REDLINING AND DE JURE SEGREGATION

A Web-based, Geospatial Visualisation

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Abstract

There persists in America an embedded network of institutional factors contributing to unequal social outcomes. Before and beyond any specific instances of explicit, personally-directed hate, are historically-defined patterns of disenfranchisement, operating outside the purview of the public sphere. Nowhere is the historic character of such institutions more apparent than in the context of wealth accumulation and distribution. A single arc can be traced from 19th century land endowment to ensuing 20th century credit discrimination, and forward to the perverse contemporary state of de facto segregation.

Compounding the issue of discursively challenging institutional structures are broad misconceptions on their character and import. When conversations are allowed to focus around only the most explicit and literal instances, it enables all else to be hand-waved away with only vague dismissals; premises are hidden and rhetoric is elevated. In public discourse, then, value can be added through direct, concise, and easily-interpretable representations of typically oblique content.

The particular case of historic redlining is a distinct candidate for such visual representation; the practice itself involved systematically denying both public and private services to neighbourhoods, based on their racial profiles. Given the clear geospatial nature of redlining and the relevant data, an opportunity exists for a graphical argument to be made on its sustained impact.

Introduction

Context

> *Those (free blacks) who are shop keepers earn a moderate living but never expand their businesses beyond a certain point. The simple reason is that... the whites, who have the money, are not willing to lend to a Negro the capital necessary for a big commercial establishment.* -Jacques Pierre Brissot de Warville, *Travels in the United States, 1788*

The patterns of wealth distribution in this country were settled not long after its inception. While newly unrestricted land was given away, quite literally, to white frontiersmen via the Land Runs and Homestead Acts of the 18th century, a broad manifold systematically denied minority populations the ability to accumulate wealth- not only by the explicit bondage of slavery, but by systemic disinvestment in free states as well. Even ostensibly 'free' individuals still faced "occupational, legal, and de facto" segregation (Immergluck 2004, 55). Today, 98% of American land is owned by whites- and the average black family in America possesses 13 times less wealth than their white counterpart. These patterns were set centuries ago- but it has taken self-perpetuating, institutionalised efforts to sustain them.

The Home Owners' Loan Corporation (HOLC) was created in 1933. Conceived as part of Franklin Delano Roosevelt's New Deal, the firm's ostensible purpose was to underwrite and refinance mortgages in default. In the process of selecting defaulting loans to refinance, the HOLC drew Residential Security Maps- delineating areas considered to be high-risk for underwriting, according to certain criteria:

> *The appraiser who went to Brooklyn in the 1930s to assess Bedford-Stuyvesant for the government summarized the neighborhood's prospects on a single page. Many brownstones in "obsolescence and poor upkeep". Clerks, laborers and merchants lived there, about 30 percent of them foreign-born, Jews and Irish mostly. Also, this: "Colored infiltration a definitely adverse influence on neighborhood desirability."* - Emily Badger, *New York Times*

The borders and boundaries drawn by the HOLC, and the beliefs which upheld them, predated the firm's existence, often by decades. But by providing an explicit schema to continue disinvestment along their lines, their effects were reinforced at a systemic level- a pattern clearly expressed in the particular case of Philadelphia.

Audience and Users

The primary discursive problem on this topic concerns the presence of a certain perception gap. I.e., despite a body of literature attesting to the presence of implicit and institutionalised biases and discrimination, public opinion is still split on the nature of their existence, particularly along racial and gender lines (Pew 2017). Even among those who accept the persisting effects of racial discrimination will often tend to deflect considerations on their own involvement, intentional or not. This leaves a niche for a particular kind of argument to be provided in public discourse within this domain- a single point, made concisely and repeatedly. The depth of academic support and context is such that communicating the content of that research can and should be accomplished with ease of transmission/interpretation in mind. This directly informs the intended audience of this project; everyone would stand to gain from a fundamental understanding of redlining's direct effects.

Definitions, Acronyms, and Abbreviations

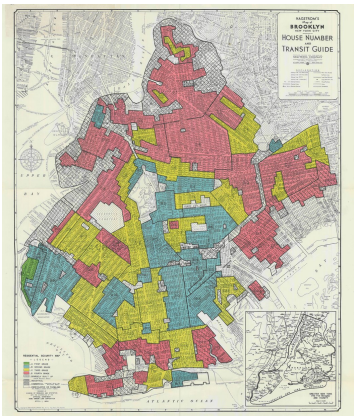
Redlining HOLC FHA S&L ReactJS Redux Mapbox GL JS React-Map-GL

TREATMENT

Data Sources

HOLC Maps

The most concrete data which exists for 20th century redlining are the HOLC neighbourhood mappings, created in the 1930's to provide federal guidance on mortgage underwriting. In practice, the surveyors in charge of determining the boundaries often did so according to conceptions of racial desirability.



