Human-in-the-loop in Virtual Reality

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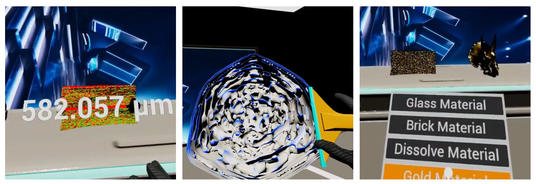
ABSTRACT

ASCRIBE-VR (Autonomous Solutions for Computational Research with Immersive Browsing & Exploration in Virtual Reality) is a virtual reality application designed to facilitate research with tools for enhanced data visualization and exploration.[1] It provides an alternative to two-dimensional interfaces, which can be difficult to use when working with 3D and multilayered data. A goal of ASCRIBE-VR is to enable human-in-the-loop decision-making for experimental validation.[1] **This project develops ASCRIBE-VR's first human-in-the-loop interface** using Unreal Engine 5.5.4 and its Blueprints Visual Scripting system. **The interface is designed for the review of image data and image classifications.** It allows users to import images into the application via a CSV file containing the images' file names, x-, y-, and z-positions in the virtual environment, and, optionally, classifications. Within the application, users can define 3D areas that contain images of the same classification. Users can update images' classifications by moving them in and out of these areas, and the updated data can be exported as a CSV file. **These functions provide a way for researchers to quickly sort image data and provide feedback on image classifications produced by autonomous systems.**

BACKGROUND

Human-in-the-loop (HITL) can improve the performance of autonomous systems, yet it is not widely used in all fields, likely due to **the lack of an ideal interface**.[2]



Pre-existing features of ASCRIBE-VR: linear measuring, slicing, and changing materials.

- **This project adds to the ASCRIBE-VR application**, which was started in December 2024 with the development of tools for 3D data exploration.
- The sample data used was generated by a **machine learning script** that **classifies images and spaces them in the 3D environment based on their similarity**, producing a CSV file.

SETUP

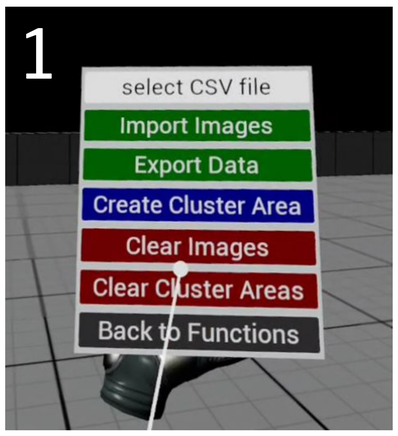
UNREAL ENGINE

Unreal Engine logo. Photo Credit: Epic Games

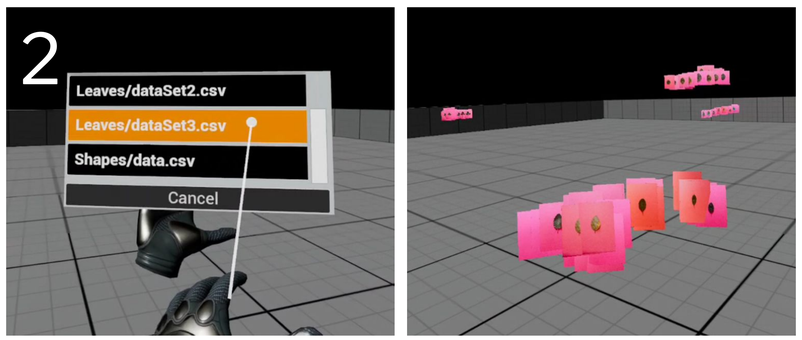
Meta Quest 3s. Photo Credit: Meta

- ASCRIBE-VR was developed in **Unreal Engine 5.5.4** using its **Blueprints Visual Scripting** system.
- The **Real Time Import/Export Plugin** to Unreal Engine was used to import images and read and write CSV files.
- ASCRIBE-VR is built for the **Meta Quest 3 and 3S.** These headsets were used to test new features.

