PIXELGREEN

A hybrid green media wall for existing high-rise buildings

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Abstract. Vertical farms and gardens are not new in dense urban environments, but few examples further explore the architectural potential and possibilities of the form to apply the same design approach to existing surfaces and walls of buildings. In addition, there is a design opportunity to exploit existing wall surfaces as 'analogue' media screens by using the vertical farm and garden as a medium of representation. In this paper we explore the opportunity for new design possibilities to achieve a hybrid architectural wall system as a reciprocal retrofit for existing building surfaces, integrating a vertical micro-farm and media screen. This architectural opportunity is explored through agile methods and the early design stages of a hybrid green media wall, PixelGreen. PixelGreen will be retrofitted to an existing wall of a high-rise building to convey mediated, graphical, artistic content and provide edible plant micro-farming simultaneously. The physical proof of concept is given through a modular mock-up with a programmed UAV (unmanned aerial vehicle) serving as the 'agent' for constant updating of mediated content, maintenance and a regular farming cycle. The outcome of this approach provides preliminary insight into how to feasibly implement a hybrid green media wall with autonomous robotics and computation technology.

Keywords. Green wall; media facade; vertical farm; architectural intervention.

1. Introduction

Traditional farming is ruining the environment, and not enough arable land remains to feed a projected 9.5 billion people by 2050. To overcome this challenge, farming in dense cities and existing built environments is becoming popular, involving the growing of crops indoors or semi-outdoors under rigorously controlled conditions. Although not a complete replacement for traditional farms, vertical farms are one viable alternative method of growing edible plants in high-rise buildings and multistorey rooftop greenhouses (Despommier 2009).

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The vast vertical surface areas of the existing walls or façades of high-rise buildings in crowded, highly populated cities not only provide an opportunity to design and implement green walls; architectural features such as media screens have also been created on building walls and façades for purposes of commerce, advertisement, communication, art installation and social interaction (Dalsgaard and Halskov 2010, Fortin et al. 2014). Typically media screens take a form where media content is shown via LED displays or projection systems embedded into the surface of a façade. The agenda for such urban media façades is to facilitate public participation and foster social interactions in urban settings (Gehring and Wiethoff 2014).

But what if, instead of using typical LED or projection techniques, the media screen was conceived of as a low-resolution analogue medium formed by a series of vertically arranged edible plants? Each plant could serve as an individual 'pixel', allowing a range of content and use scenarios to be considered. Such scenarios and content could include community media and public art, and could potentially generate income through advertising (Wiethoff and Hussmann 2017). Due to the life cycle of the edible plants, the content of this analogue media screen could be updated at timely intervals through each harvest.

Research on urban vertical farms and media screens is not new, especially in the fields of architecture and the built environment. The fields consider these topics differently, with distinct research focuses and questions, but the potential value of existing vertical building surfaces in dense urban contexts serves as a common research interest and direction. The integration of a range of disciplinary concerns will achieve a hybrid green media wall to offer a retrofittable, flexible and replaceable wall system for simple media communication, art installation and self-sufficient food supply.

This research brings together two subsets of the general fields of farming and building façade design: vertical farms and media walls. The project seeks to reveal the new design potential of a reciprocal hybrid green media wall, PixelGreen, as an architectural intervention. PixelGreen is controlled and maintained by a programmed unmanned aerial vehicle (UAV) to achieve constant media content updates and to maintain edible plants as they pass through three repeatable stages: plant, grow and harvest.

The research is conducted in two stages. The first stage includes the literature review, conceptual framework and early schematic experiments, to articulate a system for designing a hybrid green media wall. The second stage moves beyond the theoretical framework to develop a proof of concept in the form of an early mock-up of PixelGreen, demonstrating its technical and economic feasibility. The output of this research provides introductory insight into the new design possibilities presented by a hybrid green media wall in its achievement of a reciprocal and sustainable wall system for the existing built environment.

2. Integration of the vertical farm and media wall

Contemporary cities are experiencing vast changes and transformations through the current influx of hard infrastructure and industrialisation. These changes not only introduce the opportunity to review the viability and sustainability of existing urban built environments and buildings, but also suggest novel architectural programs and functions that can enhance the adaptability of existing old buildings. Eventually, these changes could transform existing buildings into a new kind of architecture that responds to current and future social, cultural and economic needs.

Our cities are also increasingly affected by problems of high density and a lack of greenery and softscapes in built-up areas. Vacant land in cities for potential use in urban gardens and farming has become scarce, especially in the highly populated cities of Asia.