US Census Tract Demographics

An obvious overlay to create atop the original maps would be demographic and ethnic data by area, collected at a granular enough level to allow for easy visual comparisons with the redlining polygons. These requirements would appear to be satisfied by U.S. census data from various points over the past century- aggregated and analysed at tract level.

Housing Market Data

In addition to the demographics data, another point of comparison could be drawn to summary statistics on real estate and housing market data, corresponding again to the neighbourhood level. Census tract level data again provides granular information in this dimension, with median income and housing value statistics bound on a tract-by-tract basis. Additionally, the recently-developed Eviction Data Lab has made its dataset on tract-level eviction and eviction-filing rate metrics available for download, allowing a more multi-dimensioned approach to viewing the state of the contemporary housing market.

NPR and Pew Research Polling Data

Beyond the component data sources listed above, the project's higher-order raison d'Ãłtre can be summarised by a series conducted by National Public Radio over the course of 2017, on "Experiencing Discrimination in America", as well as the previously cited Pew Research poll. Most relevant to our problem domain are the polls therein demonstrating a majority opinion among white Americans believing themselves to be discriminated against, and a general disbelief in the capacity for institutional factors to impact discrimination.

Philadelphia Neighbourhood Boundaries

In order to contrast to the homogeneous neighbourhoods drawn by the HOLC in the 1940's, contemporary Philadelphia boundaries can be represented via the GeoJSON city data, available through the public Zillow API.

Data Methods

The span of data aggregated and displayed for this project is predominantly quantitative- either .shp and geoJSON files for base map layers, or tabular data, to be parsed and subsequently represented within the map tiles as points, or as polygons themselves.
Conveniently, the HOLC maps have recently been made publicly available by the University of Richmond as both digitised geoJSON polygons, and georectified raster images, allowing for convenient, web-based projection, through tools such as Mapbox.

Similarly, the census tract dimensions are publically available as .shp files, which can fairly easily be converted into more appropriate geoJSON formats through CLI tools.
The relevant demographics data from the U.S. Census Bureau is available at a local level in .csv format, divided by census tract. In order to maintain similitude with other data sources, metrics from the 2010 census will be used.

The top-level results from the NPR series of polls are available through their website, as are more detailed tables and discussions of methodology in a series of supporting research papers, available for download.

Credit and Wealth Discrimination in America

The basic credit and finance environment which developed in an industrialising America was always defined in some way by certain discriminations and exclusions. Larger structures of slavery and occupational/legal segregation largely prohibited wealth generation- compounded by the fact that even were an individual successful in getting a business off the ground, surviving in hostile white markets was itself an unlikely prospect.

As the finance sector grew increasingly essential to the nation's ability to weather the harsher lows of the industrial business cycle, and to the success of the economy overall, the ability for black populations to participate in the market economy was curtailed by both explicit legal restrictions and recurring social patterns. In the slave-holding South, blacks were prohibited from owning stock or land; in the North, even wealthier black individuals were often labeled as credit risks, through reports which placed heavy focus on "character" concerns. Such prohibitions lead to a self-perpetuating cycle of segregation, as black markets collectively reacted to the exclusions by concentrating development efforts within more receptive black communities (Immergluck 2004, p.55-57).

These patterns of discrimination coalesced into systemic mortgage redlining over time- particularly as the American population grew more heterogeneous, precipitating racial tensions among the working class, and greater competition in the housing market. As early as the 1910's, metropolitan communities and municipal boards in America were noting redlining tendencies in the banking and financial sectors. In Chicago, 2 years before the Race Riot of 1919, the *Cleveland Advocate* reported on banks' unwillingness to extend loans to black communities for mass-scale development; 3 years after the riot, the Chicago Commission on Race Relations, formed in response to the riot, affirmed the mortgage discrimination faced by black Americans (Immergluck 2004, 87).

