Design Through Code
Exploring Web-development as Data Visualization Tool

Joanne Hayek (0000-0003-4186-5652)[1]

[1] Dubai Institute of Design & Innovation, joanne.hayek@didi.ac.ae

Abstract. This paper proposes to explore web-development as a tool to design interactive data visualizations. Featuring a selection of five research and design projects conducted by the author along with her colleagues and students, the study proposes a cross-disciplinary design methodology that incorporates computational programming as part of the designer's toolkit. The first three projects exemplify how approaching web-development from an architect's perspective enables a dynamic multi-layered form of visualization of complex information through the creation of interactive co-mapping platforms. The fourth and fifth projects were realized by students of the 'Digital Makers' course taught by the author at the Dubai Institute of Design and Innovation. Exposing undergraduate design students to full stack web-development, the workshop runs like a digital maker lab and promotes self-learning through making. The paper presents the five projects as case studies to help understand the modalities of design of interactive data visualization in a context where advances in open-source software and coding languages are increasing the accessibility to specialized technical frameworks. The study concludes by advocating for an intrinsic link between data visualization and programming literacy. Promoting this connection in educational and professional frameworks is essential to foster effective analysis and communication of complex data. The paper highlights guidelines to accelerate this integration.

Keywords: Interactive Data Visualization / Real-time Mapping / Animated Storytelling / Geospatial Information Systems / Web Development

1. Introduction: Background and Context

1.1. Design: a return to the craft

Back in 1919, Walter Gropius published the *Bauhaus Manifesto*, advocating for the development of an intrinsic link between art and craft through design: "Architects, sculptors, painters—we all must return to craftsmanship!" (Gropius, 1919). Calling for a cross-disciplinary approach anchored around the crafts, the manifesto, which focuses particularly on the building, articulates the importance of understanding "its composite character", both "as a totality and in terms of its parts".

Almost a century after the *Bauhaus*, Gropius' manifesto was echoed by what could be understood as a digital version of it: "Designers, programmers, engineers, we must all return to programming!" (Noble & Biddle, 2002, as cited in Amiri, 2011). Similar to architectural design in the physical realm, interaction design in the digital realm requires a certain level of understanding and integration of the crafts, at different stages of the design process, which becomes key to enable performance and innovation.

1.2. Crafting digital interaction: a cross-disciplinary approach

The collaboration of the distinct disciplines of design and programming is at once challenging and vital for interaction design projects to succeed. The difference in nature and methodology between the two disciplines creates gaps both in the representation and interpretation of interactive digital systems (Maudet et al., 2017). The cross-disciplinary teams manifest a desire for smoother cooperation and communication between designers and developers, particularly in agile software development frameworks (Jones, 2016), thus highlighting the importance of creating bridges between these two intrinsically linked yet complementary opposite disciplines (Neto et al., 2020, 155).

In this context, programming literacy becomes key for designers to be able to successfully communicate with developers and enable the prototyping of their ideas into interactive innovative artefacts: programming languages "are particularly important for specifying interactive behaviour and generative processes [...] languages are critical to innovation" (Mitchell 2003, 95, as cited in Amiri, 2011, 5). This importance of convergence between the two disciplines has given way to a new breed of hybrid practitioners trained with both design and development skills, which led to the emergence of bridge terms such as "*devigners*" and "*designoper*" to describe the merging of the disciplines of designers and developers (Fain, 2008 as cited in Amiri, 2011). Given the complementarily opposed nature of the two disciplines, the blending of the skills of both design and development comes with a set of challenges. Particularly, if one compares two of their key frameworks: design thinking and agile software development. Although both iterative and collaborative by nature, these frameworks are inherently distinct as the first is anchored around problem finding, while the second is catered towards problem solving. Despite that difference, multiple studies advocate for a form of integrated framework which merges the two approaches in order to enable digital transformation and innovation (Gurusamy et al., 2016, Corral et al., 2018).

1.3. Research Methodology

In this context, the paper investigates the potential of bridging between the two disciplines of design and development, with a particular focus on the use of web-development methodologies for the design of interactive data visualizations, both in professional and academic contexts. Featuring a selection of five research and design projects conducted by the author along with her colleagues and her students, the study proposes a cross-disciplinary design methodology that incorporates computational programming as part of the designer's toolkit.

