Flora robotica aims to make cities more liveable by coupling the long-term growth and material accumulation processes of natural plants with digital technologies that can direct this growth towards architectural objectives. We target external public space as the principle arena in which to deploy this approach, with the aim of improving liveability not only for human occupants of public urban spaces, but numerous other species that have become isolated, displaced or marginalized by city development and expansion.

Cities are artificial environments that, through their construction and expansion, displace and fragment complex native ecological communities, replacing them with habitats that are generally designed for a species mono-culture. Through pressures of population growth and increasing urbanisation, society faces the prospect of further significant urban expansion placing rich and complex habitats under the threat of degradation and loss, which ultimately has consequences for the quality of human life.

Our ambition is to create urban artificial environments that support the increase of species richness and abundance, whilst providing spaces of utility and inspiration for human occupation. By robotically steering and directing plant growth in combination with designed scaffolds, we aim to grow external urban spaces and structures that provide required and expected utility – such as seating, summer solar shading, routes and pathways - whilst simultaneously creating bio-hybrid habitats that can continuously monitored and linked to surrounding plant communities, be colonised by other species, increase bio-diversity and provide a platform for establishing complex ecosystems within urban environments.


flora robotica | bio-hybrid architecture as living habitats for increasing bio-diversity in urban public space
florarobotica

