Methodology

Survey

1. General information of users
2. Interface interaction
3. Utility and usability test
4. Evaluation of the performance
5. Feedback and suggestions

Results

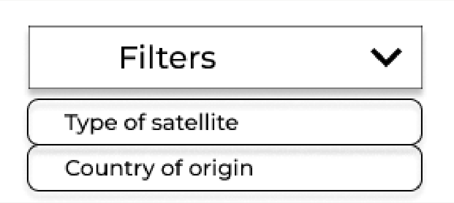
Prototype design

Outlook

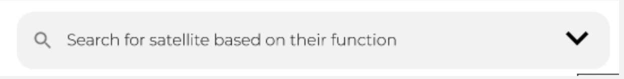
SatelliteViz

Results

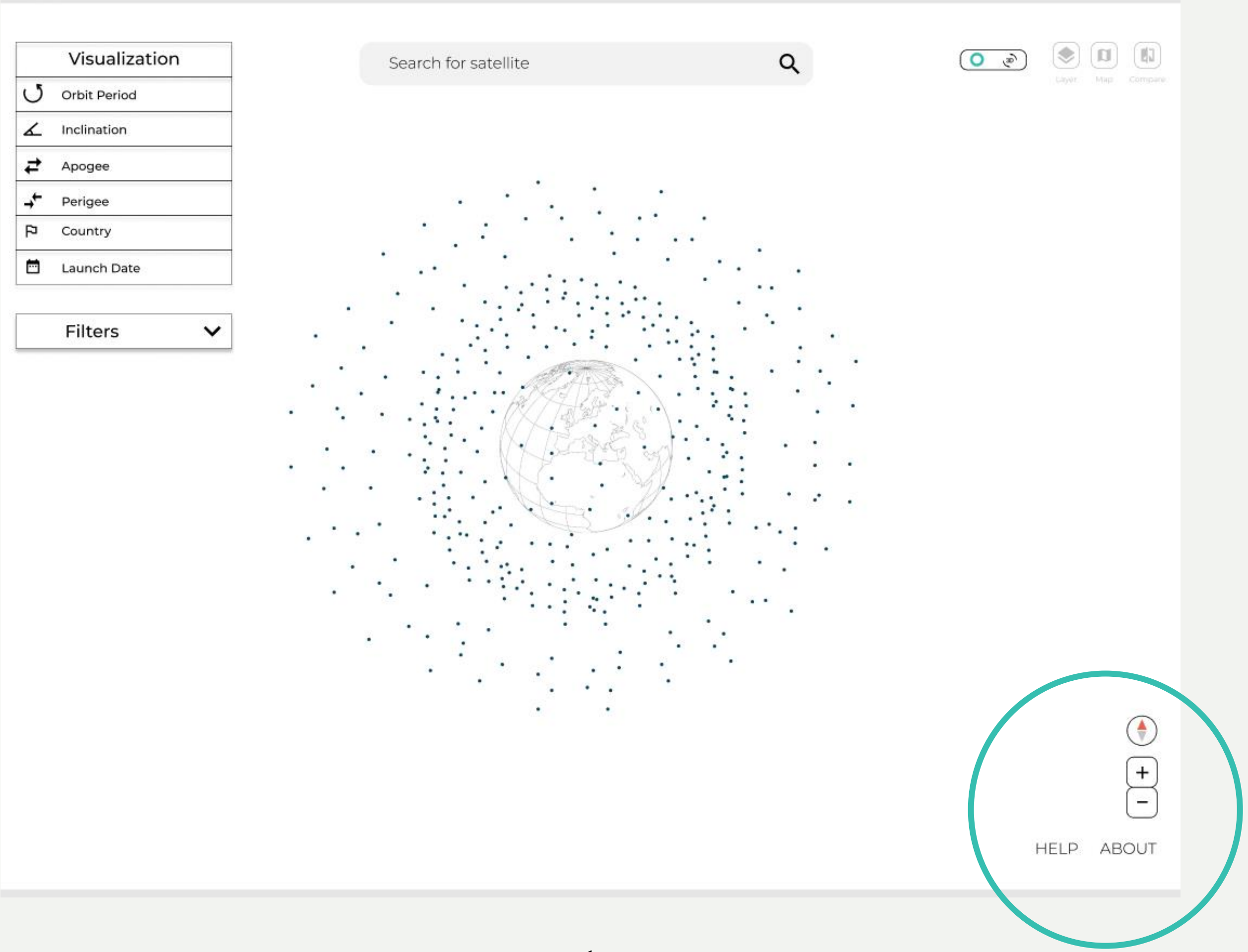
Prototype design



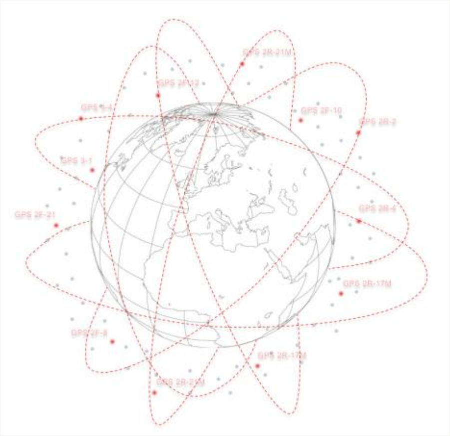
Filter



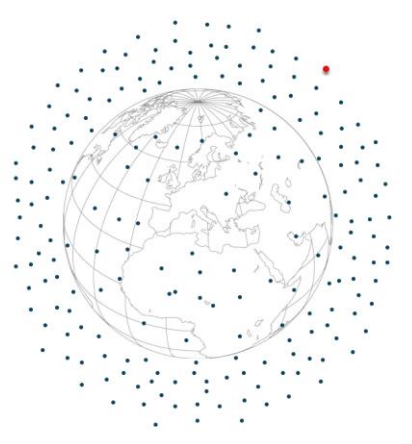
Search



Zoom-in and Zoom-out



Overlay



Retrieve

Interactions

Results

Prototype design

Limitations