As the decade progressed, the pure and explicit discrimination of lendors against black communities became codified as academic theory in urban planning, centring around the "social ecology" paradigm, exemplified by the 1925 work *The City*, developed at the University of Chicago. Within, co-author Ernest w. Burgess articulated his "succession" theory, which leveraged borrowed ecology terminology to reduce understanding of urban racial mixing to a metaphor of invasive plant species inducing disorder and destruction to a native one unable to absorb it. Taken in such a fashion, segregation and racial steering of black communities towards urban centres can be argued as common sense. Thus, Burgess' high-level abstrac-

tions affirmed the existing praxis of lenders as seemingly scientific fact, and embedded their principles formally in real estate theory (Immergluck 2004, 89-90).

Home Owner's Loan Corporation (HOLC)

It is against this backdrop of loosely-defined marginalisation and socioeconomic uncertainty that the Home Owner's Loan Corporation was conceived. In the wake of the Great Depression, the 1932 Home Loan Bank Act was passed in an attempt to establish credit reserves for an array of private mortgage lending institutions; however, mismanagement and operating inefficiency prevented the resulting federal system from effecting any kind of significant slowdown to the ongoing housing crisis, as the rise in foreclosures continued uninterrupted to a crest of approximately 252,000 in 1933. As a response, newly-elected president Franklin D. Roosevelt lobbied for the creation of a government-supervised effort to directly buttress American home ownership; two months after explicit laying out this plan, Congress passed the Home Owners' Loan Act, establishing HOLC in the process. Supervised by the Federal Home Loan Bank Board (FHLBB), the firm was given the authority to issue interest-guaranteed government bonds in exchange for mortgages held by private lenders, to subsequently refinance those delinquent loans for in-need Americans (Hillier 2003, 4).

Charged with a short-term telos (and a commensurate 3 year deadline) by Congress, the roll-out of the firm's programme was expedited faster and on a much larger scale than the precursory HLBA, or indeed any other operation the country "had ever embarked on", as characterised by FHLBB head chairman John Fahey. This context of urgency ultimately lead to a deployment of over 300 offices covering all the lower 48 states and Hawaii within 3 months, with the firm accepting applications a month after that. The firm purchased and refinanced a total of approximately 1 million loans in the initial 1933-1936 period of its existence- amounting to, by some estimates, roughly "40% of all qualifying mortgaged properties". (Hillier 2003, 6).

However, in 1936, towards the end of of its original refinancing period, the HOLC had also instantiated a separate, secret initiative, entitled the City Survey Program. Tasked with the responsibility of "graphically reflect[ing] the trend of desirability of neighborhoods from a residential viewpoint" (FHLBB 1937: 1), the program developed a set of color-coded, residential security maps for 239 American cities. The CSP subsequently delineated boundaries between city neighbourhoods, then assigned grades to each on a scale of A-D.

Yet, the CSP was initiated at a time when the HOLC had already made the majority of its loans (1933-1936)- indeed, mostly to residents of the zones the maps would later grade as C or D (Hillier 2005, 3). So with the creation of these maps seemingly uncoupled from the original appraisal and lending goals of the HOLC, their ultimate purpose can only be gleaned by a closer analysis of the longer-term motivations the firm had in mind for its investments. I.e., with the primary program focusing exclusively on the characteristics of individual applicants, the CSP ostensibly sought to manage and ameliorate the (previously-thought irreversible) decline of property valuations on the *neighbourhood* scale (Hillier 2005, 4).

The HOLC itself did not directly authorise the actual inception of the CSP. Rather, the superseding FHLBB initiated the program, intending not just for short-term intervention into Depression-caused issues, but to *affect the private real estate and savings and loan sectors* overall, in the long-run. The federal board viewed the entire industry as its purview, and along with the creation of the CSP, the 1930's saw them begin issuing reports and statistics to private S & L firms in the *Federal Home Loan Bank Review*. Advocating the FHLBB's neighbourhood-based approach to appraisal, the August 1935 issue of the *Review* ran a comprehensive series on neighbourhood standards, while encouraging private institutions to develop and rely on their *own* local maps for appraisals. The common thread of all these FHLBB actions is the aggressive pursuit of cartographic and spatial analysis in American financing and lending activity as a whole. This expansion of the FHLBB's scope and ambition influenced the HOLC's own map-making, pushing the maps outside the narrower constraints the firm imposed on direct appraising and lending; as such, the HOLC took growing contemporary sentiments on the effects of racial composition on neighbourhood housing risk and health into consideration (Hillier 2005, 6-9).

