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Respecting Historical Spatial Integrity: Building a Historical 3D Florence and Avoiding the Video Game

This article explores the process by which the Digitally Encoded Census Information and Mapping Archive (DECIMA) endeavoured to create a complete interactive 3D urban map of sixteenth-century Florence. Originally, the project consisted of a projection of tax census data from 1551, 1561 and 1632 onto an axonometric visual map from our period of inquiry drawn by Stefano Buonsignori in 1584 georeferenced onto a contemporary map of the city. Transforming this into a three-dimensional projection was a means to display census information with greater precision. However, this process was fraught with project accessibility and methodological considerations. DECIMA is first and foremost a web-based open access platform for research on the early modern city. Scaling the web application up to three- dimensions risked jeopardizing user accessibility.

Finding sources to create a historical city proved difficult since much is known about major historical structures while the rest of the city's minor architectural heritage remains elusive. To resolve these issues, DECIMA researchers opted for a recreation of the city designed to match the visuals of Buonsignori's map, preserving the framework already utilized in the original project while making the finished product an optional feature for users to ensure accessibility was preserved. Utilizing urban digital design software City Engine, the existing geographic information system was scaled up into a 3D environment enhancing the precision of the data projection and offering opportunities for further technological enhancements to the web application for more in-depth research on Florence's historic urban community.

Key words:
Visualization; Methodologies; Accessibility; Historicity

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The Digitally Encoded Census Information and Mapping Archive (DECIMA), was designed as a research tool for historians of early modern Florence. Using census data from the period projected onto a sixteenth-century map of the city georeferenced onto a contemporary coordinate system, the project helped researchers get a sense for where individuals existed with relation to each other to facilitate historical work predicated upon spatial dynamics (Terpstra & Rose, 2016, p. 6). Early research included tracing the class backgrounds of Florentine nuns, the geography of the local sex trade and the mortality of plagues (Terpstra & Rose, 2016, p. 8-9). Offered as a web-based Geographic Information System (GIS), DECIMA is an open-access platform where users can interact with mapped data points that display information about city residents, businesses and property values. Since its launch in 2011, efforts to expand the project are underway. Incorporating additional census data, refining the georeferencing of data points and scaling-up the two-dimensional GIS into a 3D reconstruction of historical Florence. Undertaking these new directions has encouraged the acquisition of new expertise by the research team with regards to making use of emerging technologies to build a 3D web GIS that better captures the spatial dynamics present in our data sets and respects the limitations of available source material all the while remaining an accessible platform to do research on a historical urban community.

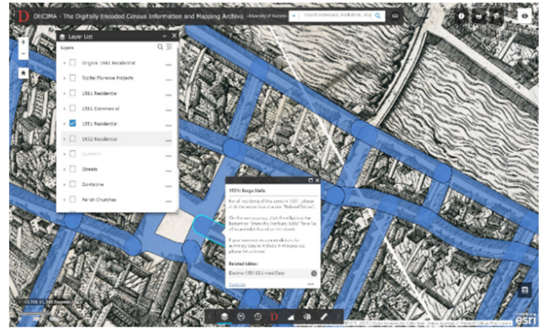
As a digital urban design project, DECIMA combines contemporary and historical urban data to generate a geolocated projection of sixteenth-century Florentine urban demography. The basic coordinate data for the web GIS was the default WGS Mercator horizontal coordinate system native to ArcGIS software, the GIS platform DECIMA has employed so far. After isolating modern Florence's coordinates in the web GIS application, a sixteenth-century map drawn by Stefano Buonsignori (from here on referred to as the Buonsignori map, or Buonsignori) in 1584 was georeferenced from a raw image file uploaded to the GIS based on the outlines of city blocks. As a map, Buonsignori lacks any inherent geographic data beyond its visuals. Operating on the assumption that the footprints of structures functionally do not move (DECIMA, n.d., Origins par. 2), the blocks on Buonsignori were aligned by their corners onto their matching WGS Mercator coordinates. Thus, the early modern map behaves as a visual source: a historical superimposition on contemporary geographic information to provide an ambience for the projection of historical census data.