0/ CONTENTS

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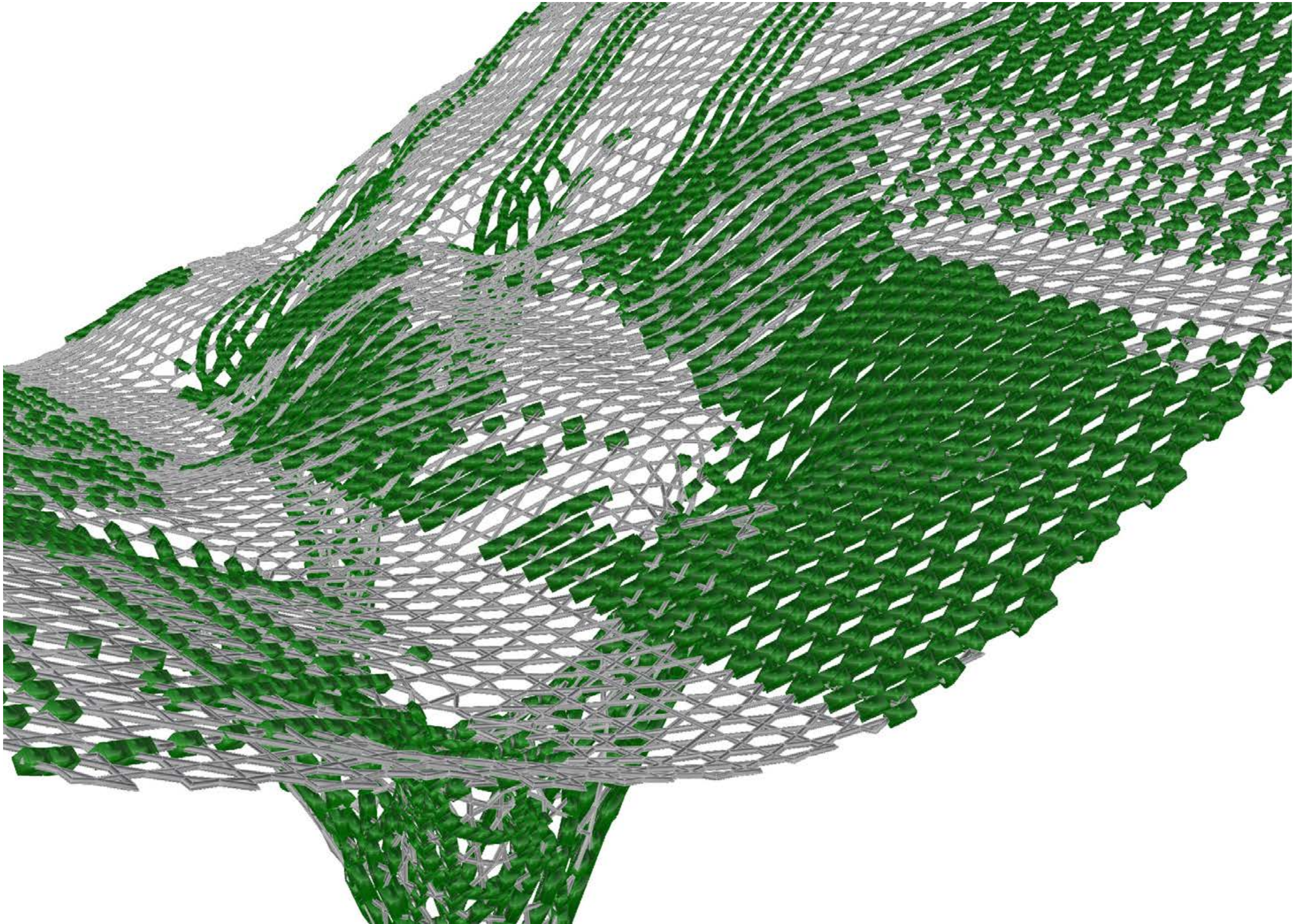
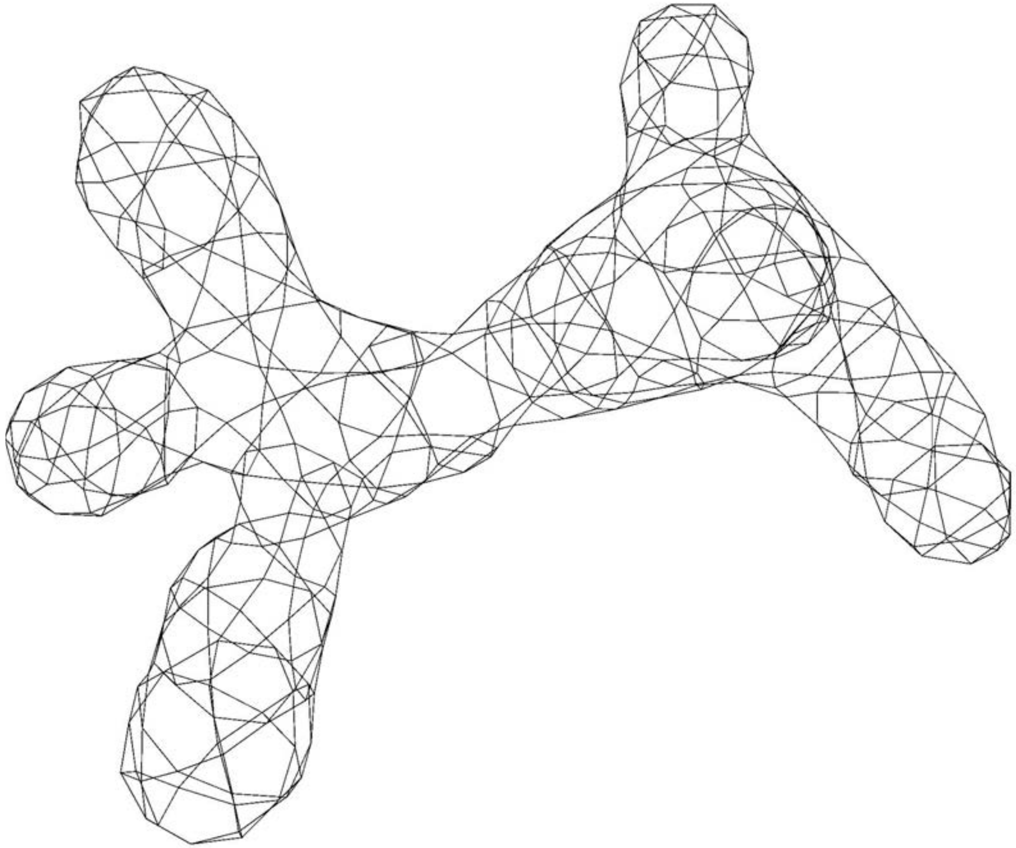
I / INTRODUCTION

flora robotica is funded under the EU's Future and Emerging Technologies programme. The project assembles a highly diverse consortium of disciplines, with expertise spanning biology, robotics, computer science, artificial life, sensing/mechatronics and architecture.

The project vision is to grow architecture from symbiotic interactions between plants and robots. The project has developed design approaches, core technologies and key concepts that contribute to the nascent field of bio-hybrid systems.

This document presents an architectural vision that draws upon the insights developed in the project, applied to an indicative urban context.

