DATAPLAY: Mapping Game Mechanics to Traditional Data Visualization

Colleen Macklin
Parsons The New School for Design
2 W. 13th St., New York, NY
macklinc@newschool.edu

Michael Edwards
Parsons The New School for Design
2 W. 13th St., New York, NY
edwarm40@newschool.edu

Julia Wargaski
Parsons The New School for Design
2 W. 13th St., New York, NY
wargaskj@newschool.edu

Kan Yang Li
Parsons The New School for Design
2 W. 13th St., New York, NY
lik43@newschool.edu

ABSTRACT

In William Playfair's 1786 book, The Commercial and Political Atlas, he states that information, "imperfectly acquired, is generally as imperfectly retained." [6] Playfair is commenting on the failure of tables to represent comparative data in way that was useful to the reader. Since Playfair, many different forms of media have arisen beyond ink and paper. Yet printed charts (or their digital representations) remain, by far, the most commonly used tools of data visualization. Their evolution over many centuries has allowed them to achieve a degree of sophistication that time-based and interactive representations have yet to achieve.

Is the supremacy of printed (or print-like) data visualization to remain unchallenged? Would it even need to be? The authors contend that new approaches may be possible, and even necessary, but would require tapping into a different way of learning that was not strictly about managing the short term visual and auditory memory of the readers [3]. This learning would involve less the experience of reading and more that of direct experience through play and games.

Jesper Juul contends that all games are learning systems [2]. That is, to play a game and become good at it, the player must learn the necessary skills and strategies to overcome their opposition. If the goal of data visualization is educational, it may be possible to use specific types of games as ways of representing specific types of data. It may be possible for a player to learn the system of the game and the system of the information together.

The authors have built three game prototypes that illustrate the ways in which different forms of data can be re-presented in the form of digital games. The first prototype, *Kimono Colors*, is based on data from a cross-referenced table that describes the types of ingredients used to create traditional Japanese dyes in the production of kimonos. The core mechanic [4] of the game has the player "fishing" for colors using one of several dyes the player has collected. By fishing for these colors, players learn the relationships between materials and the manufacture of dye.

The second prototype, *Mannahatta: The Game*, asks players literally to walk around Manhattan and connect the living and non-living elements of a directed graph representing the ecology of the island 400 years ago. Played over an iPhone, users place themselves in the middle of the dataset they are piecing back together.

The third prototype, *Trees of Trade*, uses data from two directed graphs of relationships, ecological and commercial, in a Brazilian Atlantic rain-forest ecosystem. The game involves the players re-establishing the trophic levels of the forest by navigating through the relationships and inserting the missing species on an idealized map. Through play, the user will better understand the elements of a system that is typically illustrated in a static, two dimensional directed graph illustration.

Two questions stem from these prototypes: can data create play and can play enlighten data? To answer the first question affirmatively, we need to find evidence that a system created by data has the ability to produce "choice molecules" [4]. That is, in the form of a game, does the structure of data allow the player to make interesting choices about how to proceed as he or she navigates and elaborates the data? If so, then the data in question can create play, which in turn can drive the development of a full-fledged game.

As for the second question, if the first answer holds, then the player is, in the course of a game, playing with the data. If the choices made available to a player are established in such a way that the player "levels up" through the information, then the achievement of the games goals will be coincident with the understanding of the data itself. By actively manipulating and using the data to win the game, the player will need to understand the facts and

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relationships inherent in the data itself, thus producing the desired educational outcome and a greater sensitivity to the systems that data represents.

Author Keywords
data, visualization, games, game mechanics, ecology, history, education

DOMAIN

We, as readers, immediately understand how to read a scatter plot, a time series, a pie chart, and network graph. Moreover, a single, two-dimensional image has the benefit of being in front of the reader all at once, not taxing the short-term visual memory or requiring the user to backtrack or scrub to find key data points, as in time-based media like video. All humans have limited capacity, and good informational and educational design takes this into account [2]. Game also require excellence in informational and educational design, to the extent that a game has to, at least, teach the player about itself. But what else could a game do?

Can Data Create Play?

Games are ruled based systems. Rules describe the system or the objects in the system by their behaviors and relationships under the notion of time, a sense of progression. Games are particularly good at revealing the dynamics of complex systems because players become active participants in those systems. The ways in which rules interact create a world of constraints and consequence for players. At the same time, seemingly restrictive rules are necessary to generate play. This is the central paradox in games, and it is what makes them such interesting forms to design and study. Players bring their own experiences and choices to the game, generating a vast array of play styles and outcomes.