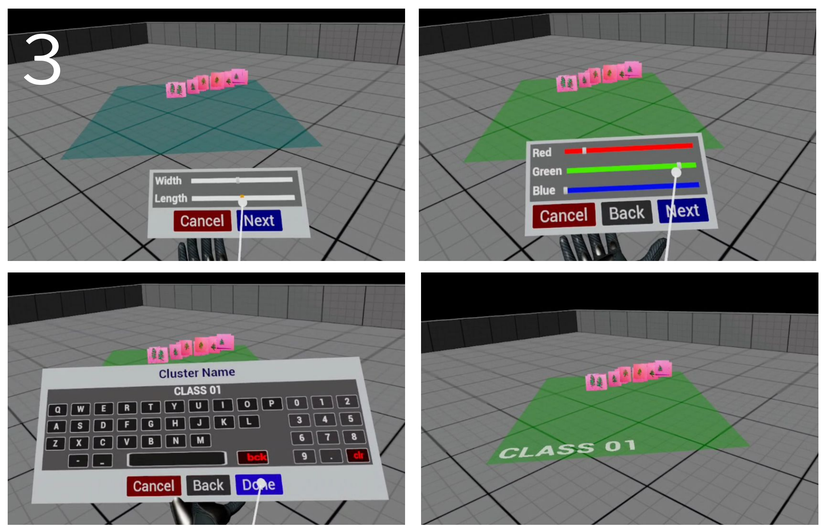
RESULTS



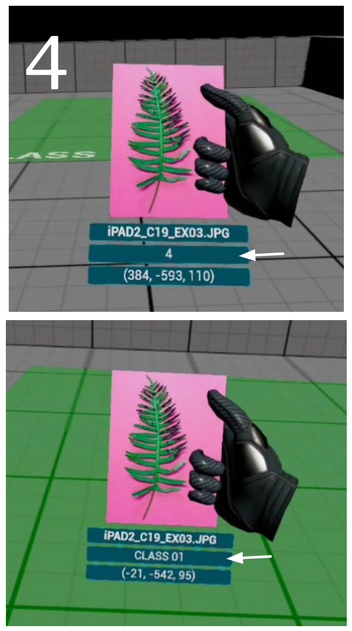
Menu with human-in-the-loop functions.



Importing images using a CSV file containing initial location with automated clustering of samples.



Creation of a cluster area: setting the size (top left), setting the color (top right), setting the name (bottom left), and the final result (bottom right).



Reclassifying images by placement in cluster areas.

```
iPAD2_C19_EX01.JPG,169.82611,-96.58374,73.14529,4
iPAD2_C19_EX02.JPG,168.61493,-107.30237,73.6191,4
iPAD2_C19_EX03.JPG,171.11897,-98.19336,73.89965,4
iPAD2_C19_EX04.JPG,145.08455,-114.95212,76.60817,5
iPAD2_C19_EX05.JPG,150.29272,-109.365204,74.41318,5
iPAD2_C19_EX06.JPG,101.0,-146.8248,80.349525,6
iPAD2_C19_EX07.JPG,125.26611,-130.38882,77.75633,6
iPAD2_C19_EX08.JPG,128.23593,-128.72568,81.42961,6
iPAD2_C19_EX09.JPG,117.13612,-139.60129,79.54898,6
iPAD2_C19_EX10.JPG,140.5929,-115.85019,78.50252,5
iPAD2_C19_EX11.JPG,112.78169,-137.55774,80.96357,6
iPAD2_C19_EX12.JPG,109.43848,-147.04675,83.050644,6
```

```
iPAD2_C19_EX01.JPG,169.82611,-96.58374,73.14529,4
iPAD2_C19_EX02.JPG,-239.023115,-592.722795,84.569763,CLASS 01
iPAD2_C19_EX03.JPG,-109.9009,-575.168808,90.834594,CLASS 01
iPAD2_C19_EX04.JPG,145.08455,-114.95212,76.60817,5
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iPAD2_C19_EX09.JPG,-241.225572,-705.890488,85.939131,CLASS 01
iPAD2_C19_EX10.JPG,140.5929,-115.85019,78.50252,5
iPAD2_C19_EX11.JPG,112.78169,-137.55774,80.96357,6
iPAD2_C19_EX12.JPG,-271.874794,-540.705804,97.153918,CLASS 01
```
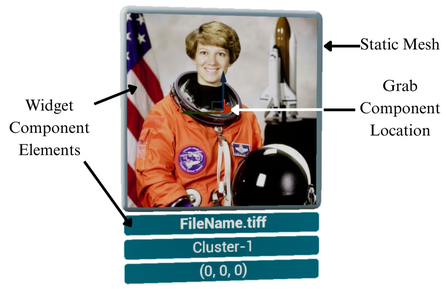

Input CSV file generated by a machine learning script (left) and output CSV exported after reclassifying images (right). Items with altered values are bolded in this diagram.

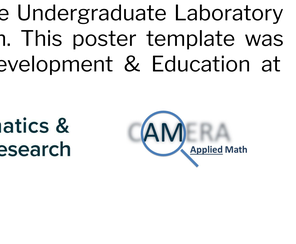
[1] D. Ushizima, G. M. dos Santos, Z. Sordo, R. Pandolfi, and J. Donatelli, "Ascribe new dimensions to scientific data visualization and interactive exploration with vr", DOI:000000/11111.
[2] X. Wu, L. Xiao, Y. Sun, J. Zhang, T. Ma, and L. He, "A survey of human-in-the-loop for machine learning", Future Generation Computer Systems 135, 364–381 (2022).

METHODS



- Images contain a grab component attached to a static mesh to allow users to move them, and a widget component that displays the image and its metadata.

- Cluster areas contain a box collision component that triggers images to update their classification when overlapping with the cluster area.
- An invisible actor is responsible for importing images and exporting CSVs.



IMPACT

- Provides a **more intuitive way to view, sort, and classify** images than a 2D interface.
- Allows users to **take into account the similarity of images based on their proximity** when making classification decisions.
- Can be used for **image quality control, isolating critical image data,** and **reviewing image classifications**.
- Future work can **expand the interface for use with other kinds of image collections.**

ACKNOWLEDGEMENTS

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