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3D Modeling of Evolved Urban Fabric around Farm Ponds

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Abstract. Farm ponds in Taoyuan, Taiwan, represent a sustainable fulfillment of irrigation demand and a resilient system to the topological change of plate elevation in early days. The old system was developed in three stages and gradually replaced by canal and reservoir, with lands abolished or demolished for other purposes. This research aims to study the land use and skyline of farm ponds based on the UAV-assisted photogrammetric 3D modeling of evolved urban fabric in neighborhood. Based on the development occurred to peripheral region and the conversation made between urban fabric and pond, case studies were made to conclude developing patterns by active segmentation of skylines. Results showed passive and active patterns of skyline existed. Each pond was surrounded by specific urban fabric and contributed to individual history. The fabric was associated with a matrix of building types and land uses. By careful segmentation of 3D model, base line between old house and pond can be created to illustrate temporal development.

Keywords: UAV, photogrammetry, farm ponds, urban fabric, skyline.
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1 INTRODUCTION

Farm ponds in Taoyuan, Taiwan, were engineered to fulfill irrigation demand under the specific regional topographic features, soil, hydrology, and river types. The topographic feature, which is changed from 1/40 to 1/120 in slope, was sufficient to catch extra water by lower ponds consequently. The irrigation area of Taoyuan Canal is located to the west. Ponds planned by early people had created an irrigation system for agriculture by taking advantage of rain water to excavate pond and to irrigate land in lower area. Farm pond system was developed in three stages: Quin Dynasty (before 1904), during Japanese Colonial Rule (between 1904 and 1945), and the completion of Shimen Canal (1963) and Shimen Reservoir (1964) (Figure 1, left) after 1945 [1-3].

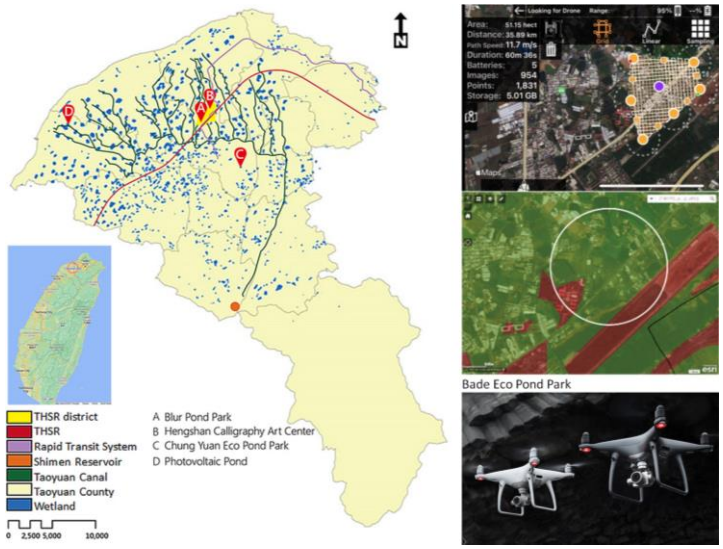


Figure 1: Pond distribution and wetland conservation boundary [4] in Taoyuan (left); unmanned aerial vehicle (UAV) plan, restricted area, Dji Phantom 4 Pro® [5] (right).

Farm ponds have been developed as an irrigation system and, in the meantime recognized as a culture icon in Taoyuan for a long time. Its role has been gradually replaced by reservoir and canal system. Many ponds, which were obsolete, had drawn people's attention. The erosion of resilience in an old ecosystem is an ecological crisis [6]. Pond-related concerns lead to the initialization of wetland act and the developing pattern for pond resilience [7]. Related studies were also conducted by central and local governments for the planning of database, activation patterns, and demonstrations by the Water Resources Agency, Ministry of Economic Affairs [8].

Urban resilience is closely related to pond resilience, in which the former details the activation plan for the infrastructure that enables tourism promotion upon the pond landscape or system. Resilience is the capability of a system or a strategy to recover from disaster or to overcome stress. The sustainable management or resilience planning of water-based ecosystems should be applied to a variety of perspective from coastal tourism [9] to lake tourism [10].