What of the outcomes of a game derived from a set of real-world rules? For instance, what if the game's rules and mechanics (actions in the game deriving from rules and game elements) expressed the federal debt, or deforestation rates in South America, or the ecological webs existent in 1609 Manhattan? Could we learn something new about these actual situations, places, and systems?

More specifically, can we reveal underlying and perhaps mysterious phenomena at work by not representing these topics as *narrative* content in a game, but in the *rules* themselves? And to add another level to our challenge, can we use the actual data—information gathered and organized—as the basis for a game's rules and express its nuances and push at its seemingly rigid boundaries through play, teaching us something new? Can data be *playable*? These are the questions we have been exploring in our research, which we are calling “DataPlay.”

In the same way that data lends itself to certain kinds of visualization, such as a proportional data in pie charts or scheduling data in grids by hour and day, data can lend itself to different interactive forms as well. Games, as an interactive media, are quite formal. They rely on rigid sets of rules, they have a goal or win condition, and oftentimes fall into certain genres (action, role-playing, puzzle, real-time strategy). In the three prototypes described below we have tried to establish rules and mechanics that are an aesthetic and interactive match to the datasets they represent.

Each dataset started off as typical collections of numbers, dates, categorizations, and relations. They were then visualized using algorithms or human-crafted design. Starting from those visualizations, we were able to "see" the formal nature of the dataset, its inherent patterns, overall scale, and general contours.

Can Play Enlighten Data?

Instead of asking only what can data do for play, we are also asking, “What can play do for data?” Play means, among other things, exploration. Data visualization is one way to explore data—and not only explore, but reveal new aspects of the data.

The classic example of Dr. John Snow's 1854 discovery of contaminated water pumps as the primary source for the widespread cholera outbreaks in turn-of-the-century London have been chronicled in Tufte's books on information design as a triumph of information design [6]. By mapping the outbreaks and adding—in a hand-drawn precursor to geographic information systems—the locations of water pumps, Snow was able to deduce cholera's cause, and prompt a revolution in urban sanitation [1].

If visually navigating through a dataset can lend itself to such revelations, what can the playful navigation of datasets reveal? We have attempted to find this out through the three projects, each of which is a meditation on the data itself, taking form and inspiration for the data and the way it is structured as well as working with information designers and scientists to bring the data to life for the game's design.

In each example, earlier dominant visualizations have framed our understanding of the data, allowing us to leapfrog the process of understanding a dataset's physical/visual characteristics and enabling the consideration of the data from the vantage point of being able to "see" it already. Using the existing visualizations as our road map, and the datasets as our raw material, we began the process of crafting game concepts, from paper to digital prototype.

PROJECTS

Kimono Colors

In Wargaski's Advanced Information Design class, students are given assignments called Information Design Experiments. Bringing science and design together has been an interest of hers, as an Information Design Professor, for many years now. Wargaski asked students in her course to synthesize a portion of the species of the planet with concept, space, and time—to merge many avenues of knowledge, navigation, narrative, beauty, and concept in to an accessible and intuitive design representation.

For her submission, student Hiromi Sugie created "Japanese Kimono Colors," a matrix of 217 colors found in traditional Japanese kimonos, cross referenced with the name and class of the plant, animal, or mineral ingredient used in its production, as well as other information, such as the length of time a dye had been used historically by manufacturers (Figure 1).

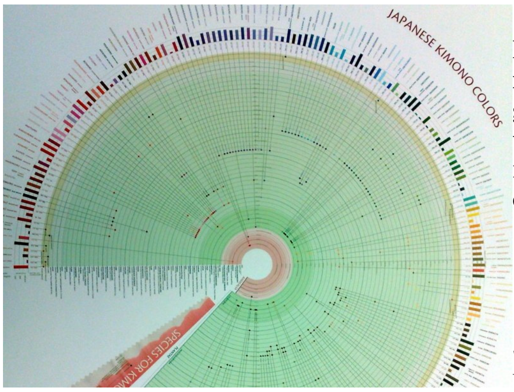

Figure 1: Sugie's original visualization "Japanese Kimono Colors"

Genre

Arcade-style "fishing" game

Description

The game prototype *Kimono Colors* is based directly on Sugie's data visualization. In the game, players are able to select a "lure" that represents a single ingredient such as *suou* (sappanwood) or *benibana* (safflower). The game screen is covered in a wide variety of colors that move around the space like fish (Figure 2). The lures, when placed on the screen by the player's mouse, attract the colors that are created with those ingredients. Ingredients that are used in a wider variety of dyes attract more colors.