The social ecology view of urban sociology had by then become accepted as mainstream theory by American lending markets. The National Association of Real Estate Boards Code of Ethics advised realtors against "introducing into a neighborhood...members of any race or nationality...whose preferences will clearly be detrimental to property values in that neighborhood." Contemporaneously, the works of Frederick Babcock and Homer Hoyt were elevated to high standing within the field- particularly in relation to the Federal Housing Administration (FHA), the government agency most directly responsible for the private housing credit market. Babcock's *The Valuation of Real Estate* (1932) built on Burgess' theories, explicitly tying neighbourhoods' racial histories to housing values, and black infiltration to "very rapid decline" in prices (Babcock 1932, 91). His perspective would eventually inform formal hous-

ing regulations directly, as he went on to become the FHA deputy administrator, and would author that administration's *Underwriting Manual* (1939). Hoyt, another FHA director (and former student of the University of Chicago team who wrote *The City*), promoted similar claims, going as far as to rank races by the degrading effects they were assumed to have on housing values (Immergluck 2004, 91).

The context of increased federal housing market involvement, acting on practically segregative policies, bore itself out to a degree in the creation of the CSP maps- as evinced most clearly by the particular map of Philadelphia. Officially, the CSP maps were informed by rounds of surveying performed by HOLC field agents, who themselves were assisted by local "map correspondents", usually from the suburbs of the cities in question - a relationship that makes ascertaining the ultimate authorship of the maps somewhat ambiguous (Hillier 2005, 11). Moreover, at least in Philadelphia's case, there is evidence the HOLC incorporated more quantitative data for the finer points of the CSP boundaries than just the qualitative input of the correspondents. The field agents there likely relied on data from a 1934 survey conducted by the Works Progress Administration- reported at the tract level and offering substantially more nuanced housing metrics than available through the federal census. The Philadelphia survey sheets which informed the maps also included a significant number of references to neighbourhood racial composition - notably singling out Jews and Italians on multiple occasions, data which had also likely been aggregated from disparate, local sources (Hillier 2005, 12).

Despite national HOLC guidelines advising the collection of large and high-dimensional data for the maps, they rarely provided explicit accounts for condensing that data into a single grade. However, the qualitative descriptions which accompanied the finalised Philadelphia map suggest the extent to which racial factors were involved. The HOLC field agents specifically avoided using preexisting boundaries (such as census tracts) so as to define city areas according to homogeneous characteristics, and their documentation often refers to the racial/ethnic character of the depicted locations (Hillier 2005, 13). A-graded zones were praised for their "homogeneity"; conversely, D-graded zones were demerited for "infiltration[s] of lower grade populations" and "detrimental influences of a pronounced degree" (FHLBB Division of Research and Statistics, 1937).

Later research efforts have largely affirmed suggestions that racial composition played a more central role than otherwise detailed by primary materials. Crucialy, the research models used have generally found distance from city centre, and race/immigrant to be significant

predictors of a neighbourhood's CSP grade, *even when controlling for the effects of housing market conditions* (Hillier 2005, 29). As much as the HOLC's advice to the S&L industry may have advocated for "scientific analysis" over "general prejudice", data specific to their CSP Philadelphia maps indicates a consistent incorporation of contemporary racist thought (FHLBB, 1935).

Ultimately, the actions within the CSP were scarcely publicised, and had little impact on the HOLC's long term legacy. By 1936, the HOLC had largely concluded its issuing of residential loans, and for the remainder of its functional existence as a federal entity focused on collecting repayments. The firm gained a reputation for leniency and flexibility in this regard; it generally only foreclosed on refinanced homes after a year of missing payments, refurbished and rented homes upon when foreclosure did occur, and eventually saw approximately 80 percent of its initial loans repaid. It was eventually assigned for liquidation in 1947 to the Home Loan Bank Board. By 1951, when its final assets were sold off to private entities, its legacy in American consciousness was generally a positive one: its foreclosure leniency had generated public goodwill, and it had still liquidated at a profit thanks to borrowers paying off their balances in the long-term. It was generally seen as a successful federal intervention into a desperately ailing economy (Harris 1951, 1-6).