- The application does not allow users to zoom in and out of the interface with the help of a mouse. The rotation of the globe is also not possible.
- The easy shift from one window to another is not possible Due to the lack of an effective back button.
- The information of the individual satellites is absent.
- The position of satellites is randomly placed, and the orbital path of the satellites is not accurate.
- The buttons are functional as per the requirement only.

Results

Prototype design

Use cases

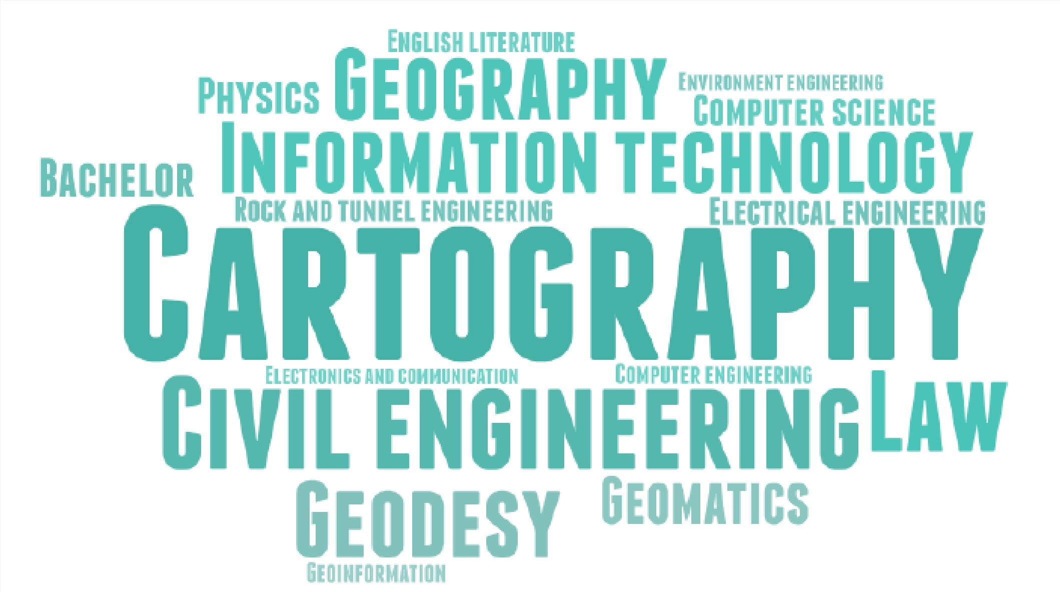
- Educational purposes
- Collision of satellites
- Space debris visualization

