THE IMPACT OF GOOGLE'S APIS ON LANDSCAPE VIRTUAL REPRESENTATION

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KEY WORDS: Representation, Visualisation, Virtual environment, Google APIs, Photorealistic Tiles, 3D city representation

ABSTRACT:

The field of territorial representation has undergone significant transformations in response to the proliferation of the internet, leading to the emergence of platforms dedicated to global exploration. Notably, Google Earth has assumed a pivotal role and stands as one of the most widely utilized tools for making territorial information universally accessible. Google recently introduced direct access to photorealistic 3DTiles via dedicated APIs, ushering in a new era of possibilities. This integration forms a robust foundation for crafting customized applications and interactive experiences within a geospatial three-dimensional environment. The primary objective of this research is the assessment of the accuracy and potential of the resources provided by Google within a workflow focused on digital twin processing and geospatial data visualization. To achieve this goal, a comparative analysis of distinct models was conducted, with each model representing a unique approach to three-dimensional reconstruction. The research introduces a methodology designed for easy replication in other case studies, demonstrating intrinsic scalability suitable for more complex or diverse scenarios. Furthermore, the study offers a comprehensive assessment of the differences and characteristics of the three methods analyzed, providing insights into their potential and limitations.

1. INTRODUCTION

The "fourth industrial revolution" (Kamarul Bahrin et al., 2016; Schwab, 2017) also referred to as the "connective revolution" (Castells, 2002; De Kerckhove, 2014; Lévy, 2002; van Dijk, 2002) has pervaded our daily lives by offering the possibility of reaching and transmitting information, which also fully affects our relationship with "maps" (Farinelli, 2009), a representation of knowledge that is placed at the prodromes of culture (Harley, 1987), an expression of knowledge (Maceachren, 1995) whose power (Wood, 1992) and ability to persuade is central to "conquer" (Monmonier, 2018) as it is today in the digital empire (Farman, 2010).

In this context, platforms dedicated to global exploration have become essential vehicles for large-scale understanding of the territory, significantly transforming the value of representation to anticipate and orient experience, with information immeasurable in terms of quantity and quality. Among these solutions, Google Earth stands out as the most renowned, covering over 97% of the world's territory, including approximately 17 million kilometres of roads documented through Street View imagery (CNET, 2019).

The issues of digital cartography are linked to access to information, which is presented as a great revolution in the democratisation of knowledge (Coleman & Blumler, 2009; Papacharissi, 2010; Pool, 1983; Sunstein, 2001) but which in reality has severe limitations in the usability of three-dimensional information, which is mainly based on satellite images. In May 2023, however, Google introduced a revolutionary information-sharing feature, allowing users direct access to Google Earth content via APIs (Google, 2023). Through the strategic use of APIs and specialised software tools, the import of Google's highly detailed and photorealistic tilesets becomes a concrete reality. This integration provides a solid basis for the development of customised applications and interactive experiences that take place in a three-dimensional geospatial environment, although the import itself still leads to export and thus usage limitations. In this context, it is intriguing to examine how Google Earth data can be used for research purposes. It is a question of assessing the reliability of spatial simulation as a fundamental requirement in possible implementations, with the aim of developing a new approach to geo-visualisation and spatial representation, characterised by speed and accuracy, while at the same time guaranteeing high interoperability with files and data of various kinds.

The key issue is to analyse the reliability as well as the usability of the information, an assessment that can emerge from the comparison with other spatial representation tools. This confrontation can be implemented with scanning technologies (C. Bianchini, 2018; Bini & Battini, 2007; Boehler & Marbs, 2002; Cundari, 2012; Migliari, 2001, 2004; Russo et al., 2011; Sgrenzaroli & Vassena, 2007) and on the evolution of the computational ability to obtain three-dimensional models through image matching (Angelini & Gabrielli, 2013; M. Bianchini, 2008; Bianconi, Catalucci, et al., 2017; Bianconi, Filippucci, et al., 2017; De Luca, 2011; Filippucci, 2010; Remondino et al., 2008; Remondino & El-Hakim, 2006; Zambruno et al., 2013), which connects to drones (Achille et al., 2015; Florido et al., 2018; Gilento, 2012).

Based on research aimed at estimating the spatial accuracy of Google Earth's two-dimensional satellite images (Potere, 2008; Zomrawi et al., 2013) and elaborations obtained through drone (Elkhrachy, 2021), the research aims to investigate the potential of photorealistic tiles for the creation of detailed virtual environments within applications focused on the study of territory, cities and cultural heritage. To achieve this comparison, given certain limitations imposed by Google and the consequent impossibility of using high-performance mesh analysis tools, specific programming was carried out to estimate the differences in three-dimensional reconstruction.