Socioeconomic Impacts, Responses, and Legacy

Over time, America saw progressively more recognition of the sustained racial barriers in place within credit and housing markets. Private financial firms, such as banks and savings and loans institutions (S&L's), came under scrutiny for their role in maintaining physical boundaries in credit markets, as well as the federal government's role in encouraging and reinforcing them. In one of the earliest comprehensive accounts of institutionalised redlining, lawyer and author Charles Abrams captures the feedback loop of endemically racist practice between private agents and federal regulations:

> These mortgage lenders were conditioned by the same attitudes on the racial issue as were the realtors and the home-builders. The mortgage officers read the same texts, swallowed the same myths... what could be expected in the formerly private fields now aided or entered by the public itself? What could be expected when entrepreneurs with their lower standards and their overruling drive for profit operated conjunctively with the government? ... In the Federal Housing

> Administration, discrimination and segregation were not only practiced but were openly exhorted (Abrams 1955, 176-229)

During this period, the FHA set housing standards by placing strong emphasis on racial composition, while 91% of its loans. were to suburban areas. Black citizens were often only able to secure housing credit via land contracts from speculating real estate agents, who would often repossess the homes to attempt to sell them again. Other times, agents would capitalise on the limited options available to black Americans to engage in blockbusting, using the spectre of racial infiltration to scare white owners into selling below market value, then re-selling to black buyers at up to 75% more than they paid (Immergluck 2004, 90-95).

Federal policy on credit discrimination only began to shift in the post-war years, as the cold war emerged and, not coincidentally, the civil rights movement broached public consciousness. With the United States pressured into an internationally-scoped defense of its doctrine and democracy, institutionalised discrimination became too prominent a black eye to ignore or endorse (Immergluck 2004, 134). 1948 saw one of the first real steps toward policy change in the Supreme Court's *Shelley v. Kraemer* ruling, which outlawed racially-prohibiting housing covenants and contracts- and spurred on the civil rights movement as it gained momentum in the following decade. Responding to the broader societal trends, the U.S. Commission on Civil Rights was established in 1958, and made explicit note of redlining tendencies in its 1961 Report on Housing, concluding that insufficient action had been taken to counteract the practices (Immergluck 2004, 92).

The influence of the civil rights movement on anti-discriminatory policy then crested in the late 1960's and 1970's. The 1968 Fair Housing Act (FaHA) was passed after a years-long sequence of racial upheaval and rioting, which unrest Congress had found to be caused at least in part by urban segregation and slumming. As part of the larger Civil Rights Act, FaHA ostensibly outlawed home lending discrimination and redlining, but left so much policy detail to the interpretation of the courts, and provided scant incentive for implementation and enforcement by regulators, that it was significantly limited in combating such discrimination in practice. Significantly, FaHA's design makes it practically effective only when victims recognise they are being explicitly discriminated against, and thereby actively pursue recompense or justice (Immergluck 2004, 134-137). Here again, implicit and structurally obscured discrimination is able to persist.

Contemporary Analysis

Attesting to disinvestment's adverse personal effects is a body of recent literature detailing the degradation it incurs on long-term socioeconomic wellbeing. Beyond its obvious, immediate disadvantages, inability to access credit has been linked to reduced entrepreneurial opportunity (Evans and Jovanovic 1989); negative impacts on consumption (Zeldes 1989); and limits on economic activity (Bernanke et al, 1999), among other detrimental effects.

HOLC Segregation Effects

Doubt has persisted regarding a direct causal link between the creation of the specific HOLC maps and the patterns of racially-oriented disinvestment that followed in the ensuing decades. Skepticism regarding the effects of the CSP pointed towards the likelihood that the maps were not widely circulated, and towards the fact that mortgage underwriting continued in the lower-rated HOLC zones after their creation (Hillier 2005, 4). While it has generally been understood that racial discrimination played a role in the *creation* of the maps, their *impact* on worsening the spatial divides was typically regarded as minimal.

However, the most recent research on this front has illuminated the more pernicious, entrenched effects that the CSP maps produced nationwide. A 2017 research effort, developed at the Federal Reserve Bank of Chicago (FRBC), revisited the question of the CSP map's long term consequences. Aside from the qualitative analysis that defined previous attempts, the FRBC team's statistical model aggregated census and credit time-series data from the entire interval since the maps' creation, finding that segregation which predated the CSP grew more pronounced along the map borders through the 20th century. The results affirmed not only that segregation existed and subsequently grew along the CSP's D/C boundaries, but also that *new* segregation developed along the C/B borders, where previously none existed-reinforcing the argument for a causal relationship between the maps and the social outcomes. Negative impacts on homeownership rates and housing values over time were also detected in both C- and D-rated areas (Aaronson et. al. 2017, 5).