The maximum number of ponds reached over 10,000, and was reduced to 8,845 after the completion of Shimen Reservoir [11]. Currently only less than 3,000 ponds exist. Based on the data released from Taoyuan City Government, survey made by National Wetland Conservation Project in 2011 concluded 2,851 ponds and 2,599.73 hectare in Taoyuan [12]. Some were filled and leveled up for the construction sites of new communities, parks, schools, or government agencies.

Water and tourism are closely connected [13-15]. Ponds are usually reactivated as ecology parks in these days. Suggestion was made to the maintenance, conservation, or restoration of ponds to improve poor water quality [16]. The leisure-oriented development redefined local pattern of urbanization. Recently developed canals have created links and revitalized local ecology system. The revitalization was specified in detail urban plan as part of the developing strategy. Two pond parks, the Blue Pond Park and Calligraphy Art Center, were planned specifically as part of the future development of specific district near the Taiwan High Speed Rail (THSR) station in Taoyuan [17].

2 RESEARCH GOAL

Farm pond symbolizes the level of urbanization. The development in peripheral areas altered the urban fabric not only through urban replots, but also by fairs for periodical promotions of local economy. In addition to the evolvement of land uses, the changes should be studied by focusing on the "vertical fabric" in local areas as a more intuitive visualization approach. Sufficient exemplification from 3D model should be made to relate the change of skyline in terms of urban artifacts, such as apartments, old houses (three-section compound or Sanheyuan), universities, or factories.

This research aims to study the land use and skyline of farm ponds based on the UAV-assisted photogrammetric 3D modeling of evolved urban fabric in neighborhood. Based on the development occurred to peripheral region and the conversation made between urban fabric and pond, case studies were made to conclude developing patterns.

3 METHODOLOGY

Active skyline comprises the changes made to local area by referring to the local topological features in vertical dimension. UAV was applied to create terrain model for skyline study. A Dji Phantom 4 Pro® (Figure 1) was used to take 300 - 500 images for each pond in 4,000X3,000 resolutions by a contractor. UAV was restricted near airport, or above specific area transportation or system. The images were used to reconstruct the 3D urban fabric by Zephyr®. In general, a circle of 700 – 1,000 m in diameter was selected.

3.1 Active Segmentation of Skylines

Although three-dimensional scan can be applied to preserve a historical settlement [18] and to integrate with GIS data for analysis purpose [19], the data efficiency should be further increased by UAV-assisted photogrammetric modeling to enable the 3D representation of local land use. The photogrammetry-reconstructed 3D models enabled cross-site sections made in different orientations (Figure 2) with purposely defined parts to highlight the local vertical fabric evolution in terms of skyline with/out new settings by old houses and new apartments, main or new circulation system, and urbanization by land uses. The three types of sections or projections were mainly made cross farm ponds to directly relate the distance and vertical density of constructions to the open area of pond. For example, comparisons should be made to the area between a pond and traditional old house (three-section compound or Sanheyuan) to illustrate the

Figure 2: Flowchart (left); 3D model and examples of section cut for active skyline (right).

Urbanization is a complex social, economic, political, and technological process, and there are no uniform patterns of this process [20]. When the process occurs to an infrastructure or specific

land use, urbanization involves many measures of indicators that help us to understand the history of development. Eight ponds were selected for individual history, designated role, and major developing type of building around them. Each pond is surrounded by specific urban fabric and thus creates distinguishing pattern of development. Selections were mainly made to ponds located near the Green Line of Taoyuan Rapid Transit System and apart from it, in order to explore their potential relationship to the concept of Transit-Oriented Development (TOD): whether ponds are developed and influenced by urban context and mass transportation system.

Skylines were applied to illustrate the interface between a pond and peripherals. UAV imagery captured the most updated fabric of constructions, circulation system, and landscape around a farm pond. The layout can tell how close a building was located to a pond. Two methods were applied to the UAV-based 3D model by creating sections and contrast projections of a specific region. The former made linear or zigzagged sections to highlight the diversified land use and land cover (LULC). The latter illustrated the impact of a specific region by turning on/off new constructions from the model. Both methods took the advantage of skyline as an indicator of urbanization, in which the context was illustrated by profile and repetitive patterns of buildings and landscape. For example, Photovoltaic Pond (Figure 3), which was located away from main circulation systems, was promoted by agricultue fair in recent years. A new profile of skyline was added at where new constructions were located. Although it still presented a rather flat profile, this method highlighted the new local identity and enabled the discovery and assessment of changes by making contrast of urban fabric being developed before and after the fair.