Learning Goals

The principle goal of the game is to familiarize players with the combinations of natural ingredients that constitute the various dyes used in traditional kimono manufacture. One of the most rewarding aspects of "fishing" in the game is exploring the richness and variety of color that certain biological and natural sources can produce—often, the game produces "happy accidents" where sudden swarms of color surround the lure of a seemingly mundane ingredient.

Challenges

Edwards and Li experimented with different approaches that players could use to analyze cross-referenced data that were both accurate and provided meaningful choices to the player. Initial tests used the grid-like structure of the matrix table itself, but this proved to be superfluous in the context of the game—the *visual* metaphor for data did not immediately suggest a *ludic* metaphor. While the games prototyped occasionally seemed fun, none seemed to require attention or engagement with the data—the play of the games did not require the player to acknowledge meaningfully the data represented. The fishing mechanic, however, was significantly different, visually, from the original visualization, but provided players with choices within the game and revealed insights into the dataset that no other previous mechanic had uncovered during play.

Figure 2: The digital prototype of the *Kimono Colors* fishing-game mechanic.

Future Goals

A full resource-management game is in the works that will allow players to more fully "level up" through the data. Because some dyes and colors are more difficult to synthesize that others, scaffolding players through simpler combinations of common dyes up through very rare ingredients mixed in complex combinations is a desirable feature of the game. Players will have better access to a saved inventory of ingredients earned in earlier levels of the game that will aid their play (and further their understanding) as the matrix comes to completion.

Beyond the color game, we want to pursue the possibility of using “fishing” for other cross-referenced data that is frequently represented on a matrix table. Although the visual representations differ greatly, we feel that the sense of exploration engendered by the fishing game could be effective on other sets of data that are similarly structured.

Mannahatta: The Game

The purpose of the Mannahatta Project, by biologist Eric Sanderson and his team at the Wildlife Conservation Society, is to unveil the ecological history of Manhattan in 1609—known to the Lenape residents at the time as “Mannahatta”—and to bring into focus the ecology of Manhattan today so as to plan for a more sustainable urban ecosystem of the future [6]. The Mannahatta team worked to painstakingly reveal, city block by city block, the ecosystem dynamics present in Manhattan's past. These dynamics are represented in a set of “Muir Webs,” named after the famed naturalist John Muir, as a way of visualizing the interdependencies in local ecosystems [6].

Working closely with Sanderson, a team of nine Parsons students, graduates, and faculty developed a prototype of *Mannahatta: The Game*, an augmented-reality game accessible via iPhone, that allows players to traverse the data in real space, making moves on city blocks and recreating the ecosystems that once existed there using the Muir Web as a structuring element. *Mannahatta: The Game* takes the idea of exploration into the city streets, encouraging players to reconstruct the ecowebs of 1609 block by block, achieving the status of "eco-master" by making the most links across the city.

Genre

Augmented reality puzzle game

Description

Mannahatta: The Game is a location-based game that enables learning about complex systems—in this case, learning about the dynamics of Manhattan's ecosystem circa 1609. The goal of *Mannahatta: The Game* is to achieve and maintain the status of “Eco-Master” across different blocks on the island of Manhattan by revealing “eco nodes” and forming sustainable “links” between them. The game employs mobile phones, a familiar and social context for young New Yorkers, to invite them to connect to the island's past and reveal the ecological potentials for the city's future. The content for the game comes from Sanderson’s work on The Mannahatta Project. The game is targeted for families with children aged 10-15, and is developed for the iPhone.

Figure 3: A screen shot from *Mannahatta: The Game* in its native habitat.

Learning Goals

Moving from the Mannahatta Project to *Mannahatta: The Game*, we have carefully merged key geographic and informatic learning competencies—systems thinking, geospatial literacy, spatial orientation, ecological content, social collaboration, communication and visualization. The game, played on an iPhone, places players in the active role of ecological web-maker, a position that encourages exploration and social interaction in players' immediate surroundings while introducing them simultaneously to ecological science.