Precluding the possibility of only capturing the influence of preexisting historical divisions, they also contrasted the economic outcomes on either side of both the actual CSP borders, and *counterfactual*, hypothesised borders, devised by the researchers entirely on the basis of having similar segregation characteristics as the actual ones, prior to the maps' creation. Contrasting with the CSP's demographic evolution, counterfactual border segregation

ameliorated over time, despite being originally identical in that regard by design (Aaronson et. al. 2017, 4).

Critically, the segregation exposed by the FRBC research reaches its nadir in the 1960's and 1970's - coinciding with the sequence federal antidiscrimination policy documented in the previous section (the FHA, in addition to the 1975 Home Mortgage Disclosure Act and the 1977 Community Reinvestment Act that followed suit). The authors suggest a causal effect between those policies and a reduction of segregation in the CSP zones in question (Aaronson et. al. 2017, 6). More broadly, these results speak to their larger arguments on the manner in which governmental action and private industry attitudes together constitute a network of factors that work to determine social equity- and how the former can either counteract, or reinforce, the latter.

Other Modern Disparities and Segregation

Beyond the specific case of the HOLC, or indeed redlining itself, racial disparities in urban America manifest in a wide set of domains. Of particular importance are those areas in which inequality is most likely to expand and self-perpetuate, long-term- i.e., access to education, and the aggregation of wealth. Since desegregation began in the 1960's, public school integration in America has actually *regressed* over time, with black enrollment at white-majority schools returning from a 1991 peak of 44% back to a 23% low in 2011, a rate identical to 1968 levels. This worsening educational inequality subsequently feeds into socioeconomic inequalities- which are already so severe that even black college graduates are less likely to own a home than white high school dropouts (Gyourko and Linneman 1997).

Additionally, the spatial components of these segregating patterns not only raise their profile and visibility- it reinforces them. American public schools are largely funded through *local* property taxes. Thus, as black Americans are steered into specific urban neighbourhoods to be starved of investment in the manner documented above, the consequences are subsequently felt in the diminishing quality of the public education servicing those neighbourhoods - leading to long-running cycles of residentially defined, multi-generational poverty (Rothstein 2014).

Product Overview

Taking into consideration this manifold of intertwined factors for institutional discrimination, and how prevalent residential segregation is within it, this visualisation projects main objective to present a single, unified case on the specific topic of redlining and spatial inequity, as an illustration of wider inequity. As mentioned in the introduction, the most direct representation of contemporary ignorance of racial disparity can be found in recent polling data. More specifically, results from NPR and Pew Research speak to numerous perspectives on how fundamentally misunderstood these social phenomena are. In the former's previously mentioned *Experiencing Discrimination in America* series, it was found that a majority (55%) of white Americans believe they face discrimination (Gonyea, NPR 2017); for the latter, a showed a significant majority of all Americans (66%) believed that interpersonal prejudice plays a greater role in racism against black people than institutional factors. For the white Americans polled, the margin was found to be even wider, at 70%-19% (Pew Research 2016).

Taken within the context of the long, ongoing history of *de jure* segregation and institutional racism, this misunderstanding and ignorance presents a profound problem. Particularly in regards to current and future policy making, it allows "policymakers to assert that the residential isolation of low-income black children is now 'de facto,' the accident of economic circumstance, demographic trends, personal preference, and private discrimination" (Rothstein 2014). Therefore, to prompt the American citizenry to obtain even a basic awareness of the history of institutionalised racism, and to connote it to the obvious current racial inequality, would be a worthwhile endeavour. The project documented herein is a modest attempt at this, through a web-based interface built ideally to incorporate the dynamism of its content in its design.

Product Description

The final product takes the general form of a scroll-based web narrative, as has become typical in online news stories and UI-driven data visualisations, binding an array of relevant data (detailed above in the *Data Sources* and *Data Methods* sections) to a series of transitioning views, built primarily using encapsulated React components. Because the product relies heavily on (often rapidly occuring) state changes, ReactJS was seen as an appropriate choice for the constructing the front-end views. Buttressing the reactivity of the overall application is Redux- a state management library designed to accommodate complex state changes. In Redux, state changes are managed outside of the front-end React context by an immutable

state tree, which is continuously updated and built out via reducing functions, constantly producing new canonical state from the old. With this functionality in place for the application's business logic, an individual component can be more concisely written and better encapsulated, maintaining enough state only to serve its own display logic and with its props bound only to the changes in the state tree that are relevant.