DECIMA's data on human geography was drawn from three early modern censuses, the 1551 Descrizione, 1561 Ricerca and the 1632 Descrizione. Each line in the 1551 Descrizione refers to a household, i.e. a group of individuals organized under a single named individual. An entry in the 1561 Ricerca refers to a parcel of property, such as a house, a shop, or part of a structure. Data in the 1632 census follows the same conventions as the one from 1551 (DECIMA, n.d., Data-Driven Histories).

Census information was projected according to the textual descriptions provided by the census takers. The censuses DECIMA utilizes were collected through door-knocking. State officials and scribes walked door to door, interviewed the residents of a building on who lived there and recorded the information.

For the 1551 and 1632 censuses, the census takers only indicate which streets they were walking down. This provided a street on which data was collected, but without any idea where the route started organizing data points spatially proved impossible. 1551 and 1632 residential information was compiled into tables and visualized in the GIS on the Buonsignori layer by a rectangular line georeferenced along the length of the contemporary street confined bounded by its Mercator coordinates. The GIS projection of these censuses preserves their textual order with the spatialization of that information defined by confines of contemporary street geography. On the Buonsignori, these datasets appear as rectangular polygons to which a table is associated containing relevant census information of that street. Since geolocation was done in accordance with Mercator street coordinates, the polygons often overlap beyond the visual constraints of the 1584 map (see fig. 2 and fig. 3).

Fig. 1 - Screenshot from author's computer of the web GIS during loading highlighting the Buonsignori map appearing over the contemporary map of the city native to ArcGIS software.



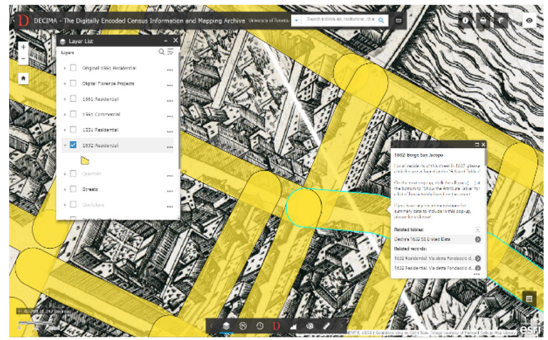


Fig. 2 (above) displaying the 1551 data layer and a data table.
Fig. 3 (below) displaying the 1632 layer and a data table. Note how the polygons exceed the visual distance accorded to each street by the Buonsignori. Both are screenshots from the author's computer.

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Conversely, in 1561 residential and commercial censuses the scribes were more precise in their spatial accountancy. They specify on which street they began their information collection and in which direction they went. This helped create a coherent spatial sequence to the data points. Starting on the street corner and following the order they appear in the text census information was organized into sets based on street and placed in order chronologically. The scribes further facilitated this task by noting in the census which properties came before and after the one from which they were currently collecting information. From this census, sets of points were generated based on each street, respecting textual order.

Geolocating data points was executed by utilizing Buonsignori visuals as a frame of reference. With the census information sequenced into points, each one was placed on a visible structure on the map along the respective street. When residential and commercial points overlapped they were placed one on top of the other on the same structure. Just like the 1551 and 1632 censuses, historical sense of space is not fully captured. An order to the data that could be visually spatialized was possible thanks to the organization of the associated textual sources, but this did not correlate a symmetrical capture of historical human arrangement. By associating points to structures visible on Buonsignori, it is assumed that the visuals align neatly with the actual number of structures present at the time. The map is limited in this respect as a clear separation between structures is not always discernible. Thus, even with the increased precision granted by the 1561 census description, the sense of historical space remains ambiguous in the DECIMA projection for the mapping process is executed on a textual and visual basis instead of abiding by the conventions of a coordinate system.

In the web GIS, each data set exists as a layer file. An integrated interface allows users to select which layers they want visible as they navigate the Buonsignori visual. Highlighting and clicking polygons with a cursor displays a data table with relevant census information (see Fig. 4).