The first three projects exemplify how approaching web-development from an architect's perspective enables a dynamic and multi-layered form of visualization of complex information through the creation of interactive co-mapping platforms. The first, *Emerge Beirut* [1] is a pilot web-app that was released at the wake of the 4th of August 2020 blast of Beirut. It features an interactive map of the city and allows to generate and customize cross-sector data visualizations from user-generated content in real-time. The second, *The Immuno-Responsive City* and *Pulsing Ground* [2] are two series of dynamic maps that were presented as part of the *Beirut Shifting Grounds* project exhibited at the *17th Venice Biennale of Architecture* in 2021. Generated through web-development frameworks, using JavaScript, Mapbox GL and Turf.js, the maps composed a spatial and temporal narrative that retraces the momentum and hardship of the grass-root efforts that have charged the grounds of Beirut from 2019 to 2021.

The third project, *Shape your City* [3] consisted of a physical installation paired with an interactive web-app that invited the visitors to take part in the making of the future of their city. Presented as part of the Dubai Design Week 2021, the data visualization of the visitors' input was aggregated and displayed in real-time through a screen situated at the end of the installation. The web-app was programmed using Javascript, HTML, CSS as well as Firebase, Mapbox GL, and Turf.js and was designed and developed through a collaborative framework that merged design thinking with agile software development methodology.

The fourth and fifth projects were realized by students of the *Digital Makers – Fundamentals of Computational Media Design* course taught by the author at the Dubai Institute of Design and Innovation in the Spring of 2022. Exposing undergraduate design students to full stack web-development, the *Digital Makers* workshop promotes methods of self-learning through making. The course runs like a maker lab in the digital space; it invites students to write their own open-ended briefs and come up with strategies to execute the design. The third project featured, *Global Refuge* [4], is an interactive web-page featuring an animated data visualization of the human migration and refugee statuses around the world. Paired with the UNHCR's API, the website makes use of Globe GL to generate a globe-based three-dimensional dynamic data mapping. And finally, *Urban Soundscape* [5], is a web-app designed and developed by a team of four students which offers the possibility to visualize the sounds of the city in real-time across different scales and mediums. The app was designed and developed using JavaScript, p5.js, three.js, Mapbox GL, Firebase, CSS, HTML and Bootstrap.

The following section explores the different case studies to investigate the processes of design through code when it comes to the systemization and visualization of complex dynamic information.

2. Processes of Design through Code: Systemization and Visualization of Complex Dynamic Information.

2.1 Collecting and exploring data through code

Designing interactive visualization of complex information requires a systemic understanding of the data structure and collection process. In some cases, such as the visualization of actor-relational networks and dynamic data such as cross-sector city mapping, the visualization takes shape asynchronously, and evolves in parallel with the incremental data collection process. This paragraph describes the fluid integrated workflow adopted in the case studies, which incorporates code-based data collection as part of the design process through three distinct complementary methodologies: multi-source aggregated data, user-generated data, and real-time data.

In the case of complex information mapping, the aggregation of data from multiple sources is key to maximize the accuracy of the depiction and validity of the information. Using web-development tools for data collection offers an efficient and flexible way to collect, analyze and aggregate complex datasets. For instance, in the case of the *Pulsing Grounds* mapping series (Fig. 1 and Fig. 2), multiple data sources were merged to create dynamic interactive data visualizations. The use of standard Geographic Information System (GIS) systems in tandem with spreadsheet software programs such as Excel and Google Spreadsheet offers a starting point yet comes with limitations when it comes to the collection and aggregation of rapidly evolving complex data with different structures and patterns. In the case of *Pulsing Grounds*, the various datasets were aggregated using the programming language Javascript and were stored in a non-tabular database, a JSON noSQL database, through the use of the backend as a service platform Firestore by Firebase.

The use of programming languages for the aggregation of data also enables the dynamic collection of information, particularly through the integration of application programming interfaces (APIs). For instance, the *Pulsing Grounds* timeline (Fig. 1, which compares the productive and the violent events that have marked the October 17 revolution of Beirut links to the Liveuamap API, which in turn aggregates data from social media and various media channels. Similarly, the project *Global Refuge* (Fig.3), which started with a static dataset of refugee information downloaded from the UNHCR platform, evolved to enable the automatic update of the data through the integration of the UNHCR API.

Furthermore, in the case of dynamic bottom-up mappings such as grassroots deployments and actor-relational networks, the incorporation of user-generated content is key to guarantee a holistic depiction. The mappings of the grassroots deployments of post-blast Beirut for instance (Fig. 5), *The Immuno-Responsive City*, were based on the aggregation of multi-source data complemented with user-generated content that was collected through the web-app *Emerge Beirut*. The web-app features a user authentication system and customizable data structure. The user-generated data sharing process is realized through a dynamic form that follows a system of tag-based categorization used to codify the cross-sector visualization of the action on the map (Fig. 6 and 7). In this particular case, the creation of the web-app was instrumental to allow the bottom-up collection of information in real-time through sharing, vetting and editing of the information by the community. This methodology, which mirrors the actor-relational networks on the ground through coordination systems (Fig.8), promotes co-design and co-mapping, which is key to enable participatory approaches to city planning.

