Dendrogram Visualization as a Game Design Tool

Tom Feltwell
University of Lincoln,
Lincoln, UK
tfeltwell@lincoln.ac.uk

Grzegorz Cielniak
University of Lincoln,
Lincoln, UK
gcielniak@lincoln.ac.uk

Patrick Dickinson
University of Lincoln,
Lincoln, UK
pdickinson@lincoln.ac.uk

Ben Kirman
University of Lincoln,
Lincoln, UK
bkirman@lincoln.ac.uk

Shaun Lawson
University of Lincoln,
Lincoln, UK
slawson@lincoln.ac.uk

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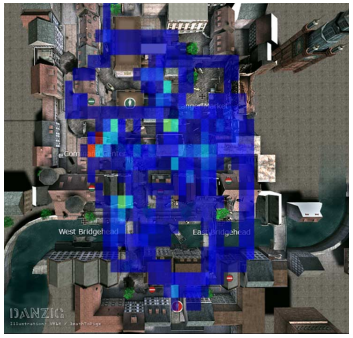
Abstract
With the advent of game telemetry, contemporary game designers have access to a huge amount of real-time data about player behavior. However, in design practice there is a lack of effective visualization tools. Activity histograms or heatmaps can suffer from data overcrowding, making it difficult for the designer to identify patterns and outliers within a large dataset. This work-in-progress explores a new meta-visualization tool for game designers that uses dendrogram representations to highlight pertinent features within large sets of heatmaps. Through interviews with professional game designers, we find that dendrograms can be used to identify outliers quickly, and are valuable in guiding designers through complex telemetry. This contributes to the ongoing work on supporting richer tools for game design practice amongst an increasingly data-filled environment.

Author Keywords
Game analytics; visualization; Games User Research; heatmaps; hierarchical clustering;

ACM Classification Keywords
H.5.m. [**Information Interfaces and Presentation**]: Miscellaneous

Sidebar 1

Screen capture of *Red Orchestra: Ostfront 41-45* multiplayer game.



Heatmap of all player movement from 40 play sessions. Blue indicates low movement count, green is intermediate and red/orange is high. It can be seen that there are "hot" points on the map – these are team objective locations.

Introduction

Many modern video game titles have globally distributed player bases, accommodating thousands of concurrent players. Designers are increasingly turning to recording player activity, known as telemetry, to try to understand what their players are doing, and to inform design decisions. Broadly, this process of drawing meaning and understanding from data is known as game analytics.

In this paper we focus on spatio-temporal telemetry data, which is commonly represented in the games industry using heatmap visualizations [4], [9]. Heatmaps are a two dimensional map which uses color gradient to indicate the distribution of the frequency of a variable within the game world. An example be seen in Sidebar 1. However, despite their perceived value, heatmaps suffer from "data overcrowding" when using multiple variables [2]. To mitigate this issue, we propose a meta-visualization tool that can order and structure heatmap data from pertinent features, such as clusters and trends, from a large dataset. The purpose is to support designers' ability to focus on interesting patterns and behaviors within highly complex datasets.

The approach taken visualizes the similarity amongst a set of heatmaps using a branching tree-like navigable graph, known as a dendrogram [8]. This calculation of similarity is based on the patterns collected through a process of hierarchical clustering. As a meta-visualization tool, dendrograms can be used to understand the distribution of data, isolate outliers and explore patterns within the dataset.

Our intention is to provide a high level overview of the interesting features of a large dataset that maybe otherwise unobserved. For example, a designer may notice an outlier group on the dendrogram visualization of several thousand heatmaps, which will guide them to subset of data. This might reveal that the players in the outlier group were blocked by an obstacle in the level, which was easily overcome by other players. Summarizing the key differences with a meta-visualization enables designers to spot important features and patterns among hugely complex collections of data that would otherwise be too overwhelming to be practicable.

In understanding the potential value in meta-visualization of this sort, we investigate how designers use game analytics in their design process, before making initial steps to explore the efficacy of dendrogram representation of heatmaps as a potential tool to aid designers analyzing large corpora of spatio-temporal player telemetry.

Related Work

Game Analytics

The adaptation of business analytics to the specific context of games has become commonplace in commercial games design, in order to better understand player. For an excellent overview of the field, see [9]. When working with large corpora of data, designers use game analytics reductively as a "first pass" filtration tool to highlight pertinent features within the data [6]. Researchers are actively investigating how designers interact with and use analytics as part of their professional work flow. Kim et al. [4] outline a framework for a telemetry visualization system, which displays spatio-temporal player data

Sidebar 2

Creation of a dendrogram:

1. Calculation of the similarity between each pair of observations (Euclidean distance).

2. An agglomerative (joining) assignment procedure, which starts with as many clusters as observations, then iteratively merges the closest clusters based on a criteria.