As a projection of Florence's early modern demographic data, DECIMA is an imprecise attempt. It uses contemporary city coordinates to situate historical census information on an early modern visual interpretation of the city. Dataset spatial arrangement is predicated upon the visuals of period cartography and researcher selection. Buonsignori fails to refine spatialization because of isometric projection's limitations as a mapping technique.

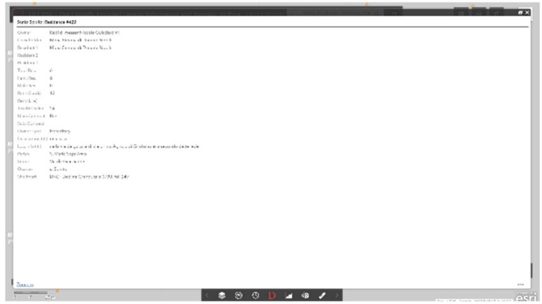

Fig. 4 – 1561 data point information for a residence in Santo Spirito owned by Niccolo Guicciardini. Screenshot from the author's computer.

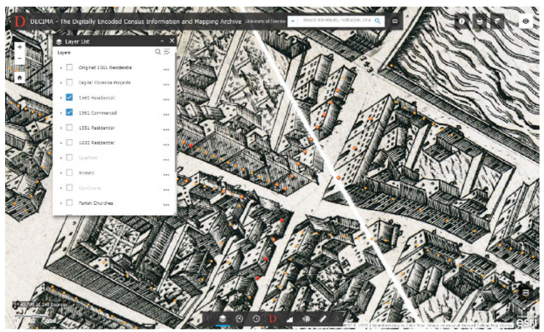

Fig. 5 – DECIMA interface with 1561 residential (orange dots) and commercial (red diamonds) displayed. When shops and residences are present at the same spot, the symbols are stacked. Note how the points do not align neatly with the structures on the Buonsignori visuals. Screenshot from author's computer.

Objects drawn will not be presented with a change in size from the viewers perspective. This causes the visible distortions in the image and the variable amount of depth visible on the map. Stefano Buonsignori created his map from mount Oliveto. As such, all perspective distortions and structural blending are produced from interpreting the city from that vantage point. The melding of structures, the inability to neatly determine the height of structures and near uniform width of streets are the results. While the map is most certainly effective for getting a sense of where streets and city blocks were, it does not precisely determine their size or distance relative to each other. Geolocating census data thus becomes a speculative process. Recourse to the textual arrangement of demographic information was necessary to create a spatial order that could only be selectively aligned with map visuals.

Produced in this way, the web GIS suffers from two notable shortcomings. The first is its inability to capture physical changes to the urban environment. Florence underwent substantial reconstruction over the course of the early modern period as its governments remodelled urban space to structurally facilitate their political designs (Trachtenberg, 1997, p. 6). As early as the fourteenth century, the city experienced significant modifications to government structures, renovation and expansion of its piazzas, and changes to the width of its streets through to the end of the nineteenth-century (Trachtenberg, 1997, p. 7). Buonsignori is a snapshot of the city as of 1584 while the data projected was from either before or after its creation. Some of the buildings seen there may not have been present during the census collection, meaning that situating points on structures is potentially inaccurate. The digital city is a static visual with data points that change without illustrating any changes to urban infrastructure; the city is static whereas the human data is fluid.

The second is the disingenuous presentation of different kinds of census data. While geolocating the 1561 census, residential and commercial data points were placed over each other when they were determined to be at the same location in accordance with the text (see Fig. 5). However, it is known that in Florence, commercial establishments were at street level with residences above (Luccardini, 2016, p. 17). As a two-dimensional cartographic projection, this dynamic is ineffectively captured.

