VR User Behavior Analysis

Planned Timeline

Sunny Guan

ACM Research Spring 2021

Introduction

Background

Dr. Prakash and his team made A taxonomy and Dataset for 360 Videos, which is a collection of 28 VR videos with content ranging from rhinos in the savanna to students walking at UTD. The dataset was initially created to address two main issues: viewport prediction and storytelling.

Viewport Prediction

Viewport Prediction was the main research topic led by Bryant as one of the four teams during ACM Research in Fall 2020. The two major goals were:

1. Proving a correlation between salient features and user viewports
2. Predicting user viewport using salient features (as well as video data)

We were able to successfully finish part 1 through various overlays that highlights the connection between salient features and the 30 users' viewports. For part 2, we made important progress in attempting to predict user viewports through image processing and machine learning. The results were very promising, but there were definitely room for improvements in that direction.

More information about the Viewport Prediction research can be seen at the Github repository.

Storytelling

Traditional videos (such as a movie) are relatively easy to produce with regards to storytelling compared to VR videos. This is because the important scenes are directly in front of the users and the field-of-view is often quite limited to funnel attention. In addition, important characters or objects are often placed in the middle of the screen for the same reason.

In VR videos, the user is free to look at every direction; although this is great for immersion, it makes storytelling much harder as there is no "middle of the screen" to direct user attention. Thus, if we could successfully detect how people consume VR content through tracking their behavior, we could gain a better understanding of how to effectively guide user attention.

Research Focus

During this semester of ACM Research, our goal is to analyze user behavior through (but not limited to) the use of heat maps and viewport tracing throughout different frames. We are aiming to get a better understanding of areas-of-interests in VR videos as well as classifying different user behaviors.

Timeline

1. Week 1: Welcomes, description of topic, summary of previous semester
2. Week 2: Go over dataset and walk through important code on Github
3. Week 3: Learn about heat map generation with **seaborn** and basic numpy if necessary
4. Week 4: Work on generating heat maps from video frames
5. Week 5: Continue from Week 4
6. Week 6: Review results and record findings
7. Week 7: Begin user-behavior classification, read research papers
8. Week 8: Work on clustering users into groups
9. Week 9: Continue week 8
10. Week 10: Wrap up results and prepare for symposium

Week 1

Objectives

1. Icebreakers and introductions (oh no)
2. Introducing project and background
3. Go over timeline and rough plan for the semester
4. Gauge skill level with different tools

Useful Links

1. VR Viewport Analysis Github
2. Main Research Paper from Dr. Prakash

Homework

1. None

Week 2

Objectives

1. Go through the dataset on Github so everyone understands where files are stored
2. Summarize VR Viewport Analysis results
    1. See Introduction on previous page
3. Go over goals for the semester
4. Miscellaneous housekeeping items

Homework

1. Research papers for your enjoyment (just kidding they're mandatory):
    1. A taxonomy and Dataset for 360 Videos
    2. Learning to Predict Where Humans Look
    3. Actors in VR Storytelling
2. Interesting reads (not mandatory)
    1. Examining VR Storytelling vs. Traditional Forms

Week 3

Objectives

1. Go over timeline again and revise if necessary
2. Check experience with Python/numpy/matplotlib/seaborn
3. Explore heat map generation in Python

Useful links

1. Basic Matplotlib Heatmap
2. Seaborn Jointplot

Homework

1. Try using frame data to generate single frame heat map (continued through Week 6)
2. Setup meeting outside of build night if necessary?
3. Brainstorm research directions (optional)

Week 4

Objectives

1. Clone Github and setup environment
2. Generate heat maps for all frames in a single video
3. Generate combined heat maps and analyze regions of interest

Note

1. Make sure environments are setup properly

Week 5

Objectives

1. Continue generating heat maps and document interesting results for each available video
2. Questions/issues from week 4 scripts
3. Briefly introduce part 2 of project

Useful Links

See Week 4

Homework

1. Finish heat map generation and documentation

Week 6

Objectives

1. Wrap up results and scripts from first part of project
2. Discuss significance/insignificance of results
3. Schedule meeting with Prakash to go over heat map results and discuss improvements/ideas

Homework

1. Clean up and finalize work on heat maps

Week 7

Objectives

1. Go over second part of project on user behavioral classification through head-tracking
2. Basic knowledge on yaw, pitch, roll and how to calculate similarities between two user's viewport traces (over time)
3. Introduce existing research on VR user classification/clustering

Papers

1. **Machine learning-based object detection and user behavior classification using virtual reality landscape images and head motion data**
    1. Uses VR data to feed into object recognition algorithm
    2. Interesting comments/approaches since they are detecting wind turbines (the main example in the paper) using user's viewports
2. **Dynamic Visual Attention on Sphere**
    1. Very math-y, recommend only reading the pictures unless the reader is very skilled in mathematics and algorithms
3. **Spherical Clustering of Users Navigating 360 Content**
    1. More accessible and directly related to topic, good to read through to understand the proposed clustering algorithm based on Bron-Kerbosch algorithm

Homework

1. Read/skim the research papers, come up with questions/comments if applicable

Week 8

Objectives

1. Go over clustering algorithms for time-series data
2. Discuss pros/cons of different approaches
3. Demonstrate using (each?) approach in Python with temporal data

Notes

1. **Dynamic Time Warping**
    1. Compare temporal data where speed might be different
    2. Why: different users might track differently if compared frame by frame but have very similar viewport traces if time was not considered (due to speed of movement)
2. **Hausdorff Distance**
    1. Measures distance between “two subsets of a metric space,” which does not take time into account
    2. More complex but should have working implementations in Python
3. **Frechet Distance**
    1. Also look into this as a possible way to calculate similarity
4. Most basic: compare distance between every dot per frame

Week 9

Objectives

1. Continue on week 8 to work on different strategies for clustering
2. Discuss shortcomings (if applicable) for each method
3. Choose best measure to use, generate results from that

Homework

1. Finish testing different algorithms from Week 8
2. Prepare to wrap up for poster presentation

Week 10

Objectives

1. Finish everything
2. Discuss progress made, future directions, etc.
3. Discuss symposium details

Homework

1. Prepare for symposium