Figure 3: Photovoltaic Pond: land use (2019), building types, and cross-site sections.

3.2 Land Use Changes

In order to relate the historical development of pond, GIS data were retrieved from the areas of different land and building types. Maps and images were cross-referred, traced, exported, and estimated with areas to verify increasing or decreasing area of land or buildings, in order to determine the changing trends. An assessment of newly developed area around pond parks should be presented to support the changes made between 2010 and 2021 quantitatively.

3.3 Augmented Reality (AR)

The evolvement of skyline and the reactivation in augmented reality (AR) presented a macro- and micro-perspective of local fabric. The pond-enlightened installations were converted to 3D AR models as a new interpretation facilitated by an interaction option. The model was cloud-accessed by scanning a QR-code into a smartphone app, Augment®. For example, a former lantern installation in the Blue Pond was remodeled in AR to enable simulation from different locations. The AR simulation was applied as a reactivation of the cultural landscape to be shared and experienced from a remote site.

4 SELECTED CASE STUDIES

This study was exemplified in more details by the selected cases of Chung Yuan Eco Pond Park and Bade Eco Pond Park. The former was located in a well-developed community, and the latter was more organized toward an ecology park under a landscape-oriented planning strategy.

4.1 Chung Yuan Eco Pond Park

The Chung Yuan Eco Pond Park is located next to the campus of Chung Yuan Christian University. The area has been well-developed since 2010. New constructions have been added to this community constantly (Figure 4). Since almost half of this area was occupied by campus, the total area of development was relatively smaller with campus excluded.

Old house	Community	Apartment	University	Commercial	Factory	Farmland	Green house	Recycling field	Transportation
O	X	O	O	X	O	X	X	X	X

Figure 4: Chung Yuan Eco Pond Park (top); land use (2019), building types, and cross-site sections (middle); the building types in the site (bottom).

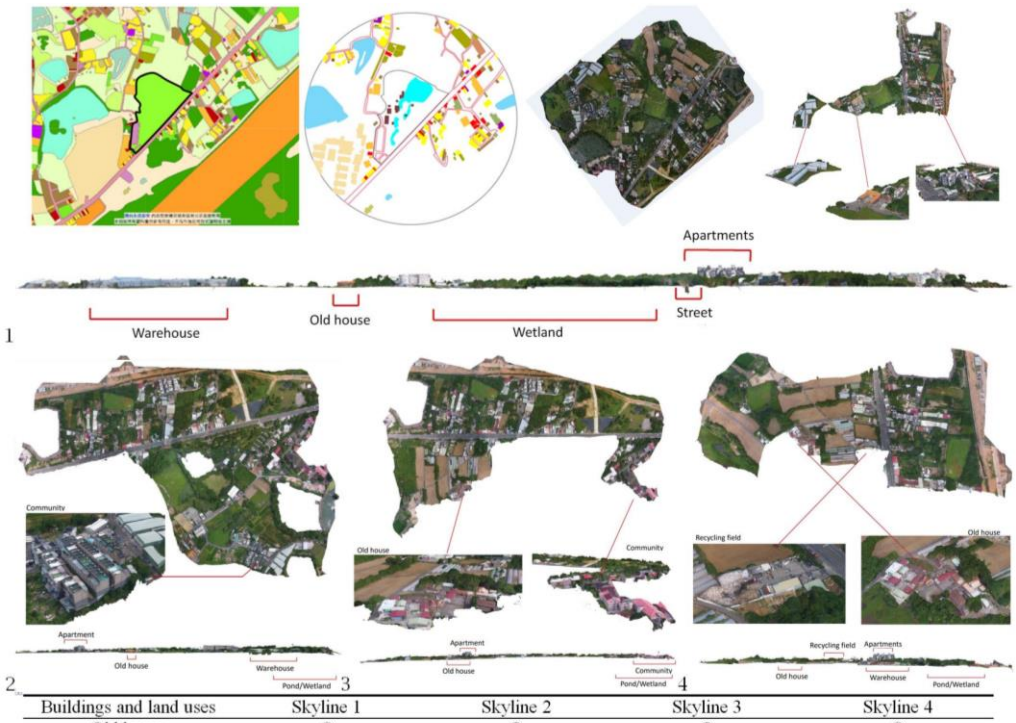
The interrelationship between the pond and peripherals has been changed from a farm pond to a retention pond to alleviate long-term flooding problem. The original layout was reconstructed into retention pond in 2016 and excavated 7 m deeper to add more than 30,000 cubic meter of water capacity [21]. The area was enlarged from 6,814 m² to 9,103 m² between 2016 and 2018, as illustrated by the calculation system shown in the aerial image of Google Earth® 2018. The undeveloped green area has been replotted for commercial use, based on the information of the Land Planning GIS provided by the Urban and Rural Development Branch, Construction and Planning Agency, Ministry of the Interior (MOI). Most of the new constructions were factories with building envelope made by sheet metal.