Since DECIMA is heavily bounded by the limitations of the primary source material these problems are unsurprising. Source ambiguities are typical of publications in the digital humanities (Cohen and Rosenzweig, 2006, p. 81) and can be acknowledged in the platform to frontload the limitations of prospective inquiries, much like the equivalent of a footnote in textual outputs (Le Deuff, 2018, p. 96). Ambiguities considered, the two-dimensional web GIS as a software tool confines research outputs to conventional urban social history. A researcher can get a sense for where people lived, property ownership, land value, and approximations of the physical distance between structures. Projects using DECIMA in this way have included research on the surveillance of sodomy, concentrations of the sex trade and the decline of Arte di Calimala guild have been realized using DECIMA's base software architecture (DECIMA, n.d., STEP Forward 2017-2018). They provide a general sense of place, but cannot capture historical geographic distance or refine the placement of census data. As a research aid, DECIMA behaves as an artistic tool: displaying historic demographic information on a historic visualization of urban space, but otherwise lacks a refined geographic framework.

Despite these limitations, the project has garnered interest from a growing range of subjects. Notably, inquiries on Florentine sonic infrastructure makes some poignant claims about the role of sound in regulating the pace of daily life (Atkinson, 2016, p. 11). Bells among other sounds are cited as important for signalling times of day and informing Florentines on what activities were permissible (Atkinson, 2012, p. 41). Using DECIMA, a project such as this could locate relevant church bells in the city and trace the movement of individuals throughout the city at different times of day according to the sonic communications indicated by the chimes. However, DECIMA's capacity to assist would end there since the database remains a visualization rather than a precise geographic projection.

To overcome the existing issues in data projection visualization and offer researchers greater capabilities, scaling up the two-dimensional web GIS to a three-dimensional map was the optimal course of action. With the emergence of new software for digital urban design and mapping, DECIMA could look towards incorporating a 3D GIS as a layer into the web application. A 3D rendered city would resolve the projection problems of the 1561 census by allowing data to be placed on models with depth, meaning that residential data points could be placed above commercial ones, augmenting the historicity of the spatialization. Moreover, it would serve as the base template for a digital space where research into sensory history would be realized and an online platform where architectural research on the city could be published.

Executing a 3D GIS required looking for a comparable attempt and selecting software that was easy to use for a research team acquiring new skills. With an eye towards the former, a rendering of early modern Florence had already existed: the city as rendered by Ubisoft in the video game Assassin's Creed II. Their digital city consists of historical structures with generic buildings laid out to create a game environment optimized for interaction by the player avatar who can navigate the digital by climbing structures (Assassin's Creed II, n.d., key features). The Ubisoft city is a visual masterpiece by all accounts. For any audience, this recreation is an immersive spectacle with a breathtaking Duomo, Santa Trinita, Ospedale degli Innocenti, and Santa Croce (Assassin's Creed II, n.d., key features). While these structures were designed with consideration to historical data, the surrounding structures are generic models. From a theoretical standpoint, the Ubisoft Florence does not capture Florence in any specific historical moment: it is instead a curated historical environment built around a broader interpretation of the period (Fletcher, 2015, par. 13). Nonetheless, this rendering pointed to some important methodological considerations for the 3D DECIMA.

Mainly, it highlighted an issue regarding the acquisition of building information. Historical structures, as exemplified in the Ubisoft city, benefit from the fact that they still exist today, have not necessarily undergone any drastic structural change over time and have extensive documentation highlighting the same (Luccardini, 2016, p. 33). By contrast, these same benefits are not extended to the city's minor architectural heritage. Ubisoft generated generic

Fig. 6 - A screenshot of Florence's Duomo rendered in Ubisoft's Assassin's Creed II. Note the contrast in façade texture detail of the Duomo while the surrounding structures have generic geometry and textures applied to them. http://assassinscreed.wikia.com/wiki/File:AC2_florence_concept.jpg

models of these buildings replicating roofs, facades and digital textures while optimizing their placement in the digital environment for interactions by the player avatar rather than historical precision (see Fig. 6). Since DECIMA endeavours to maximize historicity by respecting sense of space, a comparable approach was unviable. Project accessibility considerations also arose because publishing an online rendering of a city requires a certain benchmark of computer hardware capability. Digital humanities work has been a means to take history beyond academic confines by publishing it in an accessible format (Fletcher, 2015, par. 9). The existing GIS ran with little strain on the hardware of current desktops and laptops. Scaling the project up risked jeopardizing user accessibility, privileging those who owned computing equipment with dedicated video cards over those with integrated graphics processors depending on the sophistication of the visualization. Reduced access to the finished product is problematic because it obstructs peer review and in the case of a research tool, undercuts its utility (Zaagsma, 2013, p. 14). As an open-source research tool, DECIMA is bound by the same considerations. This needed to be addressed with careful selection of 3D modelling software.