At the top level of the display logic, React-Boostrap is employed by the application to maintain the high-level layout and basic UI components. Within that frame, the core views of the application are, as can be expected, geospatial in nature. In order to best represent the locality and spatial granularity of the data at hand (with the primary views displaying city-, neighbourhood- and tract-level cartographic patterns), the front-end software stack relies on several extended mapping libraries and frameworks, built with React in mind. Firstly Uber's ReactMapGL acts as a React wrapper over MapboxGL JS, the base library used for the full-viewport map. Uber's library acts to provide a set of React components that expose the core functionality of Mapbox, while also enabling dynamic camera transitions- although exclusively through prop inheritance. React-Map-GL components in this way is designed to be stateless- and therefore does **not** expose the full Mapbox API (a feature requiring certain workarounds detailed in the inputs section below). Its stateless and fairly bare-bones nature also means that **rendering overlays** atop the base map is functionality best satisfied by another Uber framework at the top of the stack- DeckGL. Designed to fit seamlessly with both React and ReactMapGL, the framework leverages WebGl to produce 3D overlays from data objects, consisting of up to several million elements at a time before suffering performance degradations.

Inputs

The application inputs are all extracted from the sources detailed in the *Data Sources* section- however, depending on the state and hygiene of each aggregated dataset, certain parsing and processing steps were required. As mentioned above, the full public Mapbox API is not exposed by ReactMapGL, meaning that to permute the Mapbox component's style, an immutable style object must be generated and passed in anew. In this case, the principle style transition required is the continuous transition of a georectified image of the Philadelphia 1937 CSP map, to be rendered above the base Mapbox style contingent on which stage of the scroll narrative the viewport is positioned at. Since no other style transition was required, this was achieved on the input side by simply providing paths to two style JSON files, to be immediately wrapped in an IMMUTABLEJS object, to pass into the ReactMapGL compo-

nent. The GeoJSON polygons of the CSP map, to be simultaneously overlaid for expanded interactivity, were loaded as-is from their source. The census tract data for both 1940 and 2010 were extracted from several disparate sources- for each, the census tract shapefiles had to be procured, then mapped to the demographic and economic statistics associated with each tract's ID number. In the former's case, the shapefile was extracted from the National Historical Geographic Information System (NHGIS), converted to GeoJSON format using the mapshaper.org online tool, then reprojected to a standard WGS84 format projection, before being bound to the associated 1940 demographic data, also available through NHGIS, using Mike Bostock's ndJSON command line tool. A similar process was used to extract the TIGER shapefiles for the 2010 census tracts from the United States Census Bureau site, before being coupled with 2016 American Community Survey(ACS) 5-year estimates for population, demographic, income, and housing data. Then, for both datasets, 2D point arrays, representing individual persons living in the respective time periods, were generated to represent both population density and segregation patterns. Each point array represented a single person, and took the form [lat, long, intDem], with the first two values indicating a mapped location (extracted from a given census tract via turfJS's geographic processing functionality), and with the third "intDem" value representing the index for a configuration array of RGB values, mapping to specific races and/or ethnicities. Finally, a separate set of condensed GeoJSON files was created for both the 1940 and 2016 data, with each tract's median income and median housing value as the only properties.

Outputs

The application takes the form of a scroll-based narrative, and attempts to take advantage of dynamic movement and colour transitions to . The full-viewport hero contains the title, and a progress bar to indicate completion of the sequential fetches of the data from their relative project paths. There are two primary components rendered. The ControlPanel serves as both the main content layout, and triggers scroll-based events for both style transitions(handled via internal state) and camera/overlay transitions(by dispatching actions to the Redux reducer). Beneath the ControlPanel is the MapGL component, which handles all of the Mapbox functionality. It also contains the DeckGL layer component as a child, which stores the 4 distinct overlays used in the visualisation. On load, the ControlPanel is initialised to take up the entire viewport, and first provides a text-based scroll sequence to introduces users to the main context required to understand the following visualisation- i.e., the basic definition of redlining, a brief history of the HOLC

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