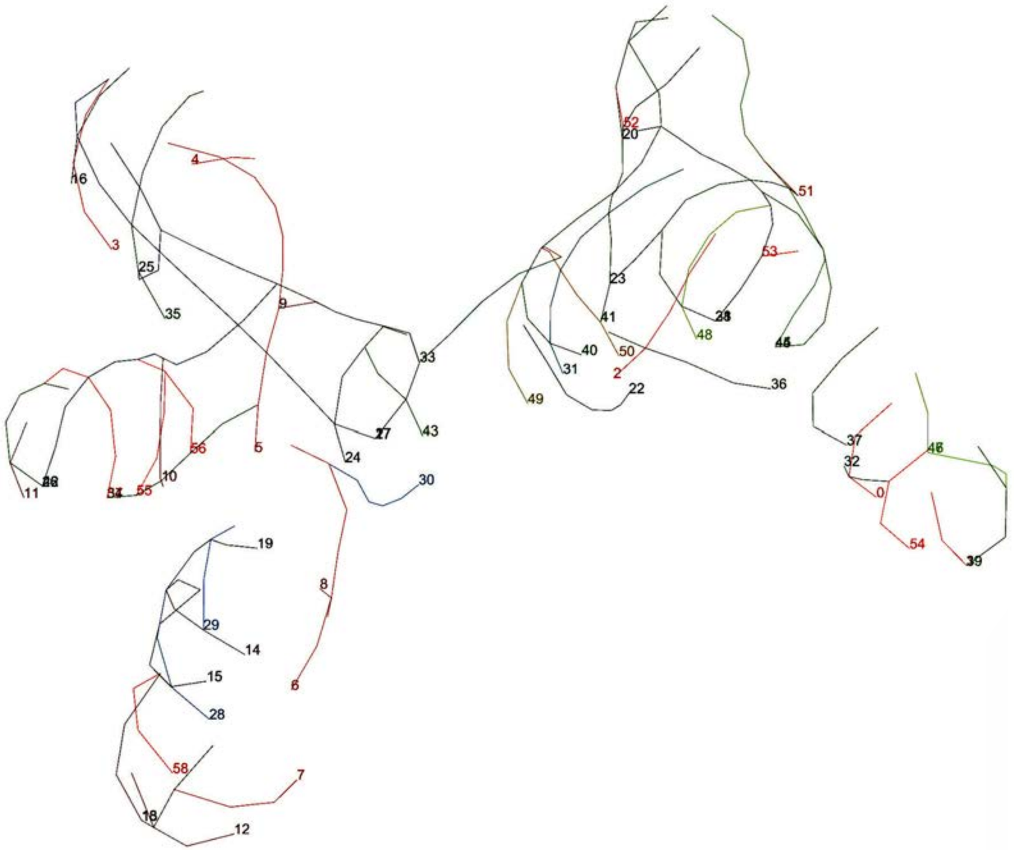


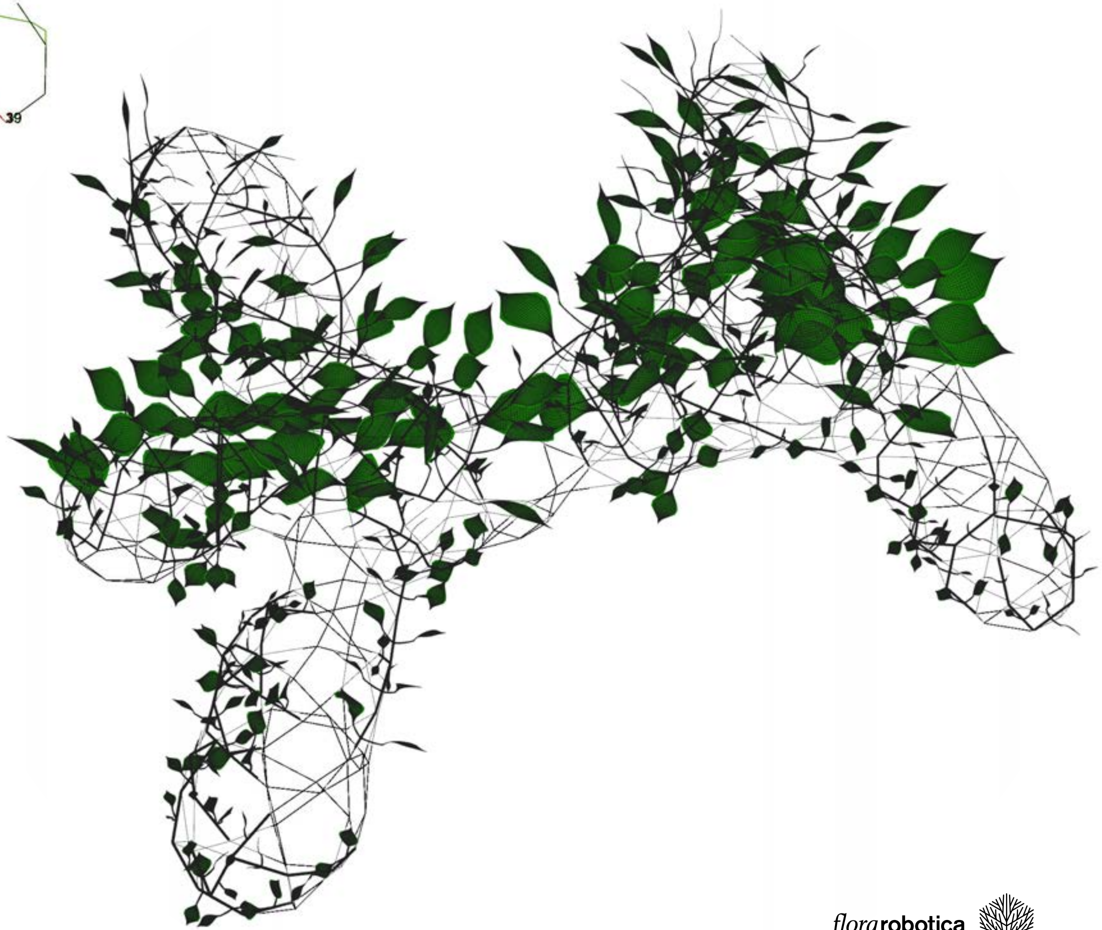


2 / LIVING WEAVES CONCEPT

Our living weaves concept combines plants with self-bracing interlaced weave structures based on the sparse Kagome pattern. The weaves act as support scaffolds while plants are young and maturing, but as they grow and stiffen, they can contribute strucutral performance back into the weave. Through computational analysis we determine the most appropriate areas for plants and the protocols for directing their growth towards these targets.

In addition to creating architectural artifacts for human objectives, these structures also double as living habitats that promote and support an increase in bio-diversity in external urban areas.