The transition from natural land to hard infrastructure has caused loss of vegetation and habitat. However, cities in Asia have recognised the importance of green infrastructure that can incorporate farming and vegetation into existing urban structure and function (Growing Green Guide 2014). Green infrastructure such as green walls and façades is not only recognised as being beneficial to human health and well-being; it also provides commercial and economic benefits including farming and food production. Green walls are commonly plants grown in vertical systems that are independently attached to internal and external walls of buildings as one integrated system of vegetation, growing medium, irrigation and drainage (Growing Green Guide 2014). Additionally, green walls largely use a hydroponic growing medium that provides effective passive cooling, a cooler microclimate and improvements to local air quality while serving as an attractive wall-design feature. However, green walls added to existing building surfaces, which can also serve as self-sustaining micro-farms with similar benefits mentioned above, remain unexplored; further research will help to exploit their full potential. Current vertical farms, such as Vertical Fresh Farms in Buffalo and SkyGreens in Singapore, provide some insights into the new design possibilities of green walls in achieving production of fresh vegetables, herbs and salad greens with minimal land, water and energy resources (Marks 2014).

Current approaches to creating vertical farms have been challenged due to their high building cost, low profitability, high energy usage and even for emitting more greenhouse gases compared to traditional field production for cities with abundant agriculture land (The Economist Technology Quarterly 2010). However, crowded and highly populated cities with limited farmland, such as Hong Kong, Singapore and New York, present a more viable context for the implementation and validity of vertical farms, in which to explore new opportunities and eventually overcome the shortcomings and challenges of existing approaches. Instead of replacing traditional farms, vertical farms retrofitted to dense urban infrastructure could serve as reciprocal green walls that contribute complementary food sources with sustainable commercial value.

The vast surface areas of the existing walls and façades of high-rise buildings in crowded and highly populated cities not only provide an opportunity to design and implement green walls; architectural features such as media walls have also been placed on building walls and façades for purposes of commerce, advertisement, communication and social interaction. Recent advances in affordable and accessible LED and fluorescent lighting, and in projection technology, have led to the appearance of large-scale 'media façades', especially in dense urban areas. The GreenPix media screen in Beijing, designed by Simon Giostra & Partners, is a salient example involving the use of conventional LED displays to facilitate public social interaction and communication through video installations and live performances by artists (GreenPix 2008). The BIX façade in the Kunsthaus Graz in Austria and the interactive computer display of the Haus des Lehrers office building at Berlin are other significant precedents of the media façade approach, and use relatively simple fluorescent lighting to create large-scale graphical displays (Elder & Elder, 2003). In addition, media façades adopting augmented digital projection are becoming popular. Tokyo's N Building provides one example of an augmented architectural surface that performs dynamic aesthetic alterations to the original appearance of its existing building façade that present real-time media experiences, communicated through two-dimensional QR codes that can be read using a smartphone (Teradadesign 2009). Such examples illustrate the range of media façades that can be achieved, turning buildings themselves into gigantic 'displays' that can be novel media for communication and art installation, especially in presenting graphical content. (Gehring and Kruger 2012, Schoch 2006). In general, the medium of the media façade is implemented through lighting or display systems with high energy consumption, which contribute to urban heat island effects that significantly warmer than the surrounding rural areas due to increase human activities.

Green walls and media façades serve as two distinct ways to augment building façades, and both involve research into building surfaces in areas including architecture, urban design, social interaction, landscape and sustainability. They participate in a common enquiry into how to fully exploit and utilise the vertical surfaces of buildings to achieve reciprocal and interactive architectural features. The present research addresses this enquiry and investigate the opportunity for new design possibilities presented by a hybrid architectural wall system as a responsive and interactive intervention for existing buildings that integrates a vertical micro-farm and media screen.

Figure 1. The identified vertical 'sites' or 'platforms' (highlighted in green) for PixelGreen in a dense area of Hong Kong.

3. PixelGreen as a reciprocal hybrid green media wall

PixelGreen serves as a reciprocal retrofit to the existing surface or wall of a building, exploring an architectural potential to improve the shortcomings of an existing structure. As a site for implementation, a series of existing walls and vertical surfaces have been identified in the dense central area of Hong Kong (Figure 1). The identified vertical surfaces are existing fire walls of the high-rise buildings, which serve as potential vertical 'platforms' for PixelGreen, allowing it to become an architectural reciprocal hybrid green media wall system that can perform media and micro-farming functions simultaneously. As PixelGreen is based on a flexible modular system, its size and form are customisable and configurable to accommodate different shapes and conditions of existing walls.