The case study selected for the model comparison is the building complex of the former psychiatric hospital, also known as the San Benedetto asylum, in the city of Pesaro, an important city in the Marche region of Italy. The building is located in a central area of the city, a few steps from the historic centre, opposite Porta Rimini, one of Pesaro's historic gates. Its construction began in 1829 at the behest of Msgr. Benedetto Capelletti, apostolic delegate for the province of Pesaro and

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Urbino (Pela, 2003). The building is a large complex, composed of several pavilions and courtyards arranged on a symmetrical plan. The main entrance is located on the north side, and is characterised by a portico with five loggias. The psychiatric hospital in Pesaro was closed in 1981, following the Basaglia law, which ordered the closure of asylums, and remained abandoned for many years, becoming a place of fascination and mystery (L. M. Bianchini et al., 1997). This case study was chosen due to the availability of a survey campaign and the accuracy of the data provided by Google.
The proposed methodology is easily replicable on other case studies thanks to its intrinsic scalability to more complex or diversified cases, offering an assessment of the differences and characteristics of the three different models connected to the different generative processes analysed, in order to provide an overall view of their potentialities and limitations.
There is particular interest in the use of such information within interactive virtual environments that can give rise to Serious Game applications (Anderson et al., 2010; Bianconi et al., 2022; Checa et al.; Hallinger et al., 2020; Larson, 2020; Skamantzari & Georgopoulos, 2016; Smith et al., 2020). This new frontier of representational research is increasingly intertwined with the programming of codes to create interaction and enhance the communication of cultural heritage.

2. METHODS

In order to analyse the accuracy and possibilities offered by the Google APIs, the Photorealistic 3d Tiles have been compared quantitatively and qualitatively with a mesh obtained through the photomodelling of the Google Earth scenery (Bianconi et al., 2019) and with the result of a drone-based photomodelling. With reference to methodologies already consolidated and documented in the scientific literature, the drone-based photogrammetric acquisition, supported by the specific software for three-dimensional processing from photographs Agisoft Metashape (Cignoni et al., 2017), allowed the generation of a digital model of the entire area of interest that is considered to be fully reliable (Bianconi, Catalucci, et al., 2017; Remondino & El-Hakim, 2006), and which is used as a reference for the comparison.
The second comparison mesh was obtained by drawing on Google Earth information, following already established procedures (Bianconi et al., 2019): by setting up a high-resolution frame extraction path, images were acquired that, once imported into photogrammetric processing software, allowed the construction of a digital terrain model (DEM) and the related texture (Remondino et al., 2008).
The third model is obtained from Google's API via Cesium (Cesium, 2023a), an open source web-based geographic data platform that provides access to high-quality geospatial information. For the creation of virtual scenarios, on the other hand, the software Unreal Engine was chosen, which was preferred over its direct competitors due to the greater ease of programming offered by Blueprints (visual scripting system) and a deeper knowledge of the software on the part of the research team.
The integration between Unreal Engine and Cesium is made possible by a plug-in called 'Cesium for Unreal'. This extension provides a set of APIs that allow developers to access geospatial data within the graphics engine.