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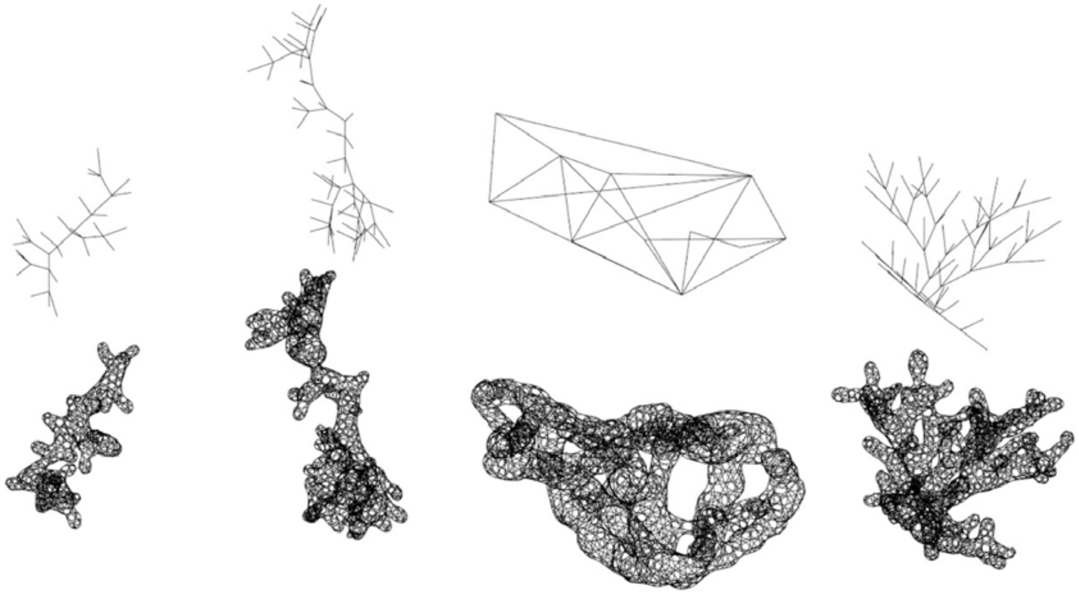