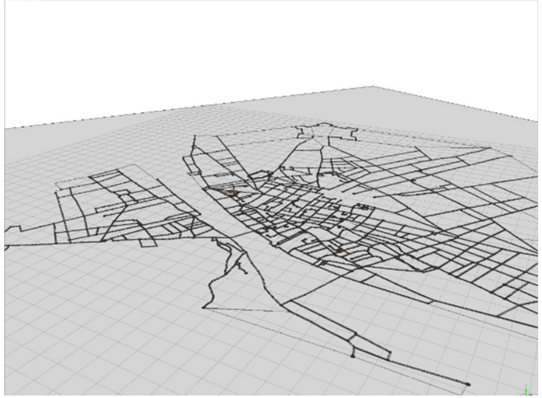

Fig. 7 – View of the streetmap shapefile uploaded into City Engine. Greyed in areas represent city blocks. Screenshot from author's computer.

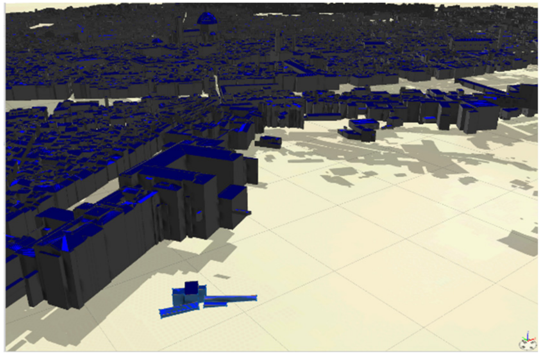

Fig. 8 – Close up view of a selection of minor architectural heritage not found in Buonsignori. Screenshot from author's computer.

To resolve the first issue, the current source base was optimized to establish a plan for building the 3D GIS. Contrasted with the structures that exist in Florence today Buonsignori is predominantly a showcase of the city's minor architectural heritage. By using the visual map as a frame of reference and current Mercator georeferencing links, DECIMA 3D would be a scaling up of the existing Buonsignori map. The 1584 visuals would determine the number of structures in city blocks and their geometry reproduced according to the axonometric perspective. Keeping the current geographic framework and using the same visuals ensured that biases between the 2D and 3D maps are congruent. As such, both would make symmetrical claims about historical space and demographic data.
After experimenting with several programs City Engine urban modelling software was selected to render the 3D GIS. Offered by the spatial analytics company Esri, any modelling done in this program would be fully compatible with the existing web ArcGIS, a program that it also provides. With this selection concerns about technological compatibility were resolved. Furthermore, the software and its output can run on a computer with current hardware (Esri, "City Engine System Requirements", table 1), overcoming most accessibility issues. To minimize accessibility reduction once 3D models were uploaded, the current GIS was going to remain the default platform for DECIMA. The 3D map would be integrated as an optional layer users can choose to view much in the same way that census visibility is selectable. With this software choice and interface configuration DECIMA would retain its accessible characteristics.
Visualization began with the delineation of city blocks by overlaying the street data as polygons onto Florence's Mercator coordinates in City Engine. City Engine benefits from the same world coordinate database as ArcGIS facilitating geolocation. A street shapefile was exported from the web GIS and uploaded as a street layer into the new software. Street shapes were modelled and textured. Rectangular polygons were drawn in between to anchor city blocks. With those steps complete, the vertices of the blocks were likewise anchored according to their matching visual block in Buonsignori along their Mercator coordinates (see Fig. 7).
To increase output pace, DECIMA purchased a contemporary 3D rendering of Florence called Cyber City. Rather than designing a city from the ground up, output efficiency was achieved by taking a modern model of the city and scaling it back to its early modern appearance per Buonsignori. The Cyber City data was divided into four clusters of models for ease of handling and uploaded into City Engine to be manipulated individually. Modern structures were identified and removed (see Fig. 8). Next, a block by block survey of the city was executed by comparing Cyber City model placemement with Buosignori building visuals.
Structures from Cyber City absent from Buonsignori were removed in a similar manner to their modern counterparts. Reversely, if a structure removed from Cyber City had a Buonsignori counterpart, a generic polyhedron model was generated using City Engine software capabilities to replace it. A building footprint was retraced where the modern structure stood and a model rule file assigned to it. Once the rule file was assigned, a model was generated. Repeating this process for each cluster continued until the number of buildings in the Cyber City render matched Buonsignori's visuals.
Using terrain information native to the City Engine geographic information database, a topographical map was aligned with the street-block map to ensure that the streets followed Florence's real-world terrain features. Afterwards, scaled down Cyber City model clusters were integrated above. In the software's language, this is labelled a scene file (.cej file) that shares properties with a conventional map layer file in a GIS. The DECIMA scene is comprised of four layers: georeferenced topographical information, Florence's city streets, blocks and the generic polyhedral models of buildings. Once combined, modern structural features were removed from the building models to create a uniformly untextured map. The result of this process was a scene file currently considered the alpha version of DECIMA's 3D GIS.
As it stands, the digital city is congruently georeferenced with the Buonsignori map on the web application (see Fig. 9). Another round of cross-checking the building count with Buonsignori is still required to 'proofread' the city to ensure maximum primary source compliance. The census data also needs to be projected into the 3D rendering as independent layers, similar to how they exist in the current web application. Once these steps are complete, the entire 3D GIS will be saved as a layer package and uploaded into DECIMA online as an independent viewable layer. At that stage, it will still be in a beta state since