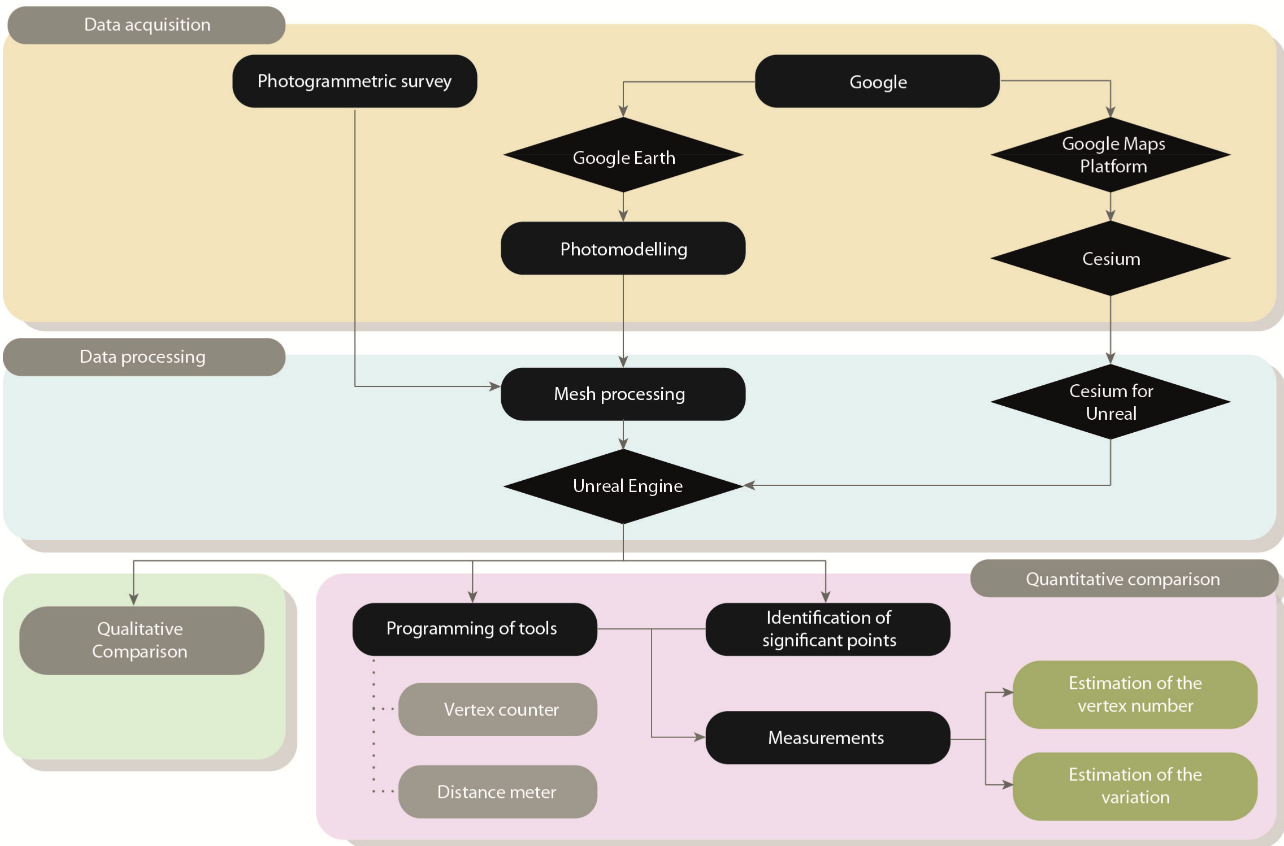

Figure 1. Flowchart for the proposed research method.

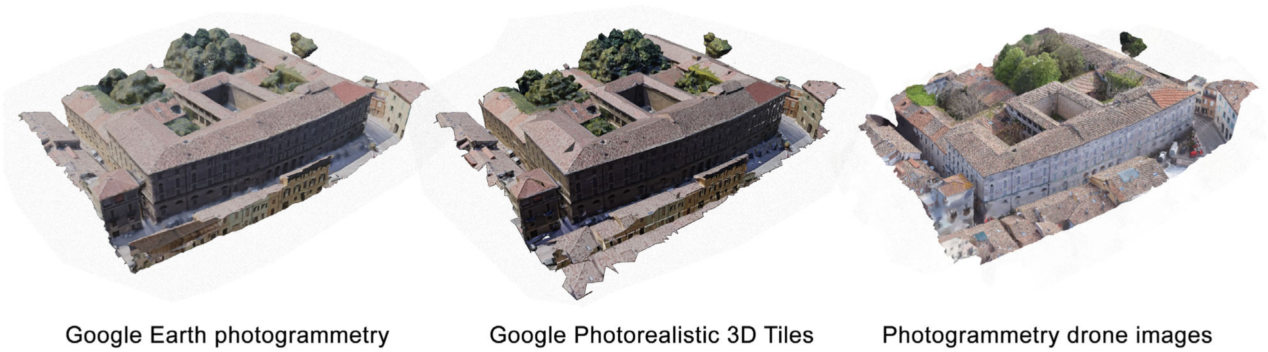

Figure 2. Qualitative comparison of 3D models obtained with different techniques.

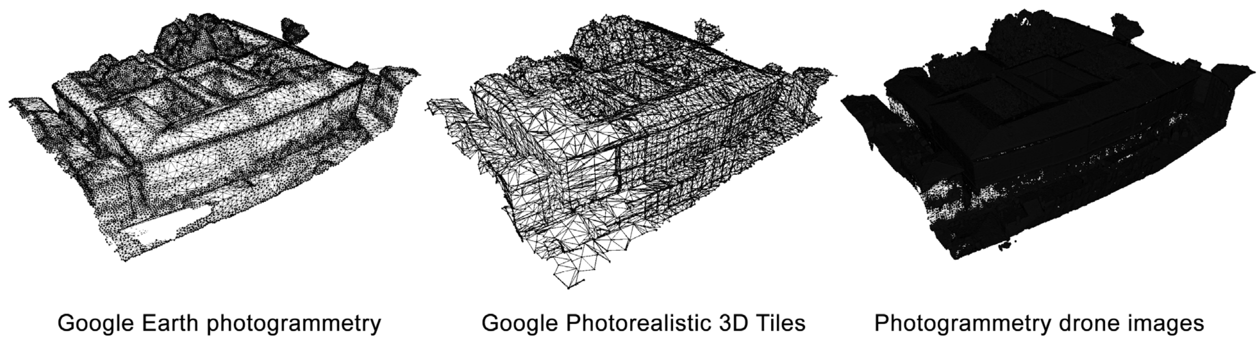

Figure 3. Comparison of the vertices of the different 3D models analysed.