The project *Shape your City* (Fig. 9-13) exemplifies the idea of use of interactive mappings to enable co-planning: its code-based digital visualization portrays the contributions of the participants to the future of their city, in real-time. This project, which merges a web-app with a physical installation, is another example of the integration of coding in the design process. Relying on real-time data collection and visualization, the project invites to reflect on the challenge of designing for information that is yet to be collected. When creating a system of interactive data visualization, one has to take into account a wide range of possibilities and outcomes, that only fully manifest once the project is deployed. In order to overcome this challenge, algorithmic data visualization is needed to adapt to the varying patterns, scopes and scales of real-time data. Paragraph 2.3 further elaborates on this idea.

2.2. Visualizing data through web development libraries

Although the basic version of some web-development languages such as Javascript, HTML and CSS, allows to code for interactive data visualization (as exemplified in the timeline in Fig. 1 which was coded using plain Javascript), the use of specific libraries could help achieve more advanced and refined results. This paragraph presents some of the libraries that were used in the case studies, and describes the workflows adopted in the context of each project.

In terms of geospatial data visualization, the library predominantly used in the case studies is Mapbox, which offers the possibility to code for GIS features on the web. Paired with its application Mapbox Studio, which allows to customize base layer maps, Mapbox GL offers a wide range of interactive features that allow the creation of dynamic maps on the web. This is enabled through built-in functions that rely on a rule-based design of the maps such as: clustering of data points and zoom-based visualizations (Fig. 14), tag-based graphic representations through color coding and symbols, and data-driven scaling of markers and layers opacities (Fig. 2 and Fig. 15).

Similarly, when paired with time-based Javascript programming, animated storytelling of these maps could be achieved. As seen in the animated map of deployments that followed the August 4th 2020 blast of Beirut (Fig. 16), time-based data visualization could be displayed and customized to enhance the user experience through fly-to features allowing to smoothly navigate between one view or scale and the other, as well as the progressive deployment of data points, in this case based on the chronology of events. The computation of the movement of the pins on the map relies on complementary Javascript libraries that enable advanced navigation features such as Turf.js described in paragraph 2.3.

Geospatial representation can also take a three-dimensional global shape. Mapbox offers the possibility to zoom out to reach visualize the entire globe, yet other libraries are specifically catered for this type of three-dimensional features and interactions. The library Globe GL, for instance, which was used in the *Global Refuge* project (Fig. 4), is based on the three-dimensional web-development library Three.js, which also relies on WebGL, a Javascript API allowing GPU-accelerated usage of physics and image processing and effects as part of the web page canvas (). As seen in the project, the library also allows the animation of the data visualization and the customization of its interactivity through complementary Javascript functions that respond to the scroll and mouse inputs of the user in real-time.

When it comes to other types of data such as sound, animated time-based visualization is also instrumental. In the case of *Urban Soundscapes*, which featured both the Mapbox and Three.js libraries (Fig. 17 and Fig. 18), P5.js, a Javascript library for creative coding based on the core principles of Processing, was utilized to code the animated visualization of sound recordings in real-time. In some parts of the app, this was overlayed on top of the map view, which allowed to immerse the user in the perception of sound in space (Fig. 17).

2.3. Algorithmic data analysis and rule-based design

One of the advantages of approaching data visualization design through programming is that it allows to algorithmically analyze the data and extract patterns that inform the visualization through rule-based design. This is particularly instrumental when dealing with dynamic data which changes based on real-time input. In such cases, the design of the visualization needs to take into account a potentially varying set of information with a bounding range that will grow and vary with time.

For instance, the *Shape your City* real-time data visualization was designed to adapt progressively to the number of data points shared by the visitors of the installation in real-time (Fig. 13). The size and legend of the diagram would adapt progressively based on the range of data inputs collected. The code-based approach to data visualization design enabled this real-time customization and flexibility. Similarly, the computation of mobility paths was enabled through the use of navigation algorithms, which are useful to analyze proximity and compute mobility time, which was needed for the mapping of the mobility and community living layers.