This pond was re-designed with a scenic overlook connecting to campus as a renovated part of local landscape. The campus buildings also reshaped the skyline as gradually evolved near where the pond was located. Selected sections were made through Chung Yuan Eco Pond Park (Figure 4, middle) along a local main street viewed from either side. The skyline illustrated lower profile with mainly factory-like façade on one side. In contrast, the area next to the pond illustrated a mixed low-and-high combinations of residential or apartments and university buildings. This case illustrated dramatically different fabric from a green space filled with factories to the pond

surrounded by a university and old communities. It was originally presumed that the farm pond contributed to part of the green space. However, the long-term community development had created a special pattern of urbanization in a preferable pond-centered distribution, which even crossed the main street to the other side.

4.2 Bade Eco Pond Park

The volumetric comparison of Bade Eco Pond Park revealed the type of development from an old low-rise community with inconsistent roof construction to a well-planned layout of apartments (Figure 5). The skyline evidenced a possibly long-term development from an irrigation-based farm layout, an ecology park, to a landscape-oriented real estate planning strategy.



Buildings and land uses	Skyline 1	Skyline 2	Skyline 3	Skyline 4
Old house	O	O	O	O
Community	O	O	O	O
Apartment	O	O	O	O
Commercial	X	X	X	X
Factories	O	O	O	O
Farmland	O	O	O	O
Green house	O	O	O	O
Recycling field	O	O	O	O
Public transportation	X	X	X	X

Figure 5: Bade Eco Pond Park: land use, building types, and cross-site section and skyline 1 (top); three skyline segmentations with corresponding configuration of land projections (middle); the similar composition of comparison matrix in the four sections and skylines (bottom).

This Pond Park was segmented into four types to highlight four different collections of building types and infrastructures.

- Segment 1: This skyline was made by referring to a local street for unique allocation of old house, communities, and green house. Apartments were located further behind as a hidden layer of skyline.

- Segment 2: This skyline was contributed by apartment, old house, communities, and factories. Apartment was located further behind.
- Segment 3: The school was elevated between the apartment and old house. The farm pond was located in front of school.
- Segment 4: This skyline was contributed by old house, recycling yard, factories, and apartments. Low-profiled farmland and green house were located in front as a separated layer.

5 AR APPLICATION

Blue Pond was designated as a satellite site of 2016 Taiwan Lantern Festival. New lantern installations also changed its fabric with a specific event-oriented temporary skyline. AR interactions were applied to re-experience the installations at redeployed sites or scenes. Figure 6 (top) exemplifies the application of an AR model from the Augment® platform at new locations. The point cloud geometries were retrieved in an as-built form. The lantern installations were simulated at three campus locations: a pond in a much smaller size, lawn, and the void space on a ground floor. The similar layout of a pond context enriched a former design. Moreover, the inconsistent layout of a different context explored other design alternations.