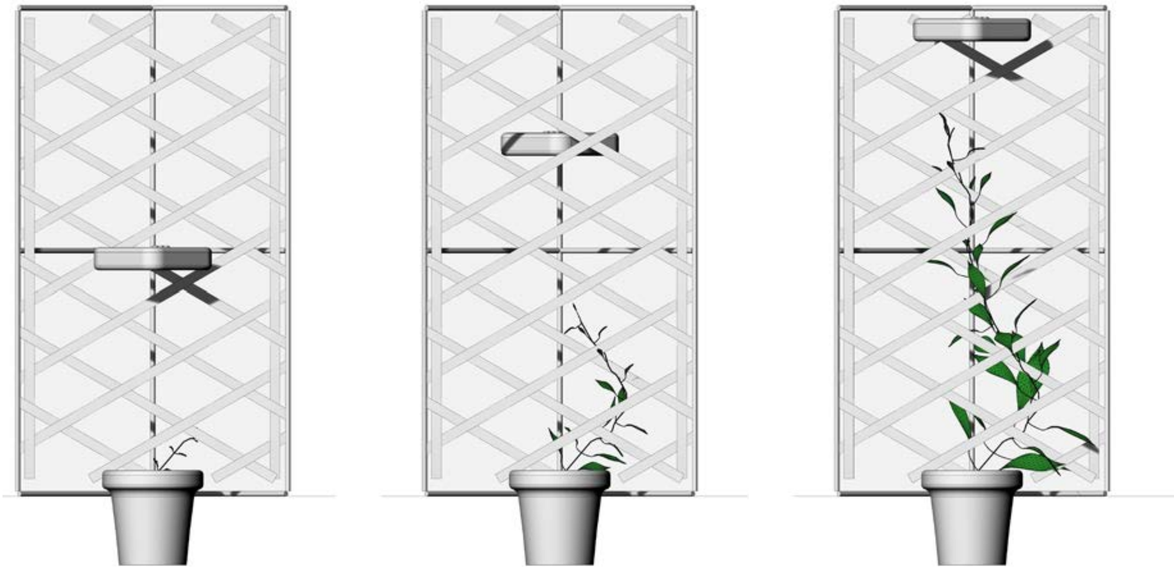
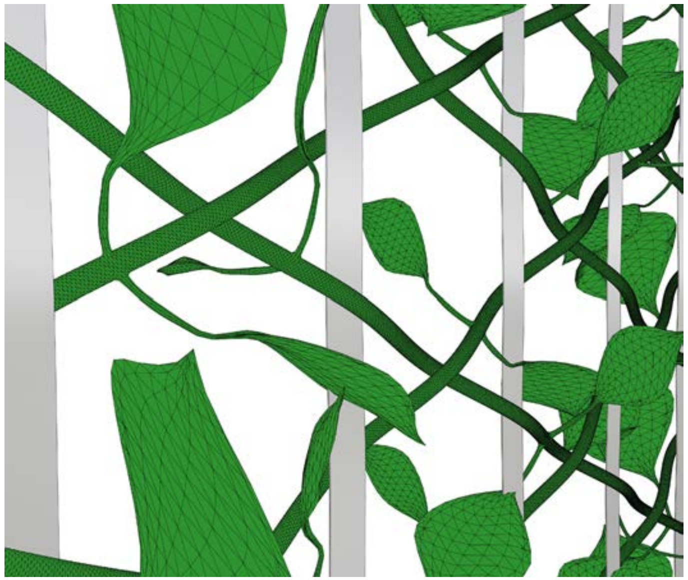
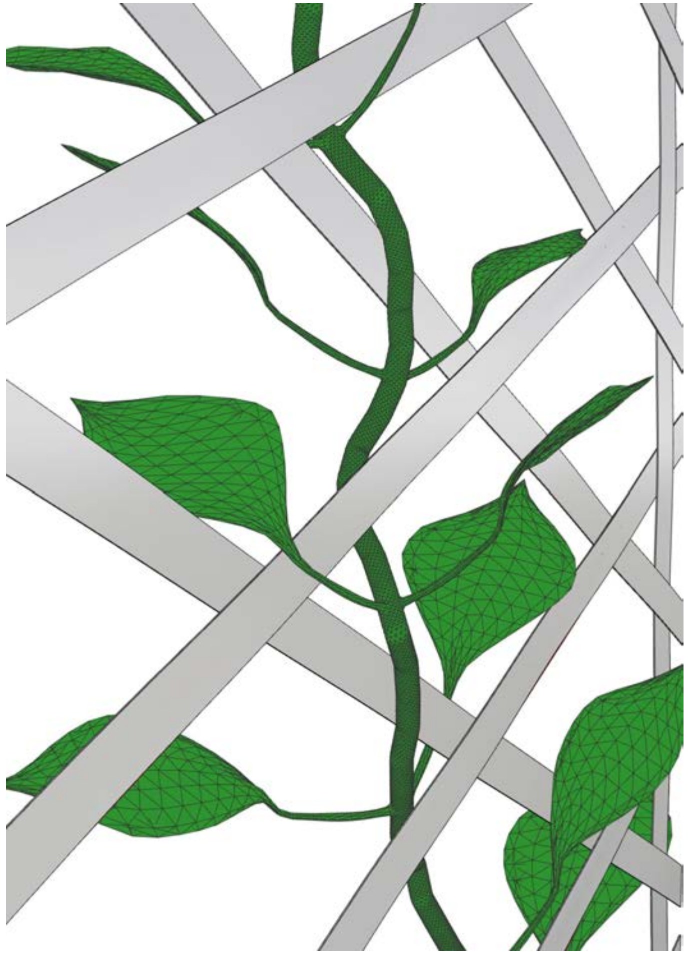