The initial schematic development of PixelGreen involves a conceptual design with mediated content represented by multiple species of edible plants in different colours. Each edible plant will be hosted by a rectangular 'pigeonhole' serving as an analogue 'pixel' of PixelGreen. The overall structure of PixelGreen is formed by a flexible modular system, with each module consisting of 25 'pigeonholes' that can be used to construct various configurations that adapt to differently shaped vertical building surfaces.

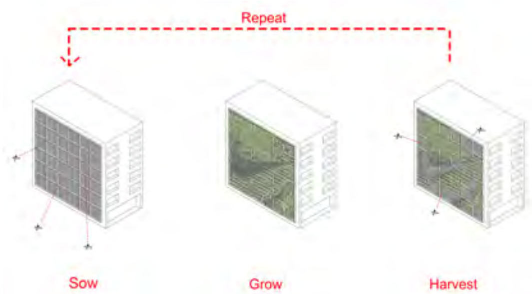

Figure 2. A conceptual diagram of PixelGreen with mediated content formed by multiple species of edible plants within 'pigeonhole pixels'. Progress through three repeatable steps—sow, grow and harvest—is controlled and maintained by programmed UAVs.

Three repeatable steps-sow, grow and harvest-are proposed for the early phase of PixelGreen to facilitate the representation of media content through the different species of edible plants (Figure 2). These steps could be controlled and maintained by a programmed UAV or drone to update the media content as it maintains and harvests the edible plants at intervals. There is a monthly interval between sow and harvest steps.

'Sow' is the initial step, in which the programmed UAVs sow the seeds of various species and colours into designated 'pigeonholes' according to the pre-set pixelated graphic of the mediated content or message. This step will be repeatable to update or change the mediated content of PixelGreen. 'Grow' is the next step, in which the edible plants might take 14 days or more to mature with appropriate irrigation system. In normal circumstances, the involvement of the programmed UAVs in this step is minimal, beside occasional visual inspections and maintenance. In the ‘harvest’ step, the programmed UAVs are required again to collect the edible plants and empty each ‘pigeonhole’ to prepare it for the following ‘sow’ step.

4. Mock-ups of and experiments with PixelGreen

A physical proof of concept, constructed as a modular mock-up, was explored to test and evaluate the feasibility of PixelGreen. As mentioned in the previous section, each module consists of 25 ‘pigeonholes’ that host edible plants, and each ‘pigeonhole’ serves as an analogue ‘pixel’. In this section, several experiments and tests involving the physical modules of PixelGreen demonstrated the simple programming schema for the UAV that enables it to sow a capsule containing seeds of an edible plant. Due to resource constraints and limitations, only the ‘sow’ step was tested in this phase to demonstrate the feasibility of the physical implementation.

4.1. THE PHYSICAL MODULE OF PIXELGREEN

The physical module was fabricated from 12 laser-cut MDF components, forming a modular assembly with 25 ‘pigeonhole pixels’ (Figure 3). A waterproof seed-holder containing soil and water was located in each ‘pigeonhole pixel’ to provide suitable conditions for sowing and growing the seeds of edible plants.

Figure 3. Left: The components of the physical module of PixelGreen. Right: The complete assembly for the physical module of PixelGreen consists of 25 ‘pigeonhole pixels’ containing a waterproof seed-holder.

Figure 4. Left: Seeds of edible plants contained in the water-soluble gelatine capsule. Right: Seeds of light-coloured edible plants (mustard, coriander and garland) and seeds of dark-coloured edible plants (broccoli, radish, red radish and kale).

4.2. THE SEED CAPSULE

To allow the UAV to carry the seeds of edible plants and sow them in a specific, designated ‘pigeonhole pixel’, a water-soluble gelatine capsule was used to hold the seeds in a format that the grabber of the UAV could carry. Capsules contained one of two types of seed for various species of edible plants, in either a dark or light colour (Figure 4). When grown in the designated ‘pigeonhole pixel’ after the dissolve of the gelatine capsule, these two types of edible plants will generate a pixelated graphical pixel representing the mediated content (discussed further in the subsequent section).

Figure 5. Left: Each ‘pigeonhole pixel’ is assigned a unique coordinate. Right: The physical module of PixelGreen with 25 assigned coordinates.