Furthermore, in some cases like the *The Immuno-Responsive City* mappings, the data was collected simultaneously with the visualization. The short timeframe of the project required the prototyping of the visualization throughout the data collection phase. One was informing the other and thus the rule-based design of the maps, generated through the use of Mapbox and Turf.js, was instrumental. Moreover, the use of algorithmic tools such as the Javascript library Turf.js allowed to shift from micro data points to macro comparative analysis. As the zoning maps illustrate (Fig. 9), the use of geospatial computation allowed to measure the density of certain data points within geographic boundaries.

3. Conclusion

As seen in the above-mentioned case studies, making use of web-development tools for the design of data visualization opens up possibilities such as interactivity, real-time response, micro-to-macro analysis, as well as customizable cross-sector depiction. From the step of data collection, to the phase of translation of the datasets to visual narratives, the use of the fundamentals of programming along with open-source languages and libraries offers the potential to create animated, multi-dimensional depictions of complex information. This reinforces the need to create an intrinsic link between design and development; and more particularly in this case, between data visualization design and computational programming literacy.

Promoting this connection in educational and professional frameworks is essential to foster effective analysis and communication of complex data. The promotion of digital makerspaces that would bridge the design thinking methodology with the agile software development framework is needed in order to accelerate this integration.

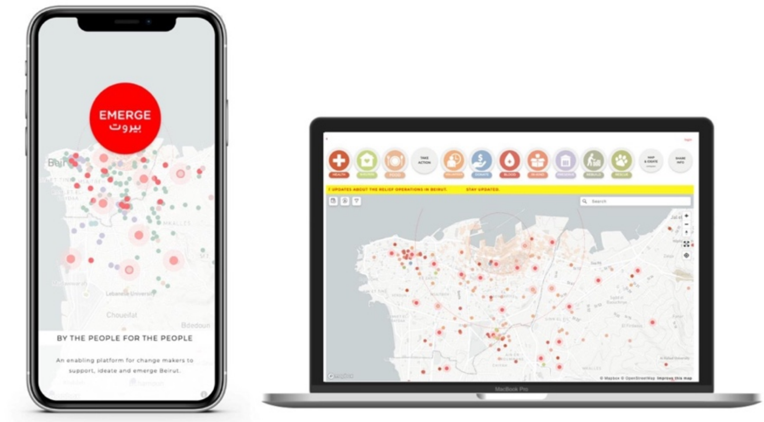

Fig 1. Views of Emerge Beirut webapp on mobile and desktop, Interactive mapping of Beirut following the 4th of August 2020 blast, Emerge Beirut, 2020. (own source).

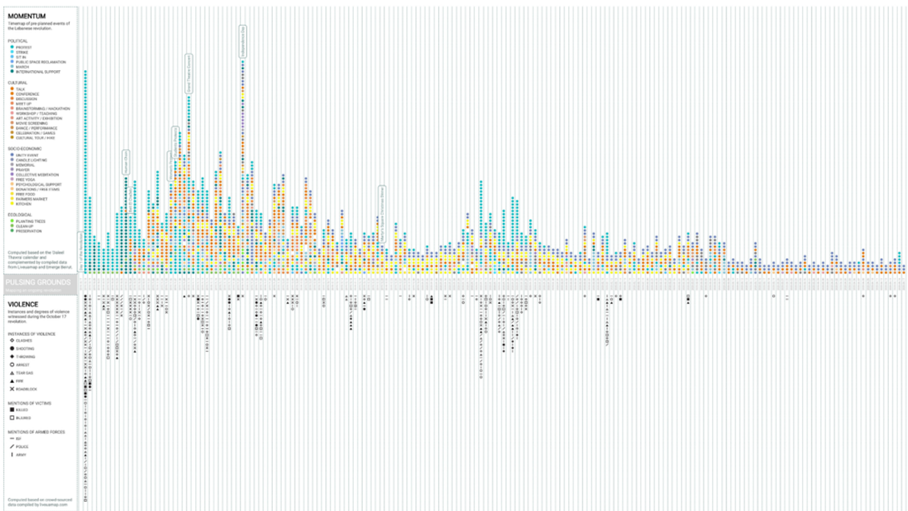

Fig 2. Extract of Pulsing Grounds, Timeline of events of the October 2019 revolution of Beirut, presented as part of Beirut Shifting Grounds, 17th Venice Biennale of Architecture, Co-habitat Exhibition, 2021. (own source).

