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SCHANZENGRABEN

A Journey from the Physical to the Digital

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"Faultless walls may be built to last forever," declared Vitruvius in the first treaty of architecture to describe the city of walls that must be constructed with the best materials, because they may remain as permanent parts of the city.[1] The history of the Schanzengraben represents a territory of peculiar spatial conditions in the city of Zurich because it is composed of walls appointed not only to contain the waters of the moat, but also to host several layers of superimposed physical, historical, and cultural elements. From the Bauschänzli bastion, one of the last remains of the Baroque fortifications of Zurich, to the Old Botanical Garden buildings and landscape, to bridges, promenades, platforms, walkways, and crossways, these multiple layers of complexity provide a challenging framework for the analysis and the conceptualization of this unique urban, architectural, and landscape space. Two distinctive and radically different mediums are chosen to explore this stimulating urban territory: physical site visits and digital 3D point cloud models. This article describes the surprising journey from the physical to the digital and proposes key discussions for the advancement of contemporary landscape architecture.

The Physical Journey

The physical journey on a sunny winter afternoon walking from Sihlstrasse toward the Old Botanical Garden reveals a unique habitat and a dynamic ecosystem, including a rich variety of vegetation, birds, and even insects buzzing right in the center of Zurich. The lower plane invites exploration of the moat's edges, where a lookout allows one to see the contained water of a surprisingly quiet moat. The attempt to reach the water's edge proves challenging because a series of ramps, stairs, and platforms are scattered around its borders, attempting to connect the water with the urbanity above. Some portions of the moat's edge successfully display a continuous promenade at the north and south portions of the moat,

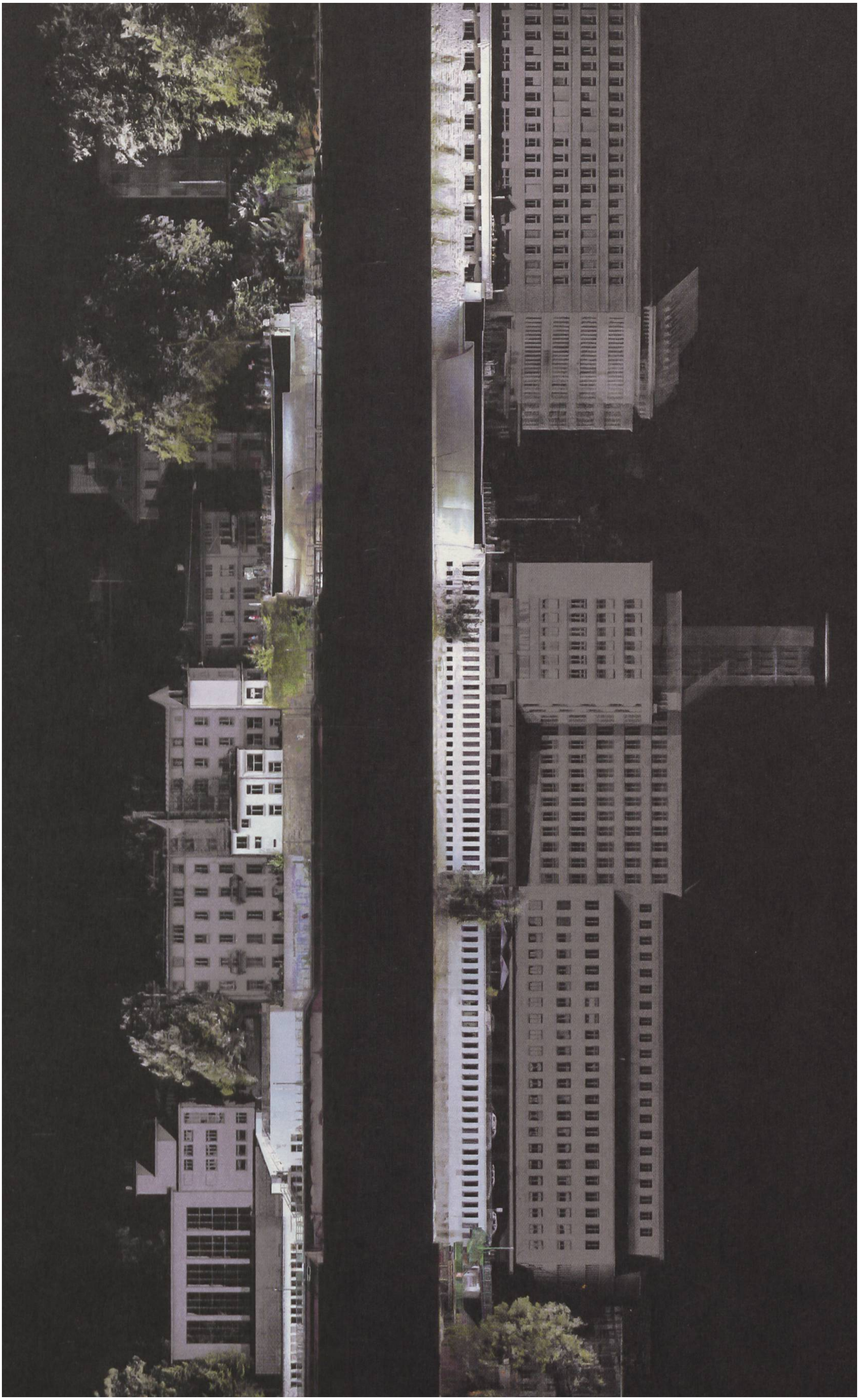
Fig.7 Schanzengraben, Zurich 2017. LiDAR data provided by the Open Data Initiative of the Canton of Zurich, colored by satellite imagery and segmented by classification. By the teaching team