Challenges

Large dataset, game play's need for simplification pr abstraction and the scientific aims of the actual data are all serious concerns. What’s more, data integrity—using the original database only and not altering it to suit the game—is a serious constraint. Also, an "end-game" with such a massive set—making potentially hundreds of connections per block over thousands of blocks, is, at best, unpredictable and perhaps even impossible. Can such a web be completed by our players on a grand scale? This is part of the experiment.

Future goals

We intend to continue gathering new data, based on player activity, user-generated content, and observation and reporting of current species discovered as players explore. To this end, we hope to begin working with the Encyclopedia of Life to support the continuation of this work.

Trees of Trade: Biodiversity and Extinction

Another of Wargaski’s students, Katharina Seifert, used her extensive research into rainforest ecosystems to produce

"Trees of Trade: Effects of Deforestation on the Atlantic Rainforest". Her project, which became her undergraduate thesis work, examined the relationships between a set of seven trees, along with and other plant and animal species, and the commercial exploitation of those trees by humans, as well as indicating the trees' levels of endangerment. Along with the work of fellow student Preethi Chethan, their design research formed the foundation of the *Trees of Trade: Biodiversity and Extinction* game prototype experiment.

The data represents two competing directed graphs, one for the life that depended on the trees and another for the commodities drawn from them (Figure 5).

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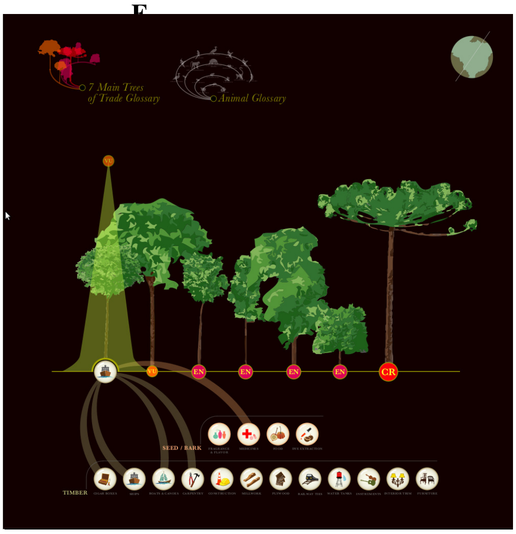

of the main screen for the *Trees of Trade: Biodiversity and Extinction* game.

Genre

Arcade puzzle game

Description

The *Trees of Trade: Biodiversity and Extinction* game uses a time-travel conceit similar to a passage from Kurt Vonnegut's *Slaughterhouse 5* [7]:

> American planes, full of holes and wounded men and corpses, took off backwards from an airfield in England. Over France, a few German fighter planes flew at them backwards, sucked bullets and shell fragments from some of the planes and crewmen. They did the same for wrecked American bombers on the ground, and those planes flew up backwards to join the formation.
>
> The formation flew backwards over a German city that was in flames. The bombers opened their bomb bay doors, exerted a miraculous magnetism which shrunk the fires, gathered them into cylindrical steel containers, and lifted the containers into the bellies of the plane...
>
> When the bombers got back to their base, the steel cylinders were taken from the racks and shipped back to the United States of America, where factories were operating night and day, dismantling the cylinders, separating the dangerous contents into minerals. Touchingly, it was mainly women who did this work. The minerals were then shipped to specialists in remote areas. It was their business to put them into the ground, to hide them cleverly, so they would never hurt anybody ever again.

The game asks players to work in a similar way—take apart the man-made products, find the trees from which they came and recreate them, un-kill the species that lived with that tree and leave the world with a complete and balanced forest ecosystem. Players pull back the "strands" in time, briefly allowing them a window in which to replace the species that were lost to exploitation. At the same time, players must remove from the world potentially useful items like medicine and timber that came from the trees.

Learning Goals

Players are asked to understand what is lost from a forest and what is gained by humans when people harvest rare and endangered trees in fragile ecosystems. They must analyze and rebuild the directed graph that represents the dependencies not only of the biological relationships, but also the commercial ones.

Challenges

Although *Mannahatta: The Game* also deals with biological relationships, is does so in the context of a relatively balanced and stable ecosystem prior to the arrival of Europeans in New York. *Trees of Trade: Biodiversity and Extinction*, on the other hand, has to contend with two frequently mutually exclusive systems. Players must work backwards in time, disassembling the present to build the past. Because we only have data from the past, it would not be an effective or accurate DataPlay to allow students to work on saving the forest in the future. Instead, they are asked to travel in time, deeper into the past's biological data as they graduate from the present's commercial data.