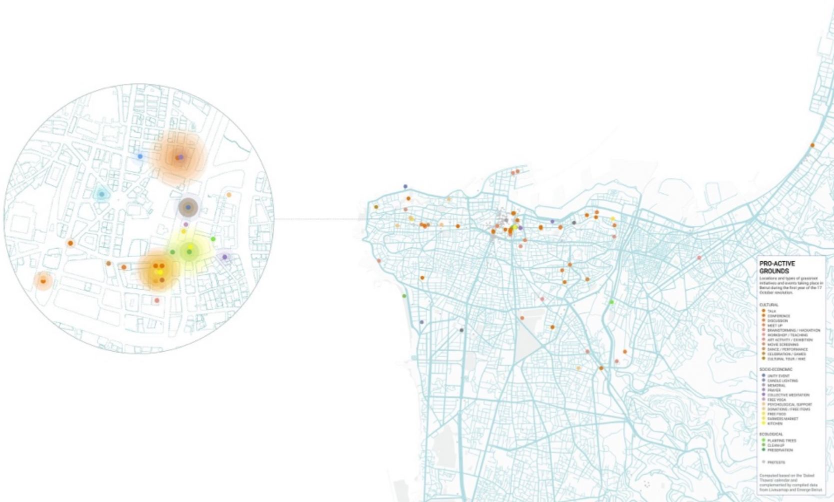

Fig 3. Extract of Pulsing Grounds, Map of pro-active events of the October 2019 revolution of Beirut, presented as part of Beirut Shifting Grounds, 17th Venice Biennale of Architecture, Co-habitat Exhibition, 2021. (own source).

Fig 4. Shahzaadee Valli, Global Refuge, Screenshots of interactive dynamic storytelling of the phenomenon known as refugees, created as part of the Digital Makers course taught by Joanne Hayek at the Dubai Institute of Design and Innovation, 2022. (own source).

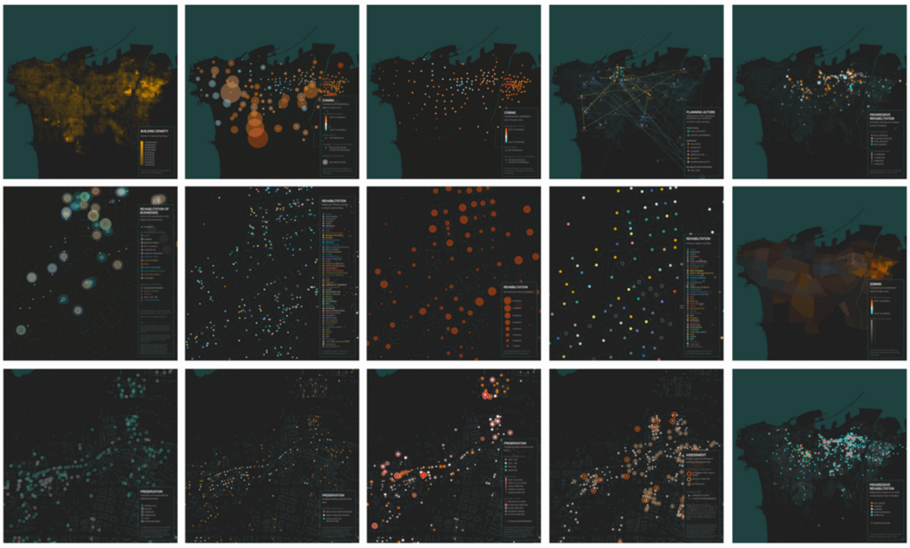

Fig 5. Extract of maps of Beirut post-blast 'The Immuno-Responsive City', documenting the grassroots deployments that followed the August 4th 2020 blast in Beirut, presented as part of Beirut Shifting Grounds, 17th Venice Biennale of Architecture, Co-habitat Exhibition, 2021. (own source).