1 Vitruvius, *The Ten Books on Architecture*, trans. Morris Hicky Morgan and Herbert Langford Warren (Cambridge, Mass.: Harvard University Press, 1914), 24.

but at its midpoint the trajectory is organized in zigzagging segments flanked by bridges that create a compressing and fragmented effect. The physical journey reveals a distinctive condition of the moat, one organized spatially along the water as the main artery, strongly defined by tall walls with impenetrable edges, sloping terrains, and buildings along the edges with their backdrops facing the waterfront. The Schanzengraben unexpectedly unveils itself with a sense of interiority as an "inner moat" segmented in a series of successive distinctive urban spaces. Singular urban "rooms" unfold one after another and can be perceived as a carefully staged scenography, a series of playrooms for the city of Zurich. Because of its lack of physical pedestrian connections, the walled waters of the Schanzengraben offer a secluded space for pedestrians and visitors. This sense of protection and contained spatiality provides a unique experience for city inhabitants, an opportunity to enjoy singular public spaces and waterfront engagement. Visitors flock to the series of distinctive and peculiar urban landscapes for unpredicted activities: kayaking, bird-watching, swimming, stand-up paddleboarding, sitting, and walking. During the summer, a timber boathouse construction hosts the Männerbad (male baths) and also features a bar during warm evenings. Thus, the Schanzengraben reveals itself as a series of oasis rooms right in the middle of Zurich, offering unexpected spaces to enjoy silence, vegetation, wildlife, sports, and simple contemplation.

The future preservation and potential of the Schanzengraben lies in the effective integration of its complex and varied urban apparatuses into the urban fabric without sacrificing its essence. Social, cultural, and ecological dimensions highlight the importance of considering temporal qualities in the design of unique urban landscapes that could help consolidate the Schanzengraben as a microcosm for everyday use. The city of walls envisioned by Vitruvius, once conceived for defense and protection, offers in the Schanzengraben a pause among the busy urban life so that its inhabitants are connected to the solidity of its history and, at the same time, to the fragility of its temporality.

Fig.8 Schanzengraben, Zurich 2017.
Double elevation of both sides, showing the interweaving of built and organic surfaces.
By Luisa Overath



The Digital Journey

Terrestrial laser scanning was the method chosen to analyze this specific area of the city of Zurich chosen by students of the ETH Zurich Landscape Architecture Chair of Christophe Girot during the fall semester 2017 elective course titled "Topology: Walled Waters." Two outputs were generated: a three-dimensional point cloud model animation and a series of two-dimensional section-elevation views.

The digital animation begins with a large 3D point cloud of Zurich in its territorial condition inserted in the valley and its bodies of waters, slowly zooming into the Schanzengraben and hovering along the water. The animation presents an environment characterized by a seamless whole, where the continuity in the space integrates trajectories at a standard speed and in constant motion, immersing the spectator in a continuous space and time. The main organizing element of this urban space is the water, which surprisingly appears as a flat and static surface.