Technical implementation:

Heatmaps were generated using Python + NumPy and Matplotlib for all the players in each session, which were overlaid on a map of the game level and plotted using a hot-cold color gradient. NumPy, SciPy and Matplotlib Python libraries were used to perform hierarchical clustering on the generated heatmaps. Single-linkage clustering with 1-norm distance metric (L1) was used, with heatmaps of individual players' gameplay as input for clustering.

along a time line, with annotated, linked video of screen capture video. Medler et al. [5] worked with the development team of Dead Space 2 to design a suite of tools, Data Cracker, which displays data to help answer typical analytics questions of the team. Work has been done by Mirza-Babaei et al. [7] to develop a new user-testing (UT) method which combines quantitative gameplay metrics and qualitative observations with physiological information about a player's state.

Data Overcrowding

The nature of single variable heatmaps means that many must be generated to get additional views on a dataset. For example, plotting the movement of each player in a 30 player game session creates 30 individual heatmaps. The designer then needs to compare each of these when looking for patterns and trends, creating n^2 comparisons, a time consuming task for manual analysis. Similarly, plotting the movement of each player onto a single heatmap only allows an aggregate view of the data. As the number of variables that may affect player behavior in a game increases, the complexity and associated costs of this analysis becomes unmanageable.

Dendrograms

In the field of computational biology, dendrograms are tools designed to display the results of hierarchical clustering of genomes [3], which visualize similarities between different. Although designed for different purposes, we argue that this kind of "meta-visualization" can be of great value to game designers.

Design of Dendrogram Pilot Study

As part of a user-centered design methodology we wish to understand how a visualization of important data features such as dendrogram representation helps designers interpret large corpora of spatio-temporal data. To do this we conducted a pilot study with professional game designers.

An initial corpus of data was gathered from *Red Orchestra: Ostfront 41-45* [10], a first person team-based shooter game based in the eastern front conflict in WW2. Player participants were recruited from staff and students at the University of Lincoln, who gave informed consent for their data to be collected. Participants were given no special instruction apart from to play and enjoy the game as normal. In total, rich player telemetry was collected from 32 distinct hour-long sessions with each featuring 7 players on average, from 266 total players. The data totaled over 500,000 spatial data points, composed of: movement, deaths, shooting and taking damage. Details of the technical implementation can be seen in Sidebar 2 and 2. To understand how dendrogram representation might be used when exploring design queries, four professional game designers were recruited. They were recruited through professional connections and public message boards, all having experience of publishing commercial games content to the general public. One participant (P4) was a lead designer at a major game developer, two participants (P2, P3) were independent game developers and one participant (P1) was a community level designer. They were all familiar with heatmap visualizations.

An interview was conducted with each designer, in a semi-structured fashion, each lasting approximately 20 minutes. Two interviews were conducted via Skype, and two conducted face-to-face. The interview was formed of two parts: the first covering their design

Sidebar 3

Figure 1 shows a dendrogram generated from the collected data from a single session of PC first-person shooter (FPS) *Red Orchestra*. Points along the x-axis represent individual player heatmaps, with connections showing the relationships between each one. The fewer connections between two points on the x-axis indicate more visual similarity between the two heatmaps.

The heatmap in **Sidebar 1** shows the aggregate of all player data from the 32 matches. **Figure 1** displays the same data, **Cluster D**, but at an individual player level. **Clusters A, B** and **C** represent further clusters identified by hierarchical clustering. This allows the designer to observe differences between patterns of player behavior, by inspecting either aggregate heatmaps, or individual heatmaps at any point in the dendrogram.

experience and usual methods for obtaining feedback on their game design decisions, and the second part comprising two hypothetical design scenarios where they were asked to suggest ways of balancing a multiplayer first-person shooter level. In the first scenario, the designers were provided with a top-down image of the game level, and a single heatmap showing the movement of 40 players from a single game session, this can be seen in Sidebar 1. In the second scenario they were again provided with the same top-down image and heatmap of player movement (Sidebar 1) as well as a dendrogram representation of the data, Figure 1. These materials were provided either on paper or as a PDF, dependent on the interview method. Dendrograms were explained before commencing the scenario. In the second part of the interview they were asked how they would use the various visualizations to solve the balancing problem, whether there was too much or not enough data present, and whether they would improve anything on the representation. Having completed these two tasks the interview was concluded and they were debriefed.

Pilot Study Findings

An inductive thematic analysis was conducted on the transcribed interview data, with game design process and usage of visualization being the focal aspects. Audio recordings were transcribed, and then split into meaningful sentence fragments. This totaled 74 sentences, which were coded into 10 themes by a single coder using a process of inductive thematic analysis [1]. Another coding iteration was undertaken by the same coder, which consolidated the data into four themes: Each theme is discussed below.