2 / plant integration approach

Triaxial, or ‘Kagome’, weave designs are computationally generated by ‘growing’ graphs. Design results can then be analysed to determine possible plant growth paths that replace specific parts of the weave. Currently we are exploring the strategy shown far right p.9, where a plant is used to replace a set of vertical weavers. A more complex strategy would involve the weaving of plants in two distinct orientations as shown bottom left, p.9.







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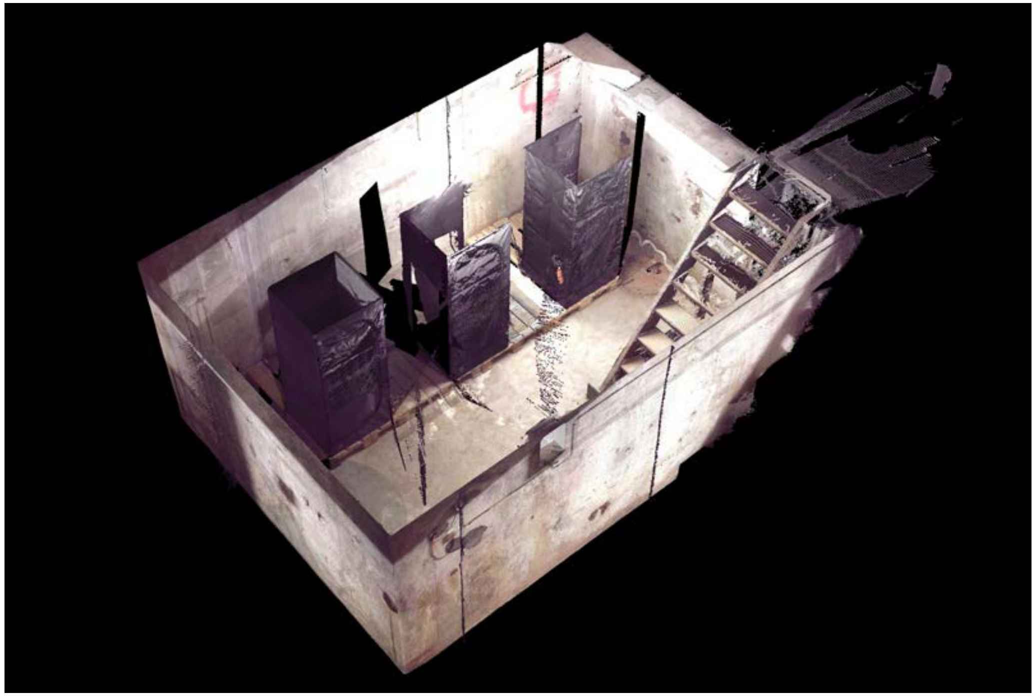
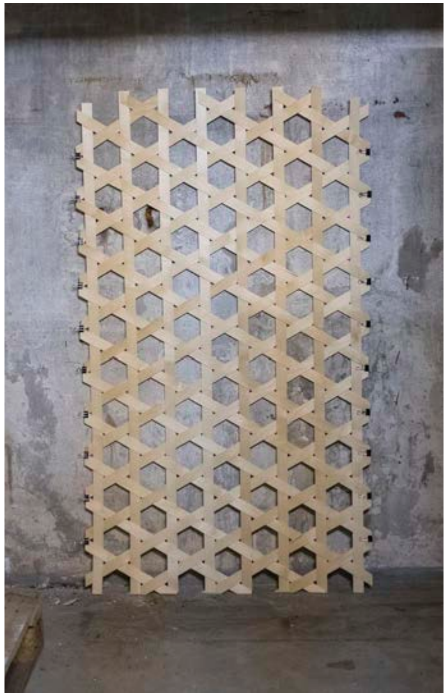
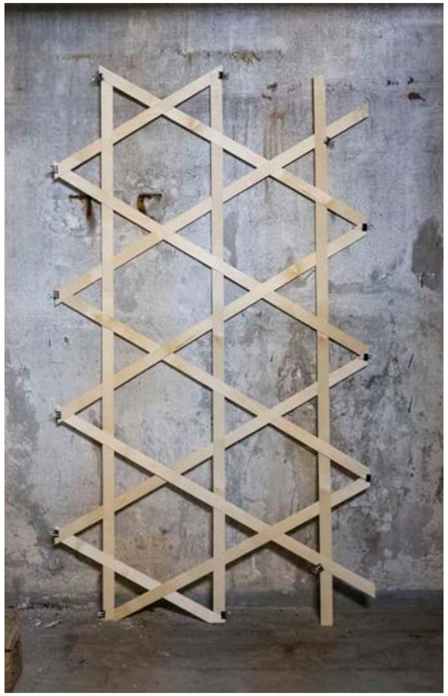