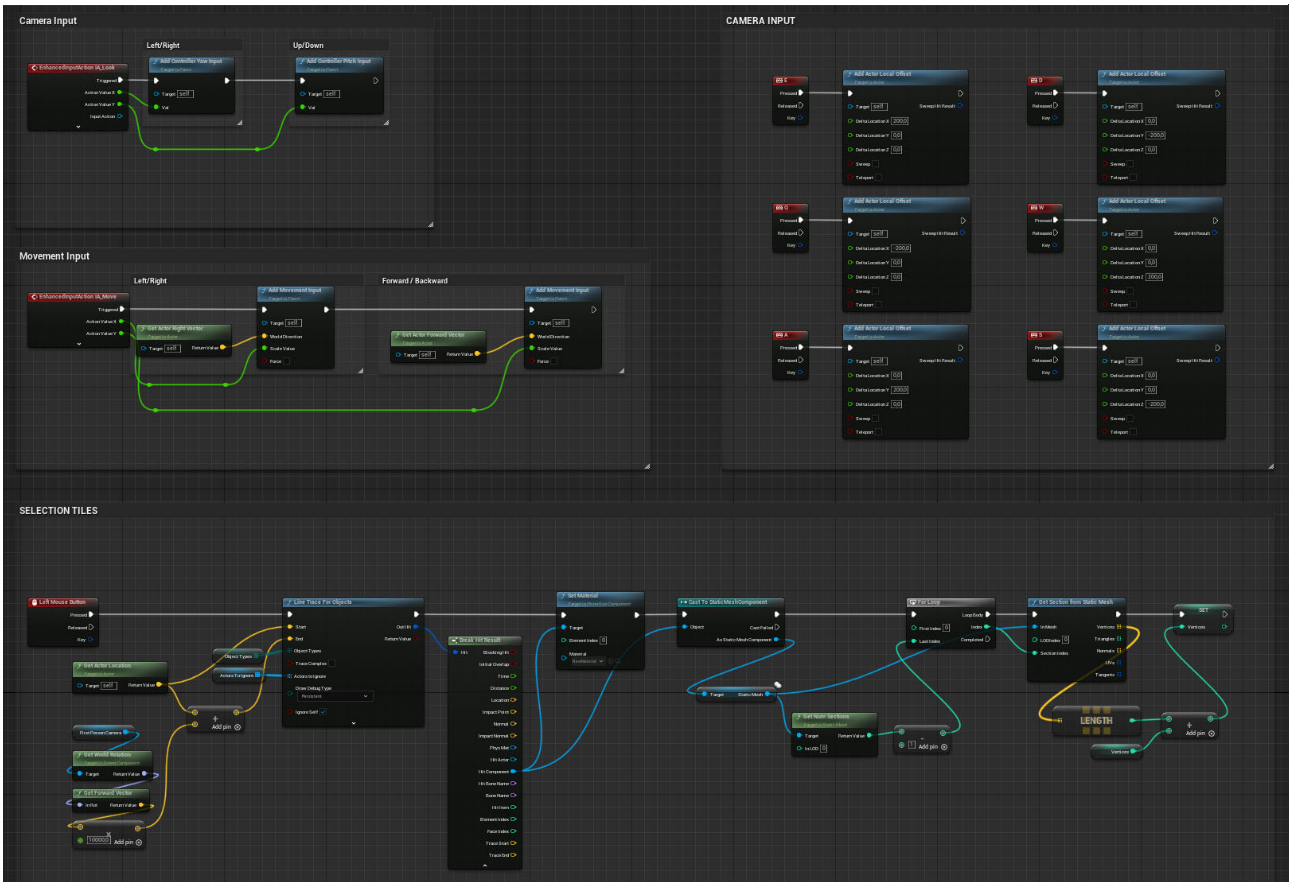

Figure 4. Blueprints development in Unreal Engine for the vertex counter tool.

Figure 5. Virtual scenario with tile selection for vertex counting.

In order to obtain the geometries, it is sufficient to follow a short configuration procedure (Cesium, 2023b) and introduce a new asset of type CesiumGeoData within the scene, which will contain the Cesium data one wishes to use.

The limitation imposed by the plugin, however, is the impossibility of managing the tiles individually and exporting meshes from Unreal Engine for use or external analysis.