Results

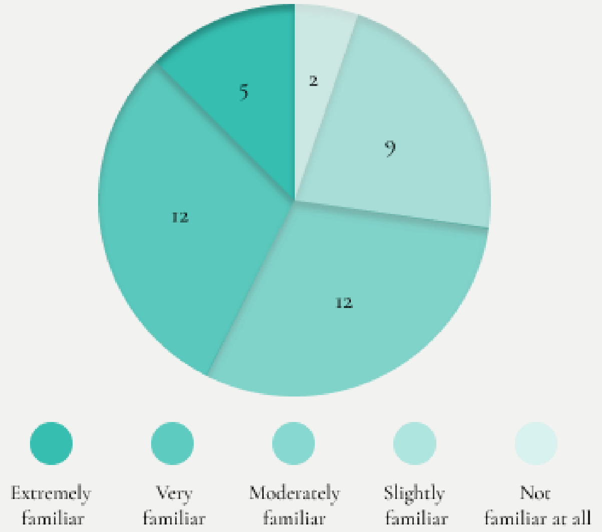
Survey

Participants profile

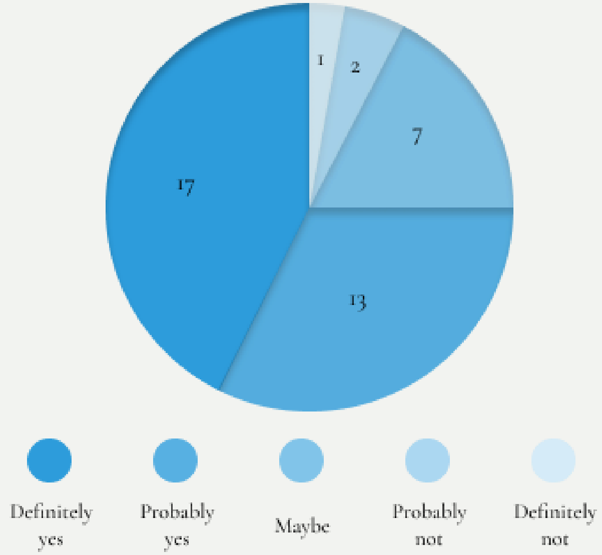
40 *participants*
m/f *28/12*
18-54 *age range*



Familiarity of users with the interactive maps



Familiarity of users with satellites and their orbits

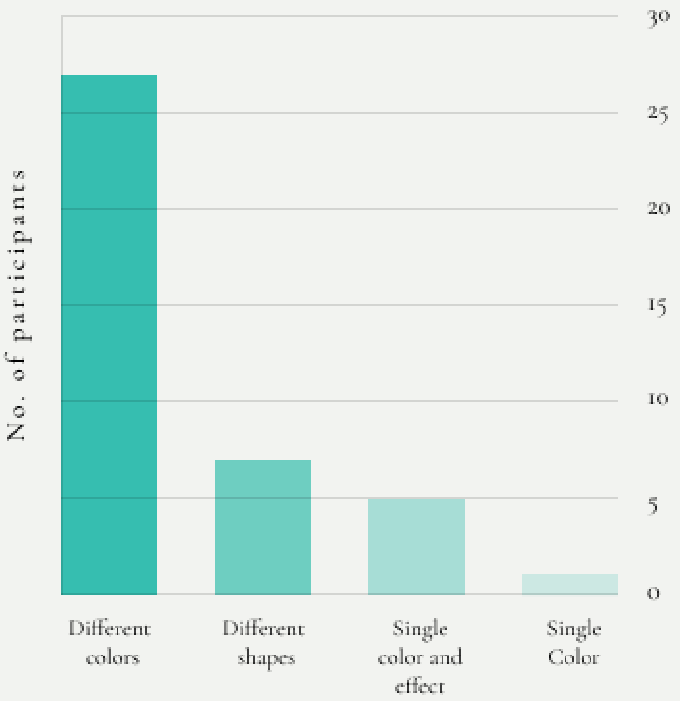


Results

Visualization

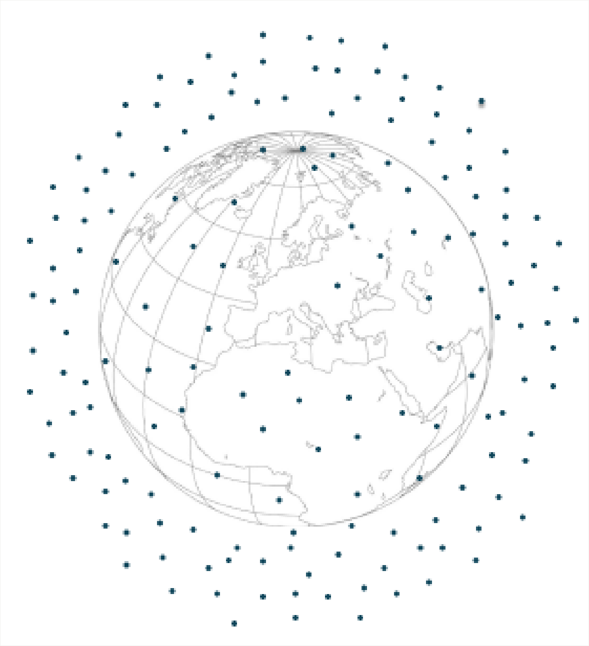
1. Satellite representation
2. 3D vs 2D map representation
3. Fixed vs customizable interface
4. Comparison of satellites