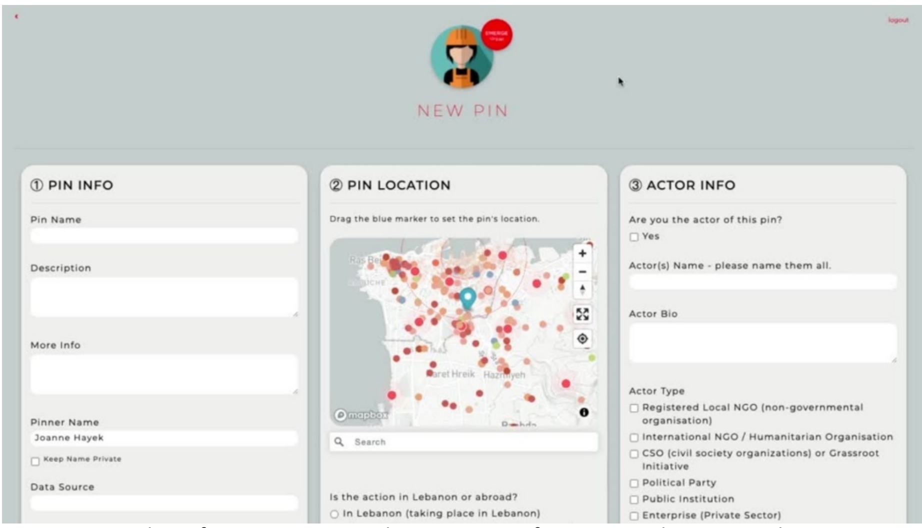

Fig 6. Screenshot of Emerge Beirut webapp, New pin feature seen here on Desktop, Emerge Beirut, 2020. (own source).

Fig 7. Views of Emerge Beirut webapp, New pin feature seen here on Desktop showing the customizable tag-based data collection system, Emerge Beirut, 2020. (own source).

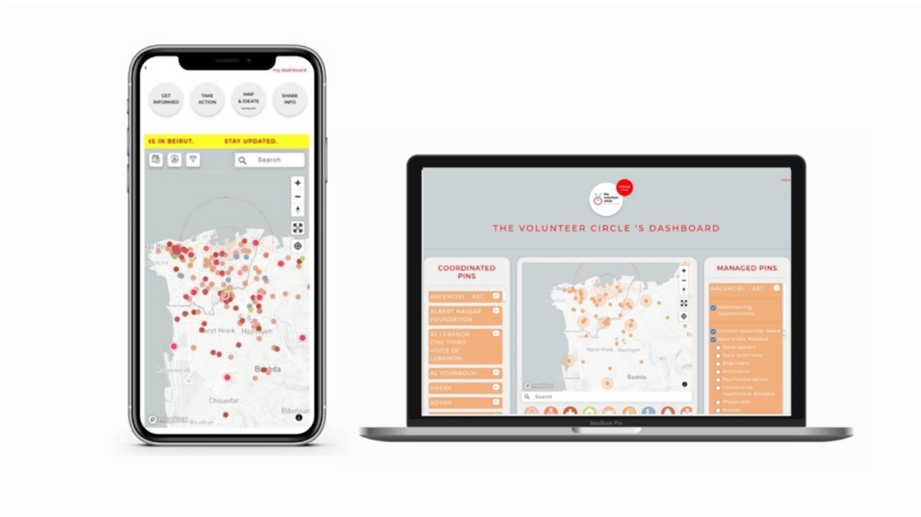

Fig 8. Views of Emerge Beirut webapp, Interactive Map on mobile and Coordinator Dashboard on Desktop, Emerge Beirut, 2020. (own source).

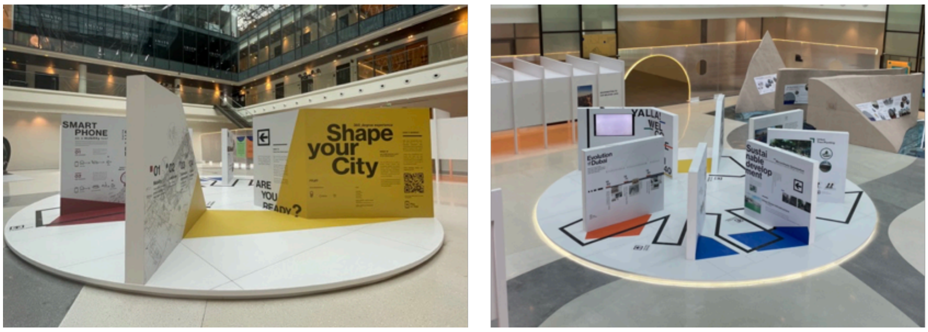

Fig 9. Shape your City, Views of the physical installation. Presented at Dubai Design Week, Architecture Exhibition, 2021. Project by RMJM, DIDI, Desert Ink, AESG, Invicta Studio and An Open Studio. (own source).