To overcome this, it was necessary to programme two tools within the rendering engine for analysing the meshes imported via Cesium. The first is a vertex counter that allows the selection of tiles and returns the number of vertices from the identified geometries. The function has been programmed to always return the number of vertices relative to the maximum detail geometry made available by Cesium. The plugin has its own integrated functionality that optimises the management of model detail by replacing tiles according to their distance from the camera, and to overcome this, a function was implemented that allows the geometry with the greatest number of vertices to be always obtained. Within the virtual scenery, the possibility has been developed to move the view at will via the classic gaming buttons (WASD) or via the directional keys, and to zoom in and zoom out in order to allow the tiles to be analysed. The selection is done by pressing the spacebar button, which activates the individual tile, colouring it red, which is then exactly below a pointer positioned in the centre of the screen. Activating and deactivating the different tiles updates a counter located in the top right corner of the screen, which returns the number of vertices of the selected geometries.

The second tool, on the other hand, calculates the distance between two vertices identified within the scene. The movement of the camera for the detection of the remarkable points is always ensured through the appropriate buttons, while the selection of the points to be compared is done through the mouse buttons. When the left mouse button is pressed, the vertex closest to the pointer in the centre of the screen is highlighted and will be the first point for calculation, while the second will be chosen through the same procedure, activated however by the right mouse button. The selection of the first and second vertex to be considered can be changed at any time, and with each change the measurement will be updated, shown in the interface in the top left-hand corner below the vertex counter. To perform the mesh comparison, models obtained by photomodelling within the same Unreal Engine scene were important, and the possibility of activating the desired individual model during the measurements was implemented. The geometries were aligned with each other using two remarkable points, represented by the ground points of the ends of the main façade, the coordinates of which were known, obtained during the on-site survey. Finally, 20 control points were identified and measured for each mesh in order to elaborate a quantitative comparison between the different geometries.

3. RESULTS

The initial phase of the qualitative examination of the three models focused on analysing the most evident differences and characteristics, both on a macroscopic and microscopic scale, of texture and geometry. From an initial visual study, it immediately emerged that the three elaborations, examined from a distance, do not show significant inequalities; however, the analysis shows increasing significance as the observation point is approached. A close perspective showed that the Photorealistic 3D Tiles present a sharper texture than the one obtained by the photo-modelling of Google Earth, and the geometry is more precise in fitting smaller elements such as chimneys and terraces. However, neither solution is accurate enough to match the quality of the photogrammetric model obtained using a drone (Figure 2).

The evaluation was then extended to the next phase of quantitative analysis, aimed at verifying the considerations that emerged from the qualitative examination. For this purpose, the numerical calculation of the mesh vertices was of particular interest. The results obtained describe markedly different situations, characterised by strongly differing levels of geometric accuracy: the geometry obtained by photo-modelling from Google Earth consists of slightly less than 50,000 vertices,