1 Satellite representation



Number of participants and their preference of satellite representation

40 *participants*



With a single color

With a single color and effect

With different color

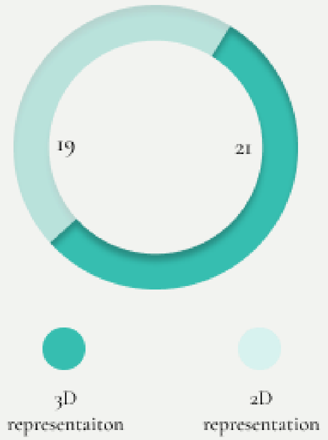
With different shapes

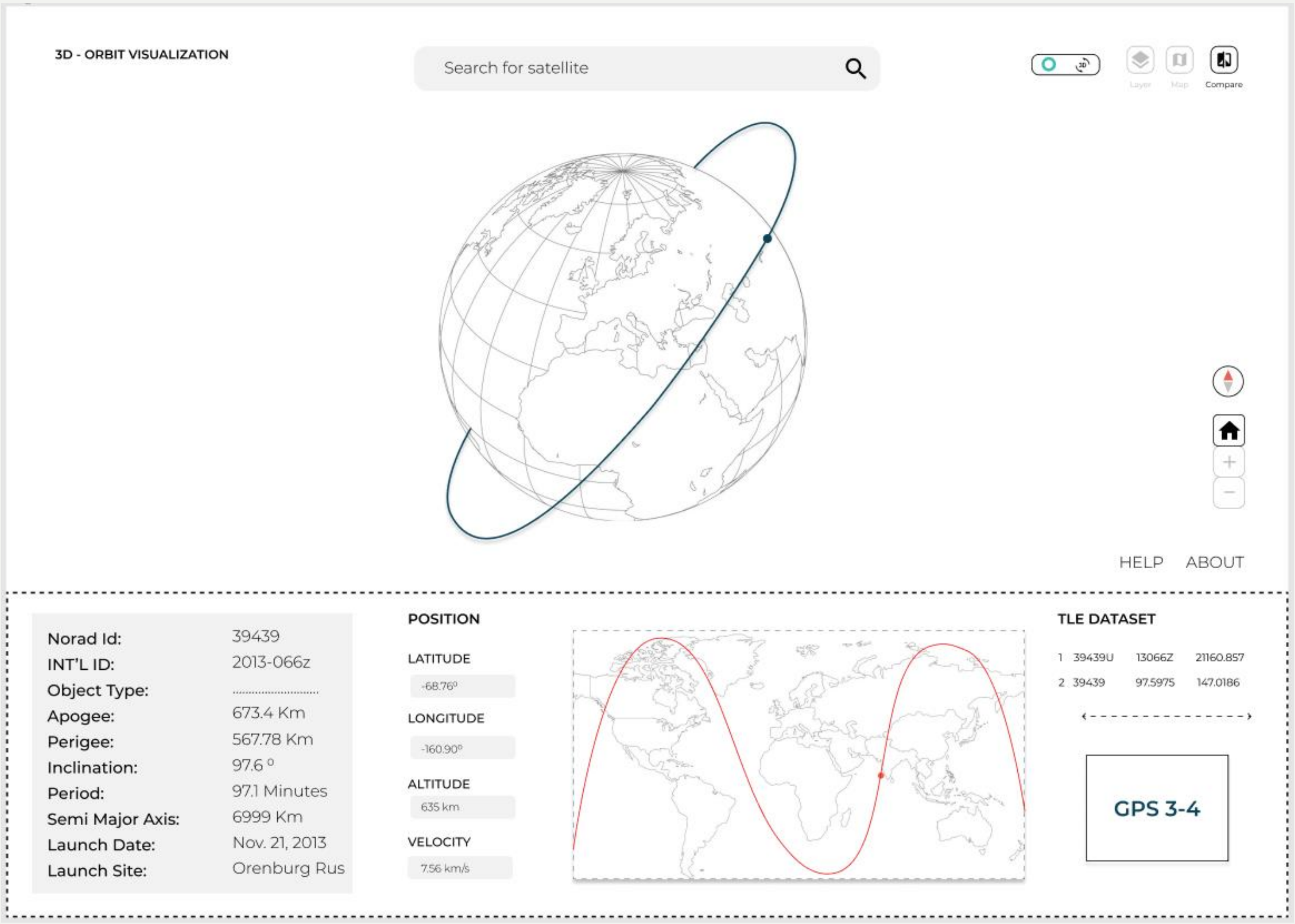
1 Satellite representation

- **geometric shapes** to the actual shape of satellites can be used for satellite representation
- the visualization of the satellites depends on the **objective** of application development
- to show only the total number of satellites, then a single color can be used.