The reconstructed spatial structure provided a great opportunity to combine the advantages of remote sensing data and field 3D scanning. The associated model and interactions, which represented the liveliness of old pond festival, enabled the possibility to reactivate former experiences and the existing urban fabric.

The active skylines, UAV 3D models, and installations were inspected alternatively. Figure 6 (bottom) exemplifies the applications of AR models for inspection or comparison, from the same or different farm ponds. For example, a pond was loaded into AR interface to illustrate the interrelationship between the agricultural fair, the pond, and photovoltaic panels interactively. Additionally, a university and elementary school was allocated side-by-side to illustrate the diversified entities of urbanization. The smartphone AR interaction extended former representation of area assessment to a more intuitive verification of the changed fabric afterward.

Figure 6: 3D model and AR simulation with screen shots of smartphone.

6 DISCUSSIONS

Urban model by skyline was applied to illustrate zoning control to accommodate diversity, new urban context, cultural festival, and eventually to converge zoning characters. We concluded that each of the ponds represent a different stage in undeveloped area, in terms of land and newly added or developed area of buildings. The stages and application patterns represent different approaches to the integration of water and urban fabric, in the meantime maintain old pond culture. For the original design, native function of a pond can be planned for flood control, as an eco-pond with night scene or a demonstrative engineering site of canal regeneration. For the urban fabric associated with extended emphases, planning was made to promote regional coordination and interaction mechanism, to connect to tourism of landscape and cultural festivals, and to enrich the diversities of local activity.

6.1 Quantitative Assessment of Urban Fabric Development

Figure 7 illustrates the comparison made between four pond parks which are located within urban planning areas. The Hengshan Calligraphy Park concluded one of the most newly developed areas in commercial use. The development was contributed by regional promotion as a special district of THSR. The newly constructed buildings included shopping malls and movie theaters. The communities, which were overdeveloped around the Xianglu Eco Pond Park and Chung Yuan Eco Pond Park, presented very limited development due to the shortage supply of lands.