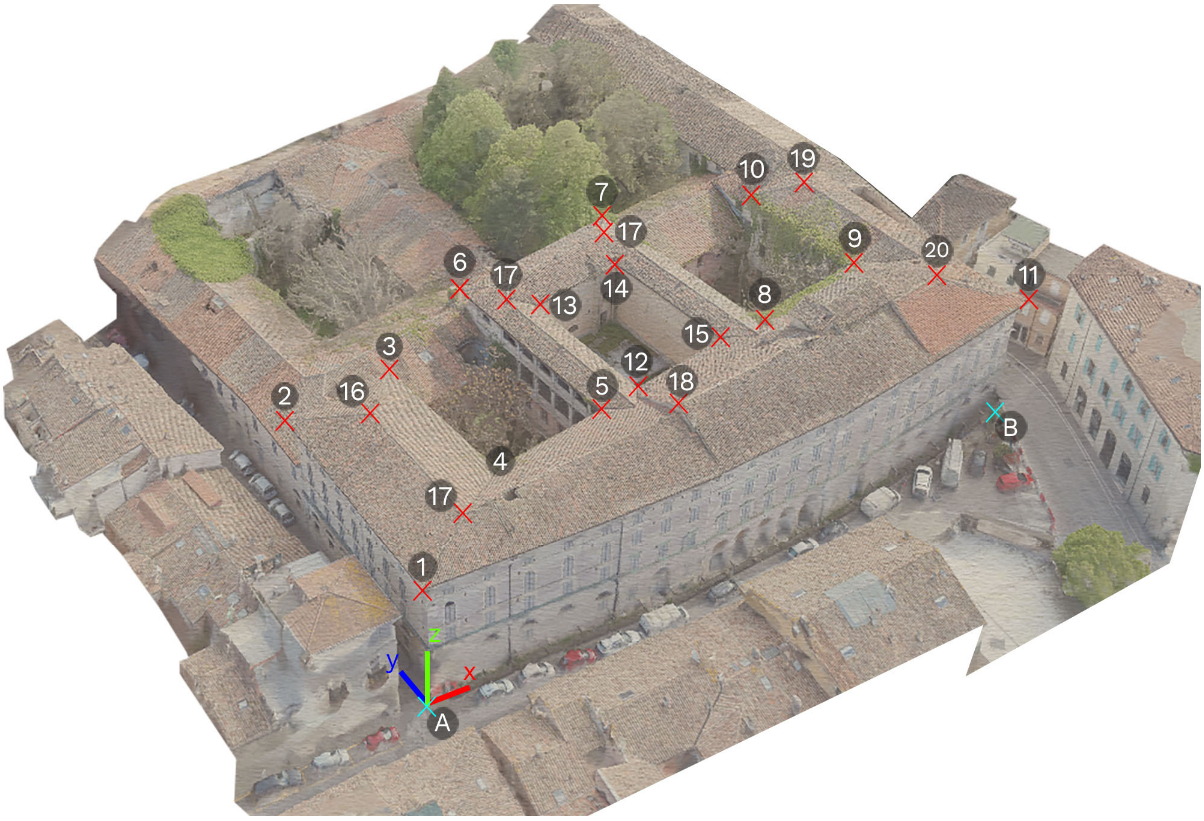

Figure 6. Axes and reference points for measurements, with indication of the two points A (0, 0, 0) and B (-74,686, 8,816, 0,887)

the model consisting of photorealistic tiles contains approximately 570,000 points, while the model obtained by drone is characterised by more than 7 million vertices.

With the intention of further investigating the degree of discordance between the three methodologies, spatial analyses were carried out by surveying the coordinates of notable points of the building, aimed at estimating the existing percentage variations (Figure 7). The direct comparison of mathematical calculation thus made it possible to assess, for each of the twenty points identified, the deviations along the three main directions from the model obtained by drone photogrammetry, reported as Δx, Δy, Δz. From the arithmetic mean of these values, the average deviations along the three axes Δxm, Δym, Δzm, and finally an average deviation value defined as Δm were obtained for both the photo-modelling from Google Earth and the Photorealistic Tiles. Specifically, for the first case, absolute values of the deviation along three main axes of Δxm=1.96%, Δym=4.32% and Δzm=1.62% were calculated, leading to an average variation Δm of 2.63%. In the case of photorealistic tiles, on the other hand, the values found are Δxm=1.95%, Δym=4.67% and Δzm=0.89%, indicating an average Δm variation of 2.51%. The comparative analysis of these values made it possible to observe how the average deviations of the two meshes from that obtained with a drone are quite similar, with the only exception of the variation along the z axis, relative to heights, which is lower for the Photorealistic 3D Tiles. This indicates that the photo-modelling from Google Earth succeeds in reconstructing the information belonging to the horizontal plane appropriately but is less reliable in reconstructing the height values. Therefore, at a general level, the interpolation of the data obtained shows a substantial disparity, given by a strong difference in the number of vertices and mesh faces in the two models, and the relative low values of the average percentage changes in distances (2.63% and 2.51%). This simultaneous co-presence firstly suggests that three-dimensional models obtained by means of photo-modelling or Google's API are valid for the development of applications with large-scale spatial representation, but the reliability decreases considerably in the most minute details, highlighting the limitations of such methodologies on a small scale.

In parallel, the analysis of the number of vertices reveals that photorealistic tiles present a more accurate geometry in terms of details and particulars than that obtained through photo-modelling, thus lending themselves more easily to the development of applications, virtual or digital environments.

4. DISCUSSIONS AND CONCLUSION

The choice of the object of analysis fell on a building instead of an open space in order to explore the applicability of photorealistic 3D Tiles also in close contexts which require a high level of detail, such as immersive scenarios. This choice, based on the availability of three-dimensional building modelling on Google Maps, aims at assessing the accuracy of such representations, expanding the understanding of the platform's potential in the detailed analysis of architectural structures. Furthermore, the consideration of Google Maps' lesser focus on micro-scale terrain modelling highlights the need to carefully evaluate the limitations and potential of the data provided by the platform.