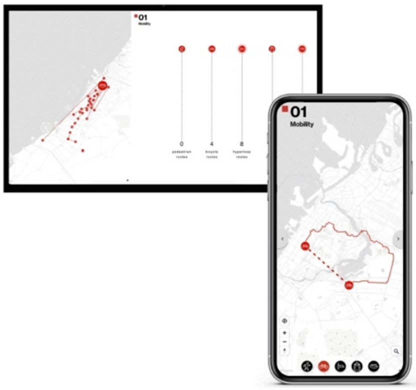

Fig 10. Shape your City, Screenshots of webapp as accessed on phone by individual users and on screen for real-time visualization of the collective inputs. Presented at Dubai Design Week, Architecture Exhibition, 2021. Project by RMJM, DIDI, Desert Ink, AESG, Invicta Studio and An Open Studio. (own source).

Fig 11. Shape your City, Screenshots of webapp as accessed on phone by individual users: mobility and landscape layers. Project presented at Dubai Design Week, Architecture Exhibition, 2021. Project by RMJM, DIDI, Desert Ink, AESG, Invicta Studio and An Open Studio. (own source).

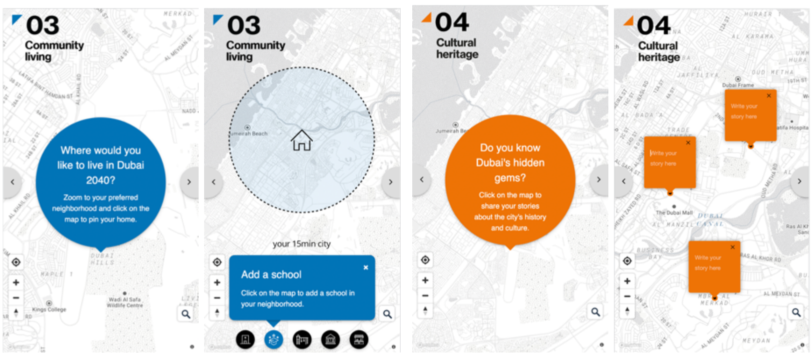

Fig 12. Shape your City, Screenshots of webapp as accessed on phone by individual users: community living and cultural heritage layers. Project presented at Dubai Design Week, Architecture Exhibition, 2021. Project by RMJM, DIDI, Desert Ink, AESG, Invicta Studio and An Open Studio. (own source).

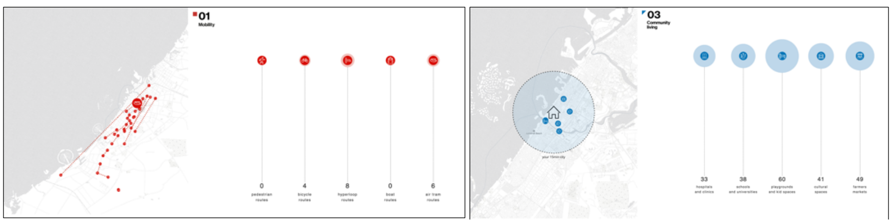

Fig 13. Shape your City, Screenshots of dynamic data visualization webapp of the collective inputs: mobility and community living layers. Project presented at Dubai Design Week, Architecture Exhibition, 2021. Project by RMJM, DIDI, Desert Ink, AESG, Invicta Studio and An Open Studio. (own source).

Fig 14. Extract of Pulsing Grounds, The five scales of mapping of the October 2019 revolution of Beirut. Presented as part of Beirut Shifting Grounds, 17th Venice Biennale of Architecture, Co-habitat Exhibition, 2021. (own source).

Fig 15. Extract of maps of Beirut post-blast 'The Immuno-Responsive City', documenting the grassroots deployments that followed the August 4th 2020 blast in Beirut, presented as part of Beirut Shifting Grounds, 17th Venice Biennale of Architecture, Co-habitat Exhibition, 2021. (own source).

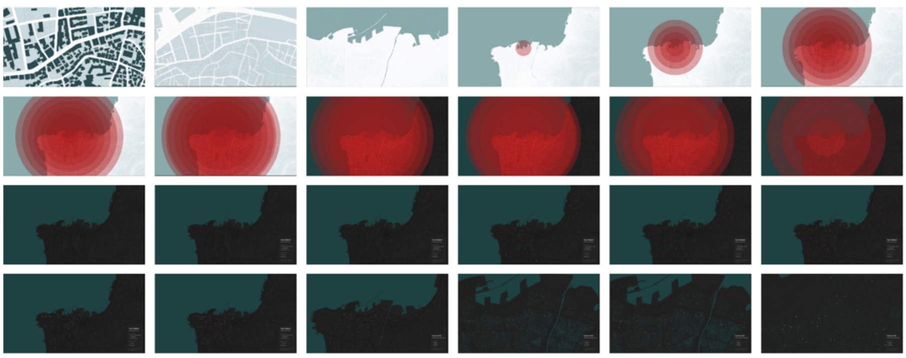

Fig 16. Screenshots from animated map video, documenting the deployments that followed the August 4th 2020 blast in Beirut, presented as part of Beirut Shifting Grounds, 17th Venice Biennale of Architecture, Co-habitat Exhibition, 2021. (own source).