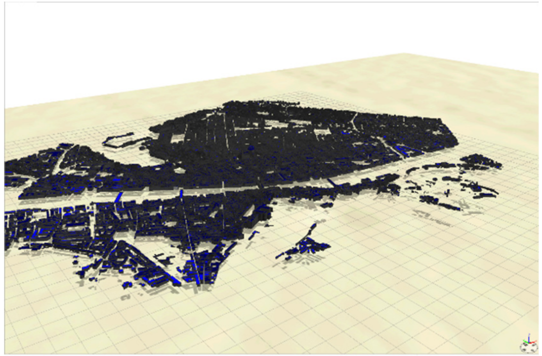

Fig. 9 – Screenshot depicting the alpha version of DECIMA 3D. The city appears as a set of grey polyhedrons. Beige layer underneath represents the georeferenced terrain layer from City Engine's software database (screenshot from the author's computer).

hardware benchmarking the online application is still necessary and ensuring that the new layer is wholly symmetrical with the 2D original to guarantee that it is, in fact, a scaled-up version.

Future directions for the 3D map include visual texturing and digital physics coding. Partly to satisfy aesthetic needs and to emphasize source congruity further, façade textures will be taken from Buonsignori and applied directly to the sides of the new GIS' polyhedrons. This emphasizes the fact that it is a recreation of Buonsignori and will assist the visual alignment with census data points along structures. The separation between building floors becomes even more distinct with the application of textures facilitating census data alignment. Given the previously mentioned interest in sonic history, incorporating a digital physics engine would allow physical properties to be assigned to structures and the mapped sonic properties of the city to be experienced as a user avatar in the 3D environment. Some early experimentation has confirmed that polyhedron data from City Engine is easily portable into the Unreal video game design engine in which physics can be coded.

The addition of the 3D map facilitates the publication of historical modelling projects on Florence, much in the same way that it has done for social history projects. Work on reconstructing San Pier Maggiore, religious walks through the city and tourist navigation (DECIMA, n.d., 2017, Affiliated Projects) will be integrated into the web application through agent-based modelling platforms that allow a user to navigate the 3D Buonsignori as a user avatar. The creation of a phone application allowing users to navigate DECIMA in an artificial reality environment is also under consideration contingent on the successful completion of the new map.