The reported data offer a critical reading of the models' performance, paving the way for a more in-depth discussion of the advantages and disadvantages of each model generation methodology. Specifically, the values of variations along the three axes and their average value stand out as indicators of the reliability of the models and have allowed us to investigate how photorealistic tiles are a middle ground between the meshes

	Mesh from the photogrammetric survey				
	No. of vertex 7230121			No. of faces 14.431.572	
				Distance From	
ID point	x	y	z	Point A (m)	Point B (m)
1	0,654	0,845	16,192	16,227	77,291
2	-1,450	-25,550	16,290	30,336	82,352
3	-13,927	-24,906	16,293	32,859	71,177
4	-14,476	-7,083	16,259	22,893	64,143
5	-27,313	-7,001	16,248	32,542	52,253
6	-27,727	-30,192	15,996	44,002	62,889
7	-48,342	-30,631	16,062	59,441	49,803
8	-49,809	-7,140	16,704	53,018	33,521
9	-63,894	-6,964	15,974	66,228	24,354
10	-64,267	-23,258	16,069	70,210	36,984
11	-74,790	9,336	16,224	77,097	15,346
12	-32,592	-7,143	16,038	37,020	47,499
13	-32,632	-23,183	15,901	43,071	54,935
14	-43,735	-23,322	15,973	52,075	47,100
15	-44,389	-7,156	16,021	47,731	37,444
16	-7,751	-18,418	18,599	27,299	74,402
17	-6,897	-2,606	18,635	20,041	70,999
18	-31,235	0,190	19,857	37,013	48,190
19	-66,341	2,768	19,807	69,290	21,545
20	-69,010	-18,982	18,300	73,875	33,289

	Mesh from photo-modellation of Google Earth							
	No. of vertex 48.105						No. of faces 59.284	
							Distance From	
ID point	x	y	z	Δx (%)	Δy (%)	Δz (%)	Point A (m)	Point B (m)
1	0,586	0,929	15,988	10,40%	9,94%	1,26%	16,026	77,176
2	-1,530	-24,701	16,139	5,52%	3,32%	0,93%	29,546	81,901
3	-13,501	-24,559	16,318	3,06%	1,39%	0,15%	32,430	71,383
4	-14,430	-7,238	15,791	0,32%	2,19%	2,88%	22,582	64,114
5	-26,646	-6,985	16,020	2,44%	0,23%	1,40%	31,866	52,788
6	-27,410	-30,202	15,807	1,14%	0,03%	1,18%	43,742	63,087
7	-47,902	-30,566	15,296	0,91%	0,21%	4,77%	58,846	49,759
8	-50,096	-7,696	16,264	0,58%	7,79%	2,63%	53,229	33,373
9	-63,712	-6,896	16,045	0,28%	0,98%	0,44%	66,062	24,435
10	-64,178	-23,322	15,466	0,14%	0,28%	3,75%	70,014	36,821
11	-74,497	8,934	15,740	0,39%	4,31%	2,98%	76,664	14,855
12	-33,123	-7,468	16,017	1,63%	4,55%	0,13%	37,543	47,134
13	-32,967	-22,994	15,601	1,03%	0,82%	1,89%	43,115	54,487
14	-42,997	-22,820	15,808	1,69%	2,15%	1,03%	51,180	47,198
15	-44,239	-7,258	15,851	0,34%	1,43%	1,06%	47,550	37,541
16	-7,586	-18,992	18,341	2,13%	3,12%	1,39%	27,471	74,702
17	-6,480	-2,735	18,474	6,05%	4,95%	0,86%	19,768	71,378
18	-31,493	0,238	19,676	0,83%	25,26%	0,91%	37,135	47,877
19	-66,584	2,455	19,491	0,37%	11,31%	1,60%	69,422	21,265
20	-69,035	-18,579	18,083	0,04%	2,12%	1,19%	73,743	32,835
	Mean values Δxm, Δym, Δzm			1,96%	4,32%	1,62%		
	Average Variation Δm			2,63%				

	Photorealistic 3D Tiles							
	No. of vertex 570796						No. of faces 215.034	
							Distance From	
ID point	x	y	z	Δx (%)	Δy (%)	Δz (%)	Point A (m)	Point B (m)
1	0,605	0,766	16,359	7,49%	9,35%	1,03%	16,388	77,285
2	-1,546	-25,708	16,437	6,62%	0,62%	0,90%	30,553	82,360
3	-13,726	-25,295	16,514	1,44%	1,56%	1,36%	33,181	71,581
4	-14,077	-7,112	16,360	2,76%	0,41%	0,62%	22,724	64,549
5	-26,591	-7,637	16,321	2,64%	9,08%	0,45%	32,121	53,123
6	-26,965	-31,102	16,012	2,75%	3,01%	0,10%	44,168	64,027
7	-47,909	-31,099	16,183	0,90%	1,53%	0,75%	59,366	50,440
8	-50,525	-7,591	16,515	1,44%	6,32%	1,13%	53,695	33,124
9	-63,950	-7,024	16,206	0,09%	0,86%	1,45%	66,344	24,512
10	-63,879	-23,610	16,353	0,60%	1,51%	1,77%	70,038	37,516
11	-74,443	8,974	16,499	0,46%	3,88%	1,70%	76,776	15,615
12	-32,642	-7,393	16,206	0,15%	3,50%	1,05%	37,186	47,593
13	-32,677	-23,651	16,205	0,14%	2,02%	1,91%	43,471	55,259
14	-42,843	-23,305	15,820	2,04%	0,07%	0,96%	51,273	47,631
15	-44,246	-7,198	16,206	0,32%	0,59%	1,15%	47,667	37,653
16	-7,532	-18,939	18,675	2,83%	2,83%	0,41%	27,644	74,809
17	-6,595	-2,729	18,675	4,38%	4,74%	0,21%	19,992	71,317
18	-31,405	0,249	19,987	0,54%	31,05%	0,65%	37,227	48,078
19	-65,856	2,587	19,794	0,73%	6,54%	0,07%	68,815	21,777
20	-68,507	-19,735	18,328	0,73%	3,97%	0,15%	73,611	34,022
	Mean values Δxm, Δym, Δzm			1,95%	4,67%	0,89%		
	Average Variation Δm			2,51%				