4.3. THE INITIAL TEST OF THE ‘SOW’ STEP VIA UAV

Although there are three steps (sow, grow and harvest) in the overall planting cycle of PixelGreen, in this section only the ‘sow’ step will be tested for feasibility, using a manually controlled UAV. In this initial test, each ‘pigeonhole pixel’ of PixelGreen is assigned to a specific coordinate so the UAV can identify the location at which to place the seed (Figure 5). Coordinates A1 and A2 were selected to implement the early feasibility test of the ‘sow’ step. First, the landing site for the UAV is identified and the seed capsule located in its designated location. Second, the UAV grabs the seed capsule and takes off to sow it at the designated A1 coordinate. Third, the UAV returns to land at its original point of departure. This initial test demonstrated the feasibility of the ‘sow’ step of PixelGreen being performed by a UAV (Figure 6).

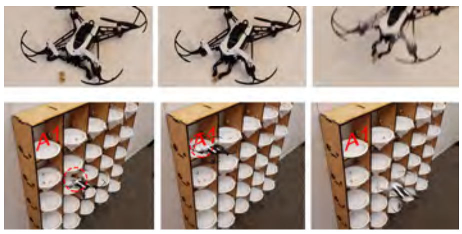

Figure 6. Top: Seed capsule in its designated position. Middle: UAV taking off with its grabber closed. Bottom: Initial test of sowing seed capsule at designated coordinate (A1) using a manually controlled UAV.

4.4. A UAV PROGRAMMED WITH A SIMPLE SCHEMA

Following the initial test of the manually controlled UAV for the ‘sow’ step, subsequent testing involved the programmed and autonomous flight path of the UAV to designated coordinates according to a simple schema. Figure 7 shows the programmed flight path of the UAV as it autonomously completes the ‘sow’ step for coordinate A1, following a simple schema that includes the major processes of grabbing, taking off, sowing, moving backwards, descending and landing, which were tested previously under manual operation. A subsequent ‘sow’ step for two coordinates (A1 and A2) was also implemented with a similar schema to sow different seed capsules for the specific ‘pigeonhole pixels’ simultaneously (Figure 7).

Figure 7. Left: A simple schema for the flight path of the UAV as it sows a seed capsule at the A1 coordinate (grabbing, taking off, sowing, moving backwards, descending and landing). Right: A simple schema for the steps of the UAV in sowing the seed capsule to the A1 and A2 coordinates (grabbing, taking off, drifting, sowing, moving backwards, descending and landing).

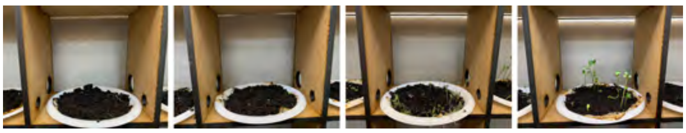

Figure 8. Screenshots of the growth timeline for edible plants in the fertilised soil of the ‘pigeonhole pixel’.

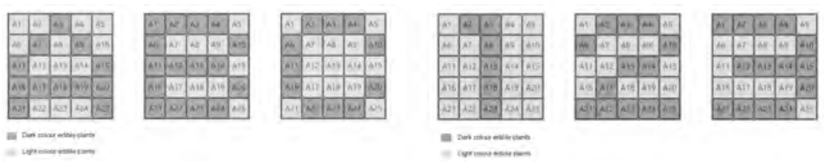

Figure 9. Right: A potential binary text representation formed by dark- and light-coloured edible plants. Left: Binary numeric presentation formed through the specific arrangement of dark- and light-coloured edible plants.

5. Potential mediated content representation through PixelGreen

The promising outcomes of early testing and implementation of the physical modules of PixelGreen and the programmed UAV provided initial insights into the system’s potential for mediated content representation. As discussed, the mediated content could be represented using different species and colours of edible plants grown in the fertilised soil of the ‘pigeonhole pixels’ (Figure 8). Besides binary images, simple messages and information could also be represented using text and numbers formed through the specific arrangement of the edible plants. For instance, Figure 9 shows the possible binary representations of text and numbers composed using the individual coordinates of the 25 ‘pigeonhole pixels’. Adding different arrangements of analogue text and numeric representation create vast possibilities of mediated and graphical representation. This potential is realised through the sowing process followed by the UAV programmed with simple schemas that place the seeds of light- and dark-coloured edible plants in specific 'pigeonhole pixels'.

The update cycle of this media representation, which coincides with the micro-veggie sowing and harvesting process, will be constantly maintained through the three repeatable steps controlled and executed by the programmed UAVs as they sow, grow and harvest. Figure 10 shows a proposal to visualise this approach through a hypothetical implementation of PixelGreen at the site of a temporary market in Hong Kong, demonstrating its design feasibility in the relevant urban context. In this proposal, the scale and the size of PixelGreen are customised to adapt to the specific conditions and constraints of the site. Besides serving as a media façade with potential commercial value, PixelGreen also produce edible plants that can be harvested and distributed to the adjacent market to achieve a reciprocal and sustainable relationship. Following this scenario, PixelGreen could be developed to become a 'pop-up' architectural feature serving as a vertical greenhouse accommodating different functions such as a café and viewing platform.