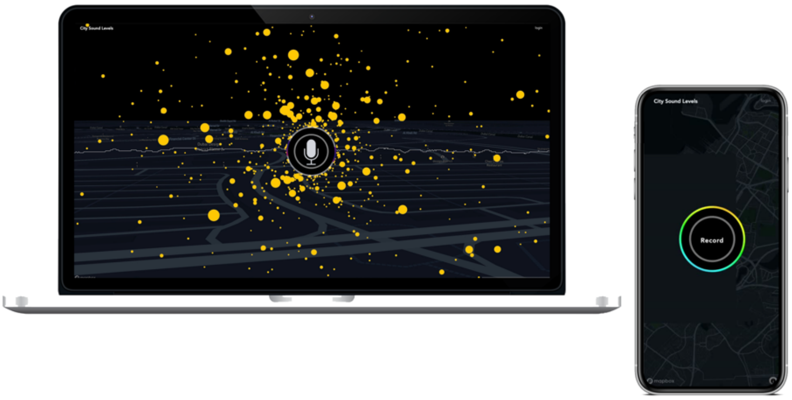

Fig 17. Aaliyah Mohammed, Areeba Shahid, Ahmad Saleh and Rand Kashlan, Screenviews of Urban Soundscapes web-app on desktop and mobile, created as part of the Digital Makers course taught by Joanne Hayek at the Dubai Institute of Design and Innovation, 2022. (own source).

Fig 18. Aaliyah Mohammed, Areeba Shahid, Ahmad Saleh and Rand Kashlan, Screenviews of Urban Soundscapes web-app, created as part of the Digital Makers course taught by Joanne Hayek at the Dubai Institute of Design and Innovation, 2022. (own source).

Fig 19. Extract of maps of Beirut post-blast 'The Immuno-Responsive City', documenting the grassroots deployments that followed the August 4th 2020 blast in Beirut, presented as part of Beirut Shifting Grounds, 17th Venice Biennale of Architecture, Co-habitat Exhibition, 2021. (own source).

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[1] The pilot Project of the Emerge Beirut web-app was co-founded by Joanne Hayek, Rawan Bazerji, Adib Dada and Fadi Katergi, and was co-designed by the team with the support of Balsam Madi, Nayla Hage-Chahine, Mitcha Sleiman, Lynn Dakkak, Roula Salamoun, Hussain Zaarour, among others. It was coded by Joanne Hayek with the help of Michel Doumet. The Emerge Beirut initiative was not funded nor incorporated, and was fully based on collaborative volunteering contribution.

[2] Beirut Shifting Grounds, research project was led by Sandra Frem and Boulos Douaihy in collaboration with ArD/ AUB faculty Carla Aramouny, Rana Haddad, Nicolas Fayad and Joanne Hayek- exhibited in the Co-Habitats Section of the 17th International Architecture Exhibition - La Biennale di Venezia curated by Hashim Sarkis. 'The Immunoresponsive City' and 'Pulsing Grounds' were created by Joanne Hayek in collaboration with Balsam Madi, with the help of-Hussein Zaarour, Stephanie Achkar, Mahmoud Baghdadi, Hisham Ismail, Hawraa el Husseini.

[3] The Shape your City project was presented as part of the Dubai Design Week 2021. It was created by RMJM in collaboration with DIDI (the Dubai Institute of Design and Innovation) – along with DesertInk, AESG, Invicta Studio and An Open Studio. The project was co-curated by George Arvanitis, Joanne Hayek, Marina Peres, Limi Suresh and Ivanna Volynets. The web-app was co-designed by the team and coded by Joanne Hayek.

[4] Global Refuge is a web-app conceptualized, designed and coded by Shahzaadee Valli as part of the 'Digital Makers: Fundamentals of Computational Media Design' course taught by Joanne Hayek at the Dubai Institute of Design and Innovation (DIDI) in the spring of 2022.

[5] Urban Soundscape is a web-app conceptualized, designed and coded by Aaliyah Mohammed, Areeba Shahid, Ahmad Saleh and Rand Kashlan as part of the 'Digital Makers: Fundamentals of Computational Media Design' course taught by Joanne Hayek at the Dubai Institute of Design and Innovation (DIDI) in the spring of 2022.