- the preference for **multiple colors** for the visualization of satellites implies that most of the users find it easy to visualize the satellites based on their **classification**
- a **combination of different geometric shapes with different colors** can be used for the visualization of satellites to give the information of satellites as soon as the users open the interface.

2 3D vs 2D map representation

40 participants



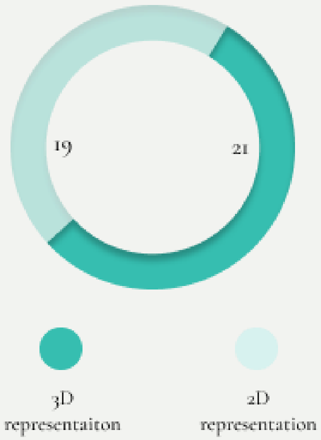


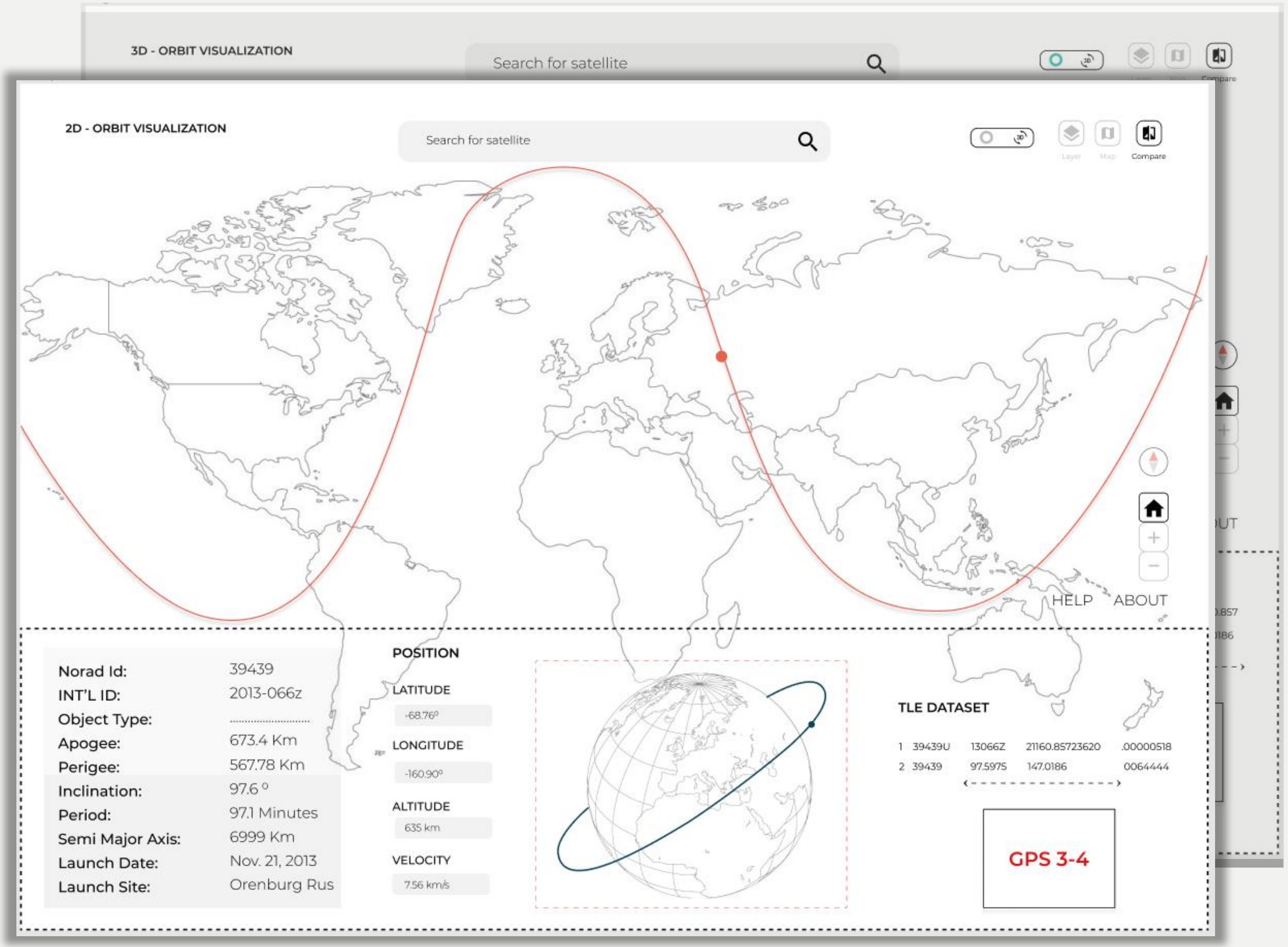
The outlook of the window when an individual satellite is selected in 3D globe representation.