The students' work is represented with a series of carefully crafted views extracted from point cloud models in the form of sections, elevations, and perspectives of specific segments of the Schanzengraben. These delicate and precise images describe the space with a great level of accuracy and detail, revealing a collection of singular relationships between the water edges and the city above. Longitudinal sections along the moat reveal some unique vertical conditions of this urban territory, with a lower moat plane defined by several dissimilar tall walls. Buildings facing the moat appear with facades disconnected from its edges and activities. On one side, several pedestrian platforms aim to connect to adjacent upper-level roads and bridges with stairs, and even some lonely visitors are captured. The upper plane displays a different and busy urban life filled with people, cars, and large trees appearing along main streets, with some minor planting located in the lower part of the moat.

A cross section of the moat at the Old Botanical Garden reveals its complex terrain composed of several superimposed elements. The gardens are defined by an upper plane with a city lookout, a lower area by the gazebo, and a narrow walkway next to the water edge. A steep vertical wall defines the enclosed moat. Abundant vegetation populates the steep terrain on both sides of the moat's edge.

The series of profile sections not only allow a precise representation of singular points along this territory, but also become operative tools for the analysis and conceptualization that facilitates the understanding of this urban space. More importantly, they reveal that ancient fortifications and bastions with water were strategically positioned with the aim of providing a protective zone in the territory, but with the evolution of the city they have inverted the relationship between the water's edges and the city behind them. The challenge is about how to create this unique water edge and experience the space as a pedestrian, with ramps, walkways, stairs, and the diverse apparatuses animating this edge of the moat. This collection of analytic sections clearly reveals that the city of walls requires a different urban typology to address how the city meets the water.

From Point Clouds to Data Clouds

If the physical site visit revealed fragmentation, friction, and disconnection of unrelated component parts and activities, the point cloud journey exposed connectedness and continuity. This dissociation is critical because traditional systems of representation used for landscape, urban design, and architecture have relied historically on graphics deeply rooted in disciplinary conventions – primarily orthogonal views or sketches – which serve both as instruments and also as stimulus for design formulations. Urban environments are constantly evolving, and to effectively revitalize urban areas into active spaces for public activities, tools must also evolve to reveal complex scenarios and their multi-scalar dimensions. The key question is how point cloud models could facilitate the surveying analysis, representation, and even the re-conceptualization of unique and complex urban territories. And how can we bridge the physical and the digital?

Point clouds prove to be a powerful representational tool able to provide an expansive framework for dematerialization in pointillism-like environments with great accuracy, resolution, and graphic appeal. However, and despite their attractive and engaging outputs, 3D point clouds must evolve from being purely representational because they have the potential of becoming an ecosystem for hosting data from which several analyses and novel scenarios could emerge.

Understanding the physical dimensions of a complex urban landscape (such as the Schanzengraben) requires, firstly, a detailed survey of its constituent elements, ranging from topography, water bodies, infrastructure, landscape, urban design, and architecture. However, points in space provide a seamless whole unable to differentiate the constituent parts. To resolve this, a human-centered process can apply cognition mechanisms to help conceptualize spaces, elements, and atmospheres. Machine learning combined with urban and space analytics can offer algorithms able to recognize elements and indicators at the architectural and urban scales. Different studies are focusing on urban perception to extrapolate metrics and novel design parameters from the analysis of human behaviors, to define novel forms of spatiality[2] or mapping occupancy,[3] and to produce metrics of urban appearance.[4] Recent approaches based on computer vision and point cloud processing are strengthening segmentation capabilities, converting whole scenes into fractionated parts, distinguished by spatial aggregation and derived mostly from coordinate and vector information embedded in each digital pixel. The Point Cloud Library can be considered as one of the most mature solutions, fully written in C++ and made available in Python programming language as an Open3D library.