Because of this, the game presents a number of interface challenges. The players must have ready access to accurate information as they work quickly (Figure 6). And they must be able to manipulate time in a way that seems intuitive yet fanciful, meaningful yet playful.

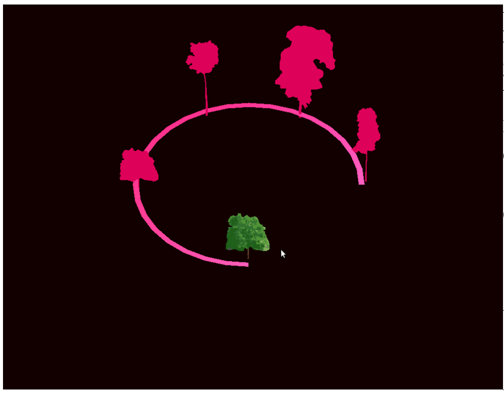

Figure 6: A sp

Species information selection interface from the *Trees of Trade* digital prototype.

Future Goals

Although several prototypes have been created, much work remains to unite the competing systems represented in the data. The complex scientific and ethical challenges of the data and its structure have created a significant challenge, but tests of individual mechanics have proved relatively successful. Bringing the disparate pieces together into a complete experience is the next step. If the game proves successful beyond a design experiment, we will look for more opportunities to combine complex datasets in ways that could allow for playful navigation and analysis over information that may not even lend itself to static visual representation but may, instead, *require* a play-based approach.

FINDINGS

Choice and Data

Our early research and the work of others has indicated to us that data can provide an interesting space for play. Since data has an inherent structure, what does it mean to play within the structure? And as one learns to play within the structure, how might advanced gamers learn to "game the system", or play with the structure of data, testing limits, challenging perspectives, and revealing new concepts? Could one set of data produce a variety of game outcomes? In order to provide a sense of "gameness", there needs to be a set of choices players can make that effect the outcomes of the game.

These choices can be micro (moment to moment choices throughout a level,) as well as macro (the trajectory of the game, the outcome.) Micro choices ultimately affect the macro choices in a game. Salen and Zimmerman, in *Rules of Play* describe these micro and macro moments of player decision-making as "choice molecules" [4]. One of the first issues we confronted in the design of games based on real-world datasets was what are the "choice molecules" inherent in the data? If we can find an element in the data that lends itself to player choice, we know we have the beginnings of a game.

For *Kimono Colors*, choice became a major hurdle. While choosing a row or column to view in a matrix table is straightforward visually, similar choices in a game initially resulted in interactions that were not especially game-like. On the flip side, experiments that we more devoted to games, such as turning the table into a side-scrolling platform game, yielded play but very little learning. By abandoning the visual representation, but retaining its vibrant and playful spirit, the “fishing” mechanic suggests that cross-referenced data can be playful, but not in ways that are obvious based on traditional representations of that form of data.

In the project *Mannahatta: The Game*, we dismantled the dataset—in this case in the form of a Muir Web akin to a network map. Instead of focusing on the nodes as movable (i.e. playable) elements, we decided to focus on the connections between nodes. These connections describe different inter-dependencies in the ecosystem, such as "food for" or "shelter for". Keeping the nodes in place, but removing their links creates an opportunity for players to reconstruct the dataset, provides a clear win condition when players use the right links, and provides a resource (the links) players can collect, win and trade. Dismantling a dataset, then, became one of our strategies for building a game.

The work of integrating datasets in *Trees of Trade: Biodiversity and Extinction* shows the difficulties of producing a single game around a complex set of relationships—the game must, like the other projects we have undertaken, be playful *and* accurate. For the game to be playful, it must be something that a player can approach, manipulate, and feel that she or he has agency over the interface to command interesting choices. For it to be accurate, the choices she or he makes must be faithful to reality, even the sad state of affairs with endangered species. Combining the complex layers of data and representation in a way that is navigable, intelligible, and meaningful is a serious challenge that will require much more investigation.

But *Trees of Trade: Biodiversity and Extinction*, like the other games, also points a way forward, suggesting that there are mechanics (or sets of mechanics) available that, with time and more work, could be used and reapplied to the kinds of data once required to be viewed in forms that were strictly static and two-dimensional. The promise of DataPlay is that the next generation's scatter plots, bar charts, and sociograms may be better understood, not in a newspaper, but in a game.

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