Figure 7. Summary table of measurements and calculation of variations

obtained through photo-modelling from Google Earth and through photogrammetric survey with a drone, both in terms of level of detail and in terms of reliability and spatial accuracy.

The results of the research have identified a partially unexpected degree of consistency, which leads to a reassessment of the reliability of Google's geospatial data, strengthening its reliability in various modelling applications. By analytically comparing the percentages of variation obtained, we can in fact see that along the x-axis the deviation is almost identical in the two cases, and the components of the distances measured along the y-axis show a very low variation between the two models, amounting to about 0.35%. These two data lead to the identification of a certain consistency between the two models, which from a dimensional point of view in the xy plane show an almost unchanged reliability. With regard to the altimetric components of the measurements taken, the Δzm relative to the photorealistic tiles is half that associated with the mesh derived from photo-modelling, denoting a slightly higher reliability of the former. Considering the minimal percentage variation observed and the numerical consistency noted between the two methodologies, it is evident that the Google data, whether obtained via photo-modelling from Google Earth or via the API of the Google Maps platform, maintain a good degree of fidelity, presenting an unexpectedly low overall deviation value from the model obtained via drone, at 2.63% and 2.51% respectively. The modelling obtained by means of Google's API is of great interest due to the method in which Cesium manages photorealistic tiles: the number of points, and consequently the level of detail, decreases or increases in line with the distance of the viewpoint. This method of management makes it possible to manage a three-dimensional model of the entire globe while greatly reducing the size of the work file, thereby also guaranteeing greater process speed. With a view to the use of the two processing methods for setting up virtual applications, both have, however, strong limitations for the development of immersive experiences, due to a low accuracy of details and particulars. Basing on the comparison with the model obtained by means of a photogrammetric survey with a drone, the photorealistic tiles in fact present a considerably lower accuracy; this is indicated by the number of vertices of the mesh, since at its maximum degree of definition the model obtained with the Google API presents a number of vertices approximately 12 times lower. At the same time, however, the model and texture obtained with the drone do not present sufficient definition to form the basis of an immersive scenario, presenting problems in the reconstruction of elements from a lower point of view, such as an attic or the realistic depth of openings in the façade, due to the very nature of the drone's data acquisition method. Therefore, considering this limitation shared by all three methodologies, the comparison acquires greater relevance when considering a larger scale, turning our interest towards spatial models such as urban digital twins. From this point of view, the three elaborations all have great applicability, as the measured variations progressively lose significant relevance. Indeed, considering a spatial scale, the performance of the three models is almost analogous, and the potential of the Google tiles emerges clearly.

Firstly, the greater lightness of the file and the associated speed of work can greatly facilitate the processing and final usability of the developed application, allowing for a smoother and more homogenous process. Another great advantage is the possibility of obtaining spatial modelling without any need for initial processing. With reference to the processes for preparing the comparative analysis, one thinks of the need to travel to the site to carry out the photogrammetric survey, which often involves travel and a great deal of time. The prospect of having a spatial modelling of any area of the world without the need to physically travel to the site is a great intrinsic advantage of the procedure involving the Google API. A similar consideration can be made when comparing with the mesh obtained by photo-modelling from Google Earth, for which it is still necessary to design a path for the extraction of high-resolution frames from the software, which then have to be processed for the realisation of the mesh and texture.

All the considerations outlined so far underline the importance of the initial definition of the purposes of the representation, so as to be able to identify from the outset the scale of analysis that will be adopted in the development phase of the various projects, and thus to assess the specific characteristics required by the study context in order to select the suitable methodology for obtaining the geometric information of the territory considered.

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