2 / **empirical experimentation**

The hypothesis that we can weave plants using only environmental stimuli to steer their phototrpic response, is currently being tested in lab conditions. Three densities of weave are being explored to determine ideal weave cover-ratios in relation to plant growth dynamics. Each weave is diagonally located within a growbox and grow-lamps are situated in either side of the weave. The grow-lamps are autonomously switched according to the side on which the apical meristem is located. The plant location is automatically determined by analysis of images captured by a bank of cameras. and this information is used to switch the appropriate lamp to direct the plant.

In a parallel study, shown bottom right, p.11, we have been manually weaving fallopia vines through weave scaffolds to explore growth rates, cover potentials and the rate of change from young soft tissues to woody resilient branches. The image shows broad cover having occured over a three week period in controlled conditions, with growth rates measured at approx. 40mm/day. There is no observable change to woody tissues yet, but these are expected within the same growth season.





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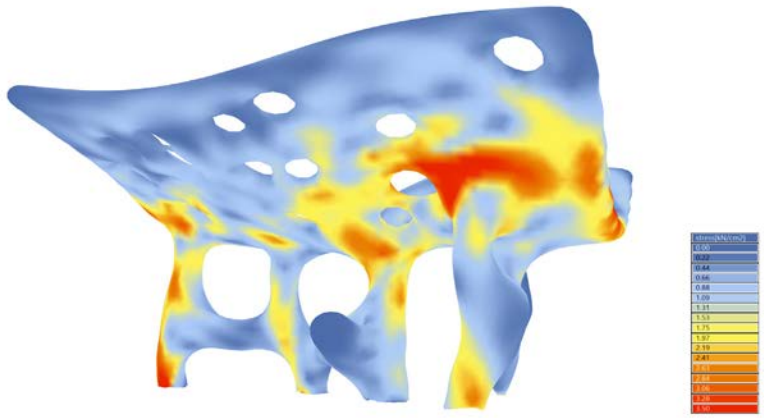
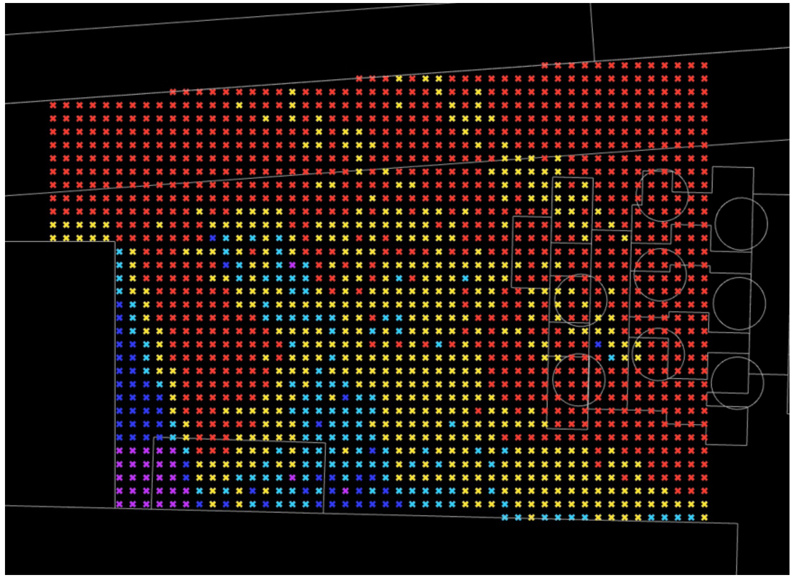
3 / DESIGN APPROACH

The *flora robotica* project has established the use of braided and woven scaffolds as an intgral element used to support early stage plant growth, act as a site for the distribution of robotic nodes for plant steering and - borrowing from horticultural practice - to mark out spatial architectural intentions in anticipation of future growth. Through our living weave concept, we propose a stronger integration between plant and weave, by considering the plant as a directable interlaced filament.