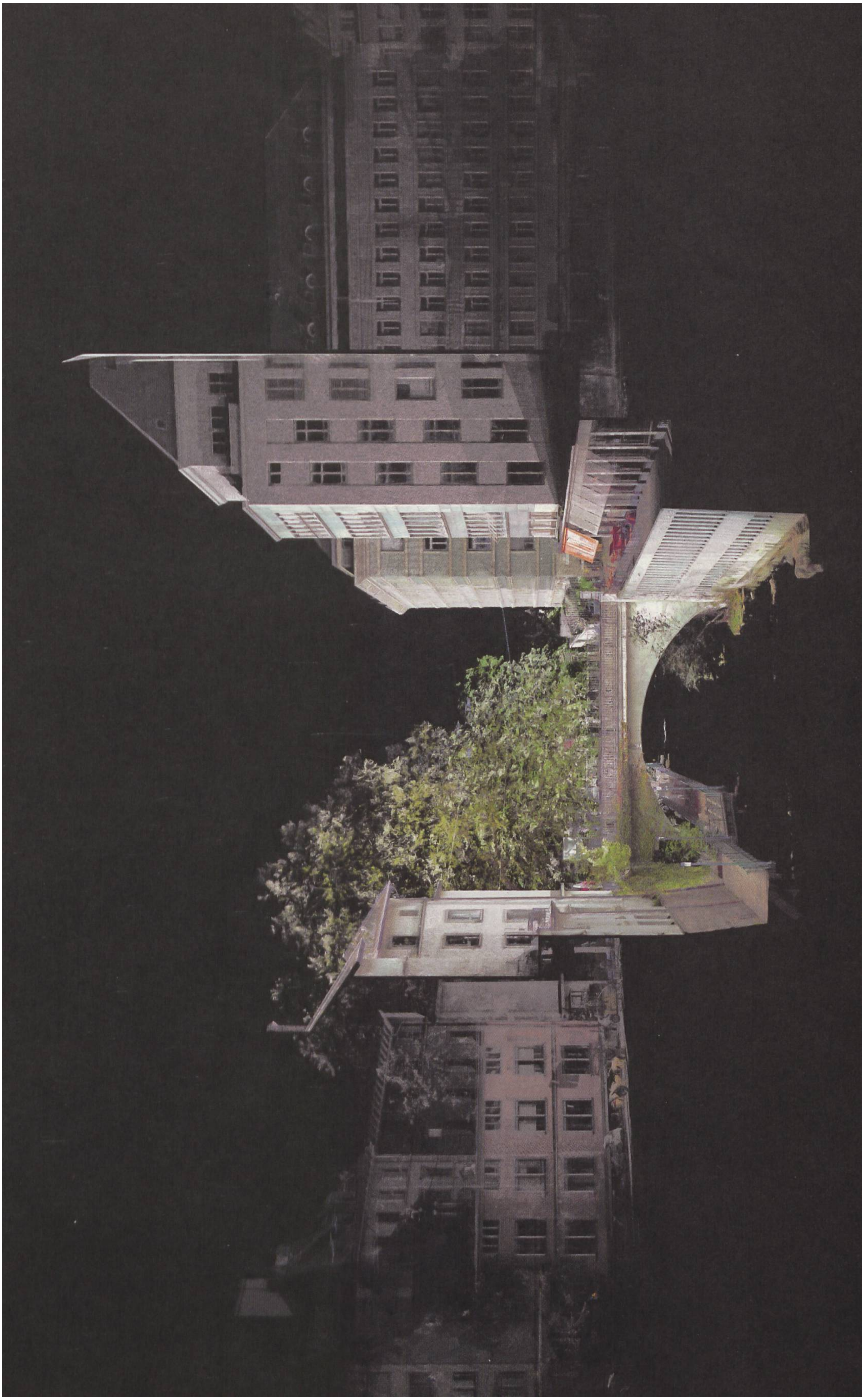
These developments are positive initiatives for the advancement of point cloud techniques and protocols. Nonetheless, point clouds are currently still struggling to achieve a clean definition of basic geometries, one of the fundamental elements in the analysis and description of the built environment. A transition is needed from point clouds to a geometry-based environment composed of surfaces, meshes, edges, or planes, and to a defined materiality that can accurately describe the solidity of the built environment, such as the degree of enclosure of its edges, or water depth, to name a few. Several tools are emerging to extract elements from point clouds (walls, floors, roofs, doors, windows,

2 Tin Kam Ho et al., "Public Space Behavior Modeling with Video and Sensor Analytics," *Bell Labs Technical Journal* 16 (2012), 203–17.

3 Jens Jørgensen, Martin Tamke, and Kare Stokholm Poulsgaard, "Occupancy-informed: Introducing a Method or Flexible Behavioural Mapping in Architecture Using Machine Vision," *Proceedings of 38th eCAADe Conference* (Berlin, 2020).

4 Nikhil Naik, Ramesh Raskar, and César A. Hidalgo, "Cities Are Physical Too: Using Computer Vision to Measure the Quality and Impact of Urban Appearance," *American Economic Review* 106 (2016), 128–32.