Figure 10. Left: The hypothetical implementation of PixelGreen in the dense urban context of Hong Kong. Right: Potential sites that combine the vertical and horizontal surfaces (highlighted in green) of existing high-rise buildings in the development of PixelGreen.

6. Conclusion and future work

The implementation and realisation of the green media wall in an existing urban environment still confronted us with challenges and limitations, especially in the areas of government policy, the building code, commercial feasibility and the property rights. Current limitations in what technologies and techniques are feasible to implement also hinder advancement of the design implications of this architectural approach. However, the potential value of the hybrid green media wall at the urban scale is to provide a range of commercial content and public social interactions; it may disseminate news, have the capacity to generate income through advertisements, or provide interactive public services, games and art. In addition, the contemporary city may suffer problems of high density, lack of greenery and softscapes in built-up areas, and a lack of food safety and food security due to over-reliance on imports. And though it may not replace the traditional farm, the greening and food-production potential of the hybrid green media wall will create awareness among the general public of a sustainable future for urban farming.

The promising outcomes generated in this research will eventually lead to a demonstration of a large-scale architectural interface in a dense urban area with commercial, social and environmental value. The early mock-ups of PixelGreen described here serve as a proof of concept giving initial insight into the possible implementation of an autonomous hybrid green media wall in the existing urban built environment. Although the preliminary outcomes of this paper represent merely the initial design stages of PixelGreen, tests of and experimentation with the physical modules in conjunction with a programmed UAV shows both the feasibility and flexibility of an implementation of PixelGreen. The next stage of this research will include the development of PixelGreen with the social interaction through commercial and art installation to adopt an approach that integrates horizontal (roof) and vertical (wall) surfaces of existing urban infrastructure to more fully exploit those surfaces, eventually providing a platform to study the advanced design implications of urban farms and media screens such as façade farming (Figure 10). User studies will also be included to collect and evaluate valuable feedback data from users and participants to be used in further advancement of the design.

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References

"Teradadesign: N Building" : 2009. Available from <http://www.teradadesign.com/works/architecture/n-building.html> (accessed 3rd August 2018).

"The Economist Technology Quarterly: Does it really stack up?" : 2010. Available from <http://gothamgreens.com/files/pdf/vertical_farming_98848600.pdf> (accessed 2nd September 2018).

"GreenPix: The Zero Energy Media Wall, 2008" : 2011. Available from <http://www.greenpix.org/> (accessed 2nd October 2018).

"Growing Green Guide: A guide to green roofs, walls and facades in Melbourne and Victoria." : 2014. Available from <http://www.growinggreenguide.org> (accessed 15th September 2018).

Dalsgaard, P. and Halskov, K.: 2010, Designing Urban Media Facades: Cases and Challenges, *Proceedings of CHI 2010*, 2277-2286.

Despommier, D.: 2009, The Rise of Vertical Farms, *Scientific American*, **301**(5), 80-87.

Elder, J. and Elder, T. 2003, Communicative Display Skin for Buildings: BIX at the Kunsthaus Graz, *in* B. Kolarevic and A. Malkawi (eds.), *Performative Architecture – Beyond Instrumentality*, Taylor & Francis Books Ltd, New York/London, 150-160.

Fortin, C., Hennessy, K. and Sweeney, H.: 2014, Roles of an Interactive Media Façade in a Digital Agora, *Proceedings of The International Symposium on Pervasive Displays (PerDis'14)*, 7-12.

Gehring, S. and Kruger, A.: 2012, Façade Map – Continuous Interaction with Media Facades Using Cartographic Map Projections, *Proceedings of UbiComp 12*, 471-480.

Gehring, S. and Wiethoff, A.: 2014, Interaction with media façades, *Informatik-Spektrum*, **37**(5), 474-482.

Marks, P.: 2014, Vertical farms sprouting all over the world, *New Scientist*, **2952**.

Schoch, O.: 2006, My Building is my Display: Omnipresent graphical output as hybrid communicators, *Proceedings of the eCAADe 24*, 610-616.

Wiethoff, A. and Hussmann, H.: 2017, *Media Architecture: Using Information and Media as Construction material*, Walter de Gruyter, Berlin / Boston.