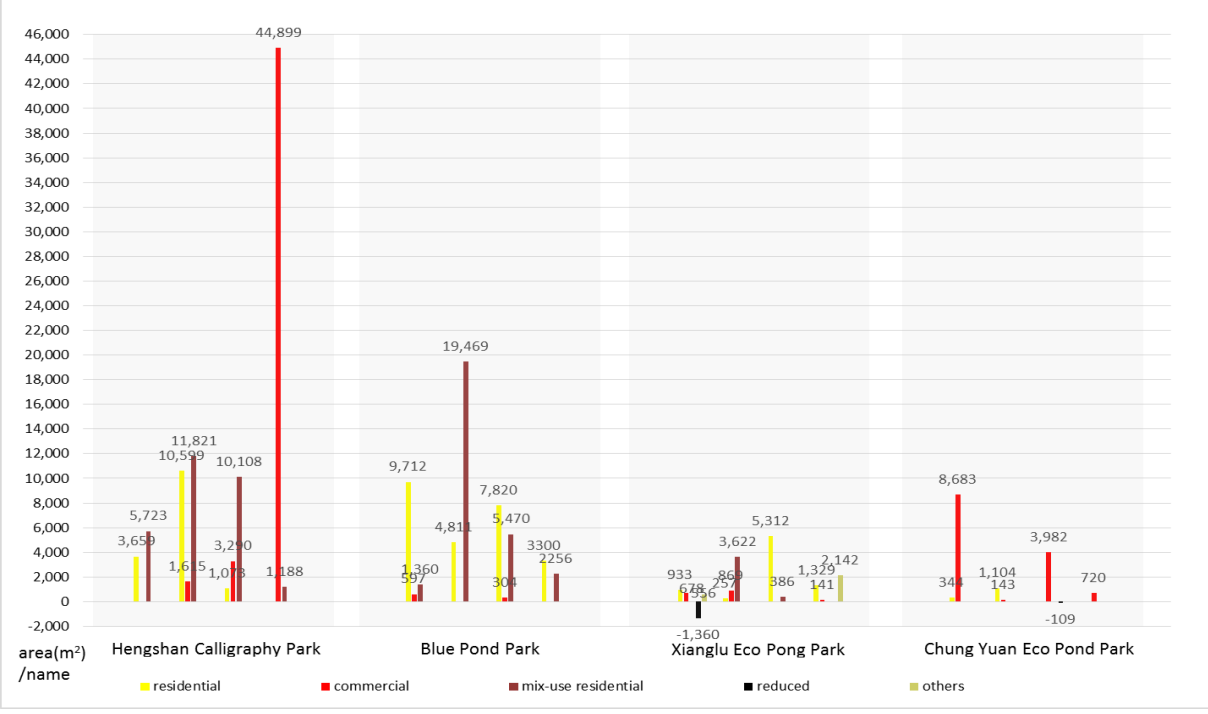


Figure 7: The assessment of newly developed amount of area around four pond parks between 2010 and 2021.

6.2 Relation of Vertical Urban Fabric and UAV-assisted 3D Model

Relation of vertical urban fabric and UAV-assisted 3D model: This study related the macro-perspective of urban fabric to the micro-perspective of constructions, in terms of skylines from the elevation and ground projection of 3D model. A traditional qualitative description of urbanization

was facilitated by 3D UAV model for visual and GIS quantitative assessment. Skylines were determined by different scales, details, expected functions, and connections to urban context. This study concluded that each pond inherited specific historical background with diversified passive and active developing patterns.

- Active skyline: It presented a higher likeness of overall tendency in creating a closer relationship with THSR circulation system and the corresponding regional developing plan. Constant investment from government has been made to increase the future credential form the detailed development plan for THSR special district. For example, a purposely designed bridge was added to enrich pond's role of variety in urban context.
- Passive skyline: It was exemplified by the photovoltaic panels installed above a pond to create the capacity of green energy. It is less likely to have construction permanently installed to modify local fabric.

6.3 Comparison Matrix

Local fabric development can be examined by referring to the base skyline which connects old house and farm pond (as indicated in Figure 3). The earliest development, or pre-urbanization stage, represented a pond-centered community planning. Local urbanization evolved while infrastructure and new constructions were added to create a different highlight of the skyline. This was one of the reasons to segment 3D model to purposely illustrate the contrast by layers classified by buildings or land uses.

- Entities: The result concluded a matrix consisting buildings and land uses, such as old house, community, apartment, commercial building, factory, farmland, green house, recycling field, and public transportation (as indicated in Figure 4 & 5).
- Temporary urban fabric: Active skyline was made possible through festival event and temporary urban fabric. The variety of festival contexts was increased by event-dependent installations to consistently activate the temporary context of local urban fabric. Active skyline segmentation was inspected along with chronological development of urbanization, in which the transfer in or out of land use was by referring to projections made from ground level. The perception from GIS system and skyline was also cross-referred with aerial imagery to retrieve the type of property or buildings that was difficult to be visualized from cadastral maps. Typical examples can be seen in Figure 4 by sheet metal constructions and unauthorized private development of land use. The improper land development had created significant impact to urbanscape which was perceived from aerial imagery, UAV model, and active skylines.

6.4 Intensity of Development

Pond contributes to the part of wetland that cannot be developed privately. Typical pattern of skyline from early development can be seen in Chung Yuan Eco Pond Park which is located in a region in high density of residences. This pond has comprised a strong flexibility as a retention pond excavated to create more water capacity, and also a typical pattern as a consequence of replotted commercial land use in an over-developed neighborhood.

7 CONCLUSION

Consistent enriches of eco-system have enabled the resilience of water resource. Local pond fabric has been changed by the saturated area of new resident building and the mass development of office buildings. The representation of urbanization was facilitated by UAV-assisted photogrammetric modeling to enable the 3D representation of local fabric. We found the development of farm ponds and evolved urban fabric was closely connected and subjected to the impact of a special zoning specification. A local trend was evolved under the convergence between the increased areas of development and the decreased area of under-development. The active skylines were feasible to illustrate the consistent enriches of urban fabric by well-developed local

characters. The diversity of emphases in matrix contributed to a combinative description of pond context. Future research would aim to detailed chronological quantitative analysis of newly developed skylines.

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