Fig.9 Schanzengraben, Zurich 2017. Sectional perspective, Sihlstrasse. By Luuk Borremanns



piping, structural elements, and landscaping) by using automated and semi-automated processes, or to automate and leverage algorithms by averaging points to extract data. The potential of object detection lies in the power to link them with larger information systems that could describe specific objects. Perhaps a point cloud model could facilitate navigating precise elements (such as the bastion walls) and connect to data clouds showcasing their historical, symbolic, and cultural dimensions. Or perhaps each tree in the Old Botanical Garden could be linked to its physical description (size, foliage, root system), history, age, or sustainable performance. Furthermore, 3D point clouds could be employed by many users to amplify their availability to a wider spectrum of stakeholders (governments, industry, design professionals, citizens) to enable cross-disciplinary collaboration in the study of interrelated projects for the exploration of novel spaces and scenarios so that, concurrently, one model contains several complementary disciplines.

The physical exploration of the Schanzengraben also reveals the importance of considering temporal dimensions within the urban landscape because of its impact on social and cultural uses. Seasonal, daily, or climatic (temperature, wind, humidity) parameters can be unveiled by using laser scanners combined with sensors. Computer vision and machine learning offer processing capabilities to extract data from images, the engine of all photogrammetric processes of 3D point cloud reconstruction. Data processing can generate point clouds, and store color (RGB), vegetation (NDVI), thermal, and acoustical data over the same geometrical organization. Artificial intelligence can automate the process by analyzing and evaluating fluctuations over time and space. Multiple studies have generated a dynamic vision of urban habitats by manipulating the data embedded into each image pixel and channels,[5] processing urban environments,[6] studying environmental components,[7] observing weather conditions,[8] and defining new metrics for urban

5 Nicolas Audebert, Bertrand Le Saux, and Sébastien Lefèvre, "Beyond RGB: Very High Resolution Urban Remote Sensing With Multimodal Deep Networks," *ISPRS Journal of Photogrammetry and Remote Sensing* 140 (2018), 20–32.

6 Andrea Bottino et al., "Street Viewer: An Autonomous Vision Based Traffic Tracking System," *Sensors* 16 (2016), 813.

7 Bill Yang Cai et al., "Treepedia 2.0: Applying Deep Learning for Large-scale Quantification of Urban Tree Cover," *IEEE International Congress on Big Data* (2018), 49–56.

8 Mohamed Elhoseiny, Sheng Huang, and Ahmed Elgammal, "Weather Classification With Deep Convolutional Neural Networks," *International Conference on Image Processing 2015* (2015), 3349–53.

perception.[9] Point clouds can be used as a three-dimensional dashboard to visualize and project fluctuating spatial data, so a point cloud model could be developed that is able to host dynamic data that can be mapped to visualize several changing scenarios for the Schanzengraben, for example during summer days or during snowy days in winter, to reveal the growth of vegetation, patterns of usage or events, and climatic data, among other parameters.

The increasing capabilities of geometrical recognition and reconstruction from point clouds trigger data interoperability toward more specific families of digital models. From point clouds it is possible, under multiple levels of accuracy and manual intervention, to shift toward object classes compatible with building information modeling (BIM). At the city scale, data collected from LiDAR scanning can be interpreted to create 3D building models with various levels of detail, such as Zurich's city model,[10] which is based on aerial scanning with datasets ranging from topography and vegetation to buildings, bridges, and footbridges. If building elements along with the functional utility of building, public spaces, infrastructure, or landscape areas are so defined, they can be used for various applications. For instance, if the 3D building models are to be used for the assessment of solar energy potential, then the area, slope, and aspect of the roof surface defined can act as an input to the solar empirical model to assess the solar potential of the building.[11] Point clouds have shown the potential to inform urban landscapes by introducing diverse means of data acquisition for the analysis, evaluation, and representation of its physical, environmental, and social characteristics. But point clouds can also offer a dynamic and expansive ecosystem for the reconceptualization of future habitats that are evolving, interrelated, and collaborative.

9 Daniele Quercia, Neil Keith O'Hare, and Henriette Cramer, "Aesthetic Capital: What Makes London Look Beautiful, Quiet, and Happy?" *Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing* (2014), 945–55.

10 Stadt Zürich, "3D-Stadtmodell," https://www.stadt-zuerich.ch/ted/de/index/geoz/geodaten_u_plaene/3d_stadtmodell.html (accessed June 5, 2022).

11 Purnima Jayaraj and Anandakumar M. Ramiya, "3D CityGML Building Modelling from LiDAR Point Cloud Data," *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 42, no. 5 (2018), 175–80.