The use of GIS technologies, especially those like City Engine dedicated to the modelling of urban spaces, has proven to be invaluable in furthering DECIMA's project ends. Limited by the availability and content of primary source material, recreating a historical city in a digital environment is a daunting task. Geographic, demographic and infrastructural data is not equally available, meaning that reconstruction will never achieve full congruency with a historical urban space. Context becomes limited if not entirely lost by the translation of primary materials into a digital environment, limiting the range of claims possible by digital history (Brennan, 2018, p. 6).

In DECIMA's case, resignation to Buonsignori as an artistic interpretation of sixteenth-century Florence into which data could be projected provided a workable base from which a 3D city could be built within the limits of primary sources while showcasing them simultaneously. Once completed, the 3D GIS will exist as a scaled-up replica of the 1584 snapshot originally captured by the cartographer with the ambiguous placement of demographic information preserved on modern geographic coordinates. Recreating historical communities in digital environments requires compliance with what can be historically known and how sources communicate that information. In these respects, DECIMA researchers have embraced new technology and reconfigured primary source presentation to preserve the historical sense visible in the data.

Fig. 10 – Duomo as seen in Buonsignori with surrounding minor architectural heritage. Note how the latter is preserved in the 3D alpha view (see Fig. 11). Textures from the Buosignori image will be applied to the Duomo in the alpha.

GIS technology has become increasingly accessible and with that, comes the opportunity for experimentation with the recreation of historical cities. In any multimedia recreation of urban space, the degree of historicity will be heavily predicated upon the extent to which primary sources are used in the reconstruction. Utilizing only historical structures entails limited historicity when attempting to lay claim to the reproduction of a city; the minor architectural heritage also requires capture (Dore & Murphy, 2013, p. 56). As DECIMA's experience demonstrates, sources can prove very limiting even when a map is employed. Maps as historical documents provide a momentary snapshot of urban space and are themselves limited by the spatial understandings of their production methods. They do not represent urban structural change. Resigning oneself to these constraints is necessary and translating them from the map to computer software is essential for a proper historical evaluation of an urban environment (Knowles & Hillier, 2008, p. 17).

Buonsignori's axonometric presentation of Florence confines digital representation to the spatial framework of where buildings were with relation to each other and the geographic insights end there. Consequently, the data on human geography found in the censuses can only be spatialized by textual content aided by any recorded sense of place. Using these parameters for urban digital recreation means that physical change to city infrastructure cannot be captured beyond the cartographic snapshot, but an approximation for demographic change can be shown but only speculatively spatialized.

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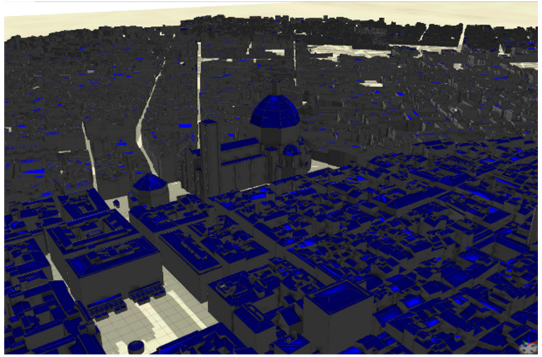

Fig. 11 – view of the Duomo in the 3D alpha. The piazza surrounding it has been cleared of structures to resemble the Buonsignori visuals (screenshot from author's computer).

All of a city's architectural heritage requires acknolwedgement while respecting spatial organization as understood historically to avoid a partially historical digital environment (see Fig. 10 and 11). Advanced technologies allow a historical city to visualized, but as an artistic creation contingent on the spatial data available.

Nonetheless, experimenting with new technologies offers great potential for assessments of human life in historical architectural spaces such as projections of demographic information, sensory mapping, agent-based modelling and digital architectural reconstruction providing of course that the physical space has clear historical sourcing and abides by those source limits. Since its creation, DECIMA was a showcase of of the first. Thanks to the expertise acquired in the 3D visualization process, DECIMA's researchers have acquired new software proficiencies that will facilitate experimentation with the remainder.

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