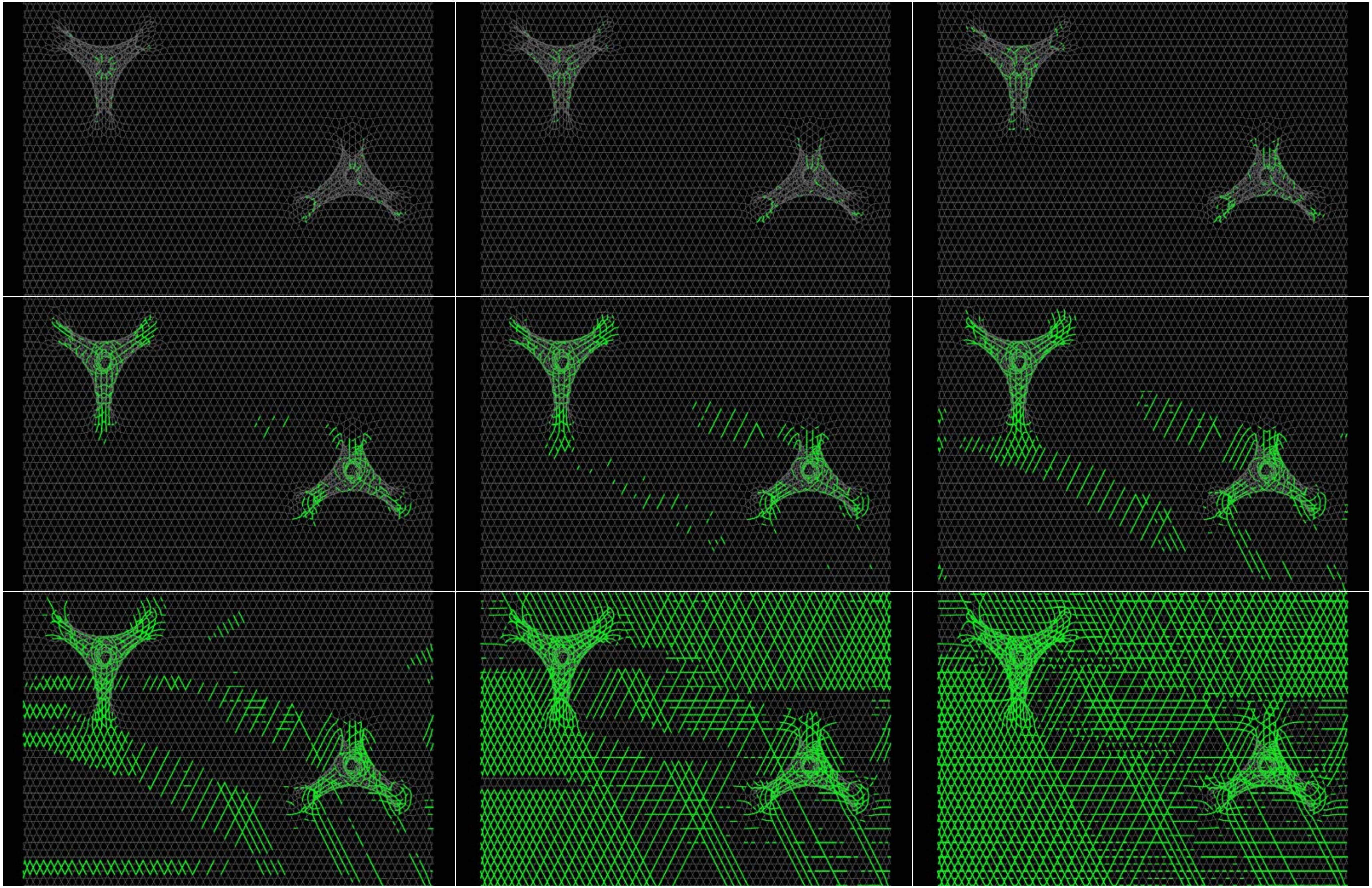


3 / performance informed iterative simulation

Plant growth is a source of continual change. As such, we need to establish tight iterative cycles of analysis and simulation in order to study emerging design opportunity and project design intent. In the following proposal we focus attention on the simulation of plant growth across a designed structure and analyse changing structural perfomance and aggregated daylight/self-shading conditions to determine the specification of ideal growth paths and spatial conditions through plant cover and density.