2

3D vs 2D map representation

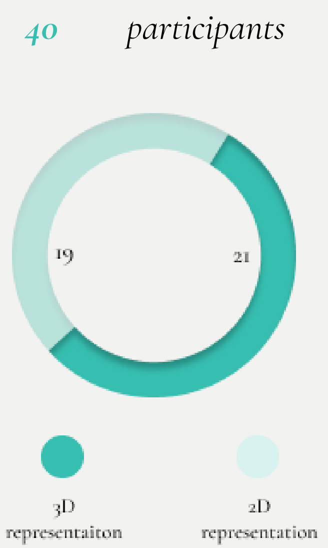
40 participants





The outlook of the window when an individual satellite is selected in 2D globe representation.

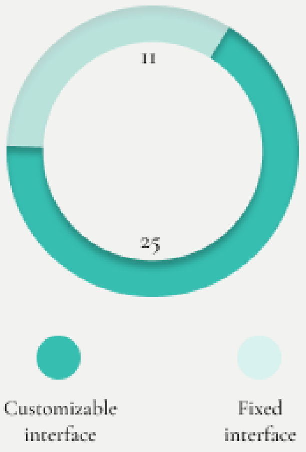
2 3D vs 2D map representation

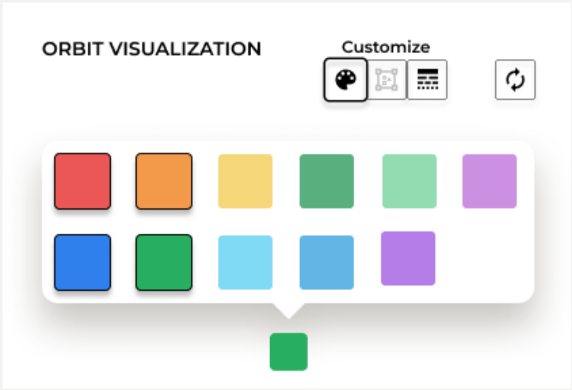


- the 3D map was preferred over a 2D map by users for the visualization of multiple satellites.
- when the multiple satellites are to be displayed at once, then the virtual 3D globe is effective.
- the use of a 2D flat map is suggested when the individual satellite is visualized.
- the combination of the 3D and 2D maps in an interface is considered to be effective.

3 Fixed vs customizable interface

36 participants



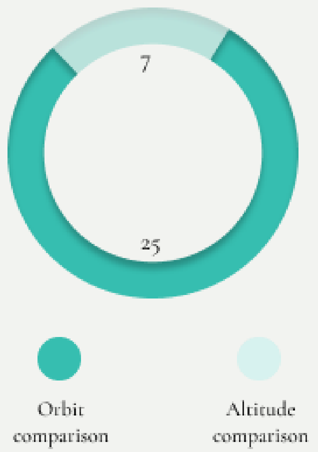


- color, shape (for satellites),
- line type, line color (for orbits).

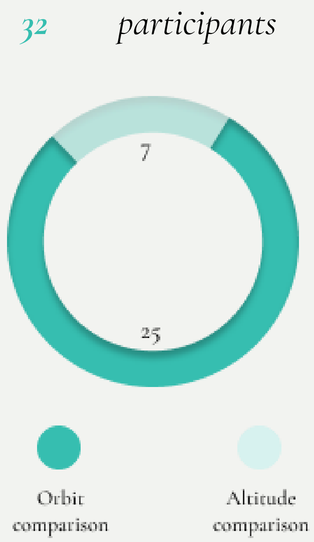
- the inclination of the users towards having a customizable interface as compared to a fixed interface was found
- the customizable option allows the users to freely interact with the interface, is personalized, and contains multiple choices
- other visual variables such as transparency, saturation, texture, orientation, and arrangement can be included to provide additional options to users

4 Comparison of satellites

32 participants



4 Comparison of satellites



- an orbit comparison method was chosen over the altitude comparison visualization approach for the comparison of user-selected satellites

- the orbit comparison allows the users to visualize the satellite orbits in the past, present, and future, many users were in favor of that.