Value of Metric Feedback

P2, P3 and P4 expressed the value of metrics to understand player behavior in the game industry. For example, P2 outlined how they gather data about players in their game: *"[When using our metrics] if there are players spending an abnormally long time in a room, maybe the enemy's health is too inflated and needs to be changed...to make sure [the level] has a nice [difficulty] curve."* P4 talked about the testing process: *"They put a lot of analytics into it [the game] and sent the game to people remotely so they can track how long they were playing for and what they were using."*

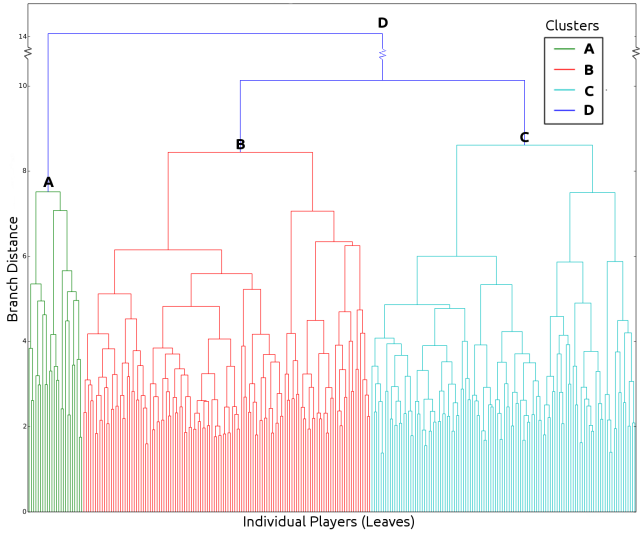


Figure 1. Dendrogram of Player Movement Heatmaps.

Issues for Design

The way analytics are used to answer questions on a case-by-case basis during the design process was discussed by participants. P4 illustrated how they

combat data overload from quantitative metrics: "*We tracked everything... you've got reams of data, which is counter-intuitive. We tried to figure out what questions we wanted to ask and then put in the right amount [of analytics] to answer those.*" P3 echoed this statement, outlining what kind of questions they ask when using metrics: "*I'd like to be able to take out...the guys doing really well, what's he doing different and how can I bring him closer?" and "the guy who's really struggling, why is he struggling?*"

Heatmap Utility

The utility of heatmaps for the design process was discussed. P2: "*You could see if two classes are working together they're gonna have a similar heatmap, that's a good dynamic*" and P1: "*It would be useful to find out how the map is flowing, how they're moving from one part to another.*" and also "*my eye is drawn to the hotspots but the [small] points are still important, you could argue they are more important.*" The issue of large data sets of heatmaps was raised by participants. P3: "*If it's 50 [heatmaps] for each level, there's too much data to actually analyze usefully. You want it down into something more succinct*" and P2: "*I would definitely look at it [all], but I probably wouldn't pay as much attention to the smaller details*".

Dendrogram Utility

None of the designers had encountered a dendrogram before, however, when interpreting the dendrogram representation during the design scenario, points were made regarding its use. P2: "*You can instantly see where the problems are lying then you could look at the heatmaps to find it.*" P4: "*this would help show you how similar all the players are to each other, or not. Maybe you would know if you needed to look further.*" P3: "*With the more players you get, the more useful something like this is going to be.*" P4: "*As long as I can do that [click on items], it's quite easy to click on it and say what is it that's made them similar. I think that could be really useful.*"

Problems with the representation were also highlighted. P3: "*I'm seeing a lot of noise. I think you'd need to use it a few times before you really understood. There's a lot of data there and it's knowing how it's gone together*". P4: "*When you first look at it and are uneducated as to what it is, it looks more like it's only the lines that are important and that the white space doesn't represent anything.*"

Discussion & Future Work

Existing practices among the designers confirms a question based approach to using analytics [5]. This also suggests the designers are trying to extract pertinent data when answering questions. It is also evident that telemetry data is used to directly influence and inform decisions [6]. The designers expressed the potential utility of heatmaps as part of the knowledge discovery process, but also acknowledged the limitations when dataset size increases. They outlined the usefulness of dendrogram representation to highlight features within the dataset. This reinforces the idea of game analytics as a "first pass tool" [6], which give the designer a starting point within a large corpus of data. Detection of outliers can be useful, and our data reflects that dendrogram representation could help guide queries to the most pertinent and relevant parts of the dataset.

Interestingly, points were raised regarding the usage of the dendrogram. P3 and P4 found it difficult to

understand initially, but noted that might be mitigated with familiarity. This could be caused by the use of paper and PDF representations of the dendrogram, as the designers were unable to explore the visualization interactively. The designers reaffirmed the need for such meta-visualization. They expressed that dendrogram representation highlights the interesting features within a large collection of heatmaps, which guides them towards the underlying data of interest.

To build upon these findings, we are planning to conduct a hands-on design exercise, using a larger sample of designers. This will include the use of a digital, interactive version of the dendrogram meta-visualization. This process will also accommodate more heatmap and dendrogram examples for designers to work with. A design exercise will provide an insight into the use and applicability of this tool as part of game design practice.

This paper identified the potential value of dendrogram representation and hierarchical clustering as a game design tool to highlight important features within collections of heatmaps. It contributes an understanding of how spatio-temporal data and game analytics are used by designers and proposes the use of dendrogram representation as a form of meta-visualization. This work contributes to the growing body of work interested in supporting tools for game design practice amongst an increasingly data-rich environment. Findings confirms "data overload" that occurs when analyzing large amounts of player data, and participants show optimism towards the use of interactive meta-visualization to identify clusters and patterns in complex player data.

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