- when the orbit is compared, one can check if any objects are going to collide

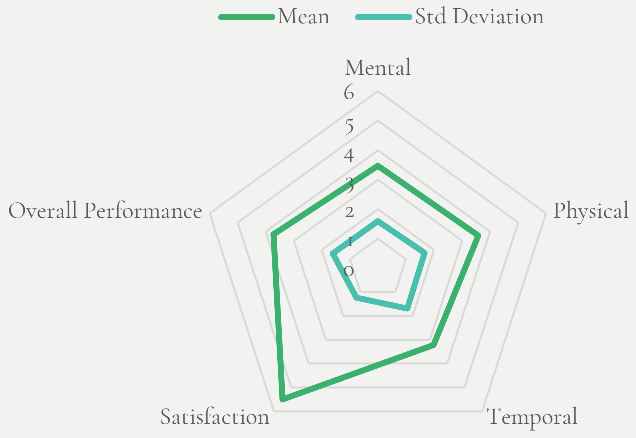
Results

Evaluation

1. Questionnaire
2. Utility and usability
3. Benchmark tasks

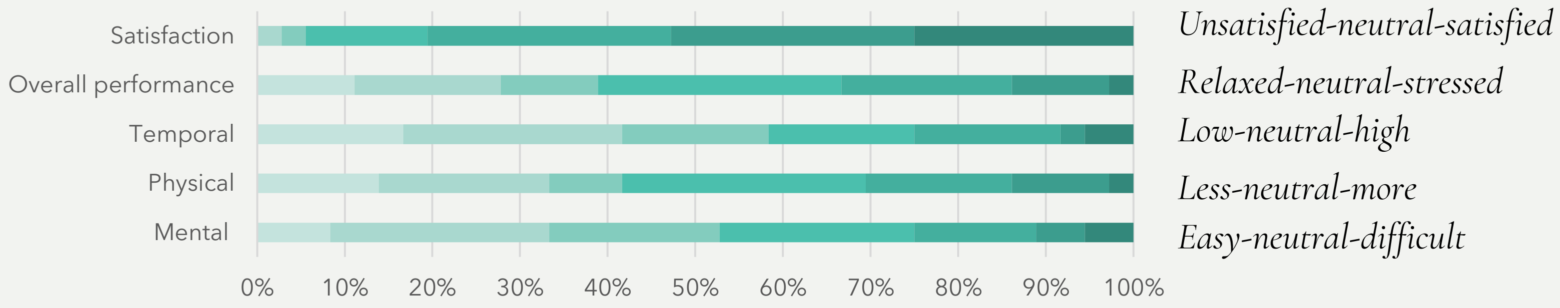
1 Questionnaire

36 *participants*



Radial chart showing mean value and standard deviation of questionnaire evaluation

Questionnaire evaluation



	Mental	Physical	Temporal	Overall performance	Satisfaction
1	3	5	6	4	0
2	9	7	9	6	1
3	7	3	6	4	1
4	8	10	6	10	5
5	5	6	6	7	10
6	2	4	1	4	10
7	2	1	2	1	9

Number of participants and their evaluation to the questionnaires

36 participants

eight positive questions
two negative questions

- 4.16 being the user's average result in terms of utility
- it shows that they found the interface to be a bit more useful than average

S.N	Utility Rating	1	2	3	4	5	6	7	Avg.
		Disagree				Agree			
A	I would use SatelliteViz frequently.	6	5	4	11	7	0	3	3.56
B	It is not an application of my interest.	6	7	3	8	5	5	2	3.61
C	It would be useful for the visualization of satellites and their orbits.	1	1	0	1	7	10	16	5.94
D	It would be applicable for those users who want to understand the satellites and their orbits.	2	1	0	1	8	6	18	5.83
E	It would not be helpful for the users who are experts of the satellites.	10	4	6	5	4	3	4	3.39
F	It is a novel approach to provide information about satellites to general users.	2	2	4	5	6	8	9	4.97
G	It has all the required functions to explore the satellite data.	1	3	4	6	6	8	3	4.14
H	It has all the essential functions to analyze satellite data.	1	3	4	6	6	8	3	4.58
I	It has all the necessary visualizations to understand the mechanism of satellites.	4	1	6	10	4	6	5	4.31
J	It provides many ways to visualize the satellite data.	2	0	3	5	5	11	10	5.33
The average rating for positive questions (8)		4.83							
The average rating for negative questions (2)		3.5							
Overall average with negative questions inversed		4.16							

Number of participants and their evaluation to the interface utility

2 Usability and Utility

36 participants

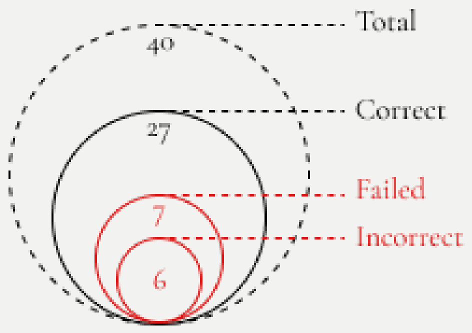
six positive questions
four negative questions

- 3.98 being the user's result in terms of usability
- it shows that they found the interface to be a bit less practical than average

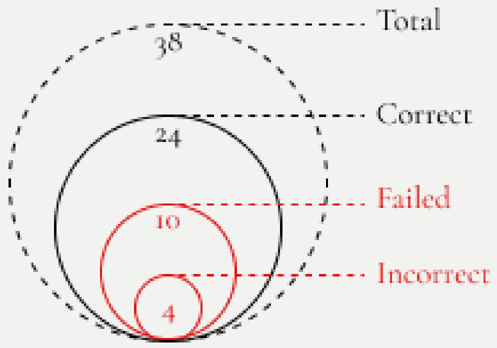
S.N	Usability	1	2	3	4	5	6	7	Avg.
		Disagree				Agree			
A	SatelliteViz was easy to use.	4	3	2	6	10	8	3	4.42
B	It was troublesome to use.	8	6	4	8	5	2	3	3.39
C	A support of a technical person is needed to be able to use SatelliteViz.	10	6	2	7	7	1	3	3.28
D	Some detailed help and tutorial is required to be able to use SatelliteViz.	1	3	4	8	10	4	6	4.64
E	Many people will be able to learn to use SatelliteViz quickly.	2	0	2	13	8	7	4	4.72
F	Some previous knowledge of using an interactive map is necessary to be able to use SatelliteViz.	3	3	5	4	12	5	4	4.39
G	I felt confident while using SatelliteViz.	3	1	4	10	10	6	2	4.36
H	I was often confused about where to click or where to look when using SatelliteViz.	5	4	2	8	7	5	5	4.19
I	The visual design of the application is well done.	2	0	1	9	6	8	10	5.25
J	SatelliteViz violates basic cartographic principles.	11	10	4	8	1	2	0	2.56
The average rating for positive questions (4)		4.69							
The average rating for negative questions (6)		3.74							
Overall average with negative questions inversed		3.98							

Number of participants and their evaluation to the interface usability

3 Benchmark tasks



Evaluation of finding of the operational satellite task.



Evaluation of finding of the junk satellite task.

Tasks	Total	Correct	Failed	Incorrect	Success percentage
T1	40	27	7	6	67%
T2	38	24	10	4	63%

effectiveness

Conclusion

- The research had two-fold objectives: (i) in-depth study of the existing literature to examine UCD for interactive maps; (ii) a design and evaluation of an interactive web-based application prototype.
- In practice, there are a few satellite visualization applications. The TLE dataset can be extracted from two available sources to get the available information of satellites.
- The evaluation of the designed interface was done by considering the success rate of the benchmark tasks, utility, and usability.
- For future reference, this prototype can be implemented into a coding-based application.
- Other loops of UCD can be implemented to improve the utility and usability of the interface.

VISUALIZATION

- The use of multiple colors can be used when the application demands to visualize the satellites based on their classification. Nevertheless, if the goal is to visualize the total number of satellites, then a single color visualization can be used.
- The combination of the 3D and 2D maps in an interface is considered to be effective.
- The inclination of the users towards having a customizable interface as compared to a fixed interface was found.
- An orbit comparison method was chosen over the altitude comparison visualization approach for the comparison of user-selected satellites.

References

Pietsch, M. (2015). *Peer reviewed proceedings of digital landscape architecture 2015 at Anhalt University of Applied Sciences: International Digital Landscape Architecture (DLA) Conference on Information Technologies in Landscape Architecture, held in June 4 - 6, 2015 at the Anhalt University of Applied Sciences Campus in Dessau, Germany* (E. Buhmann, Ed.). Wichmann.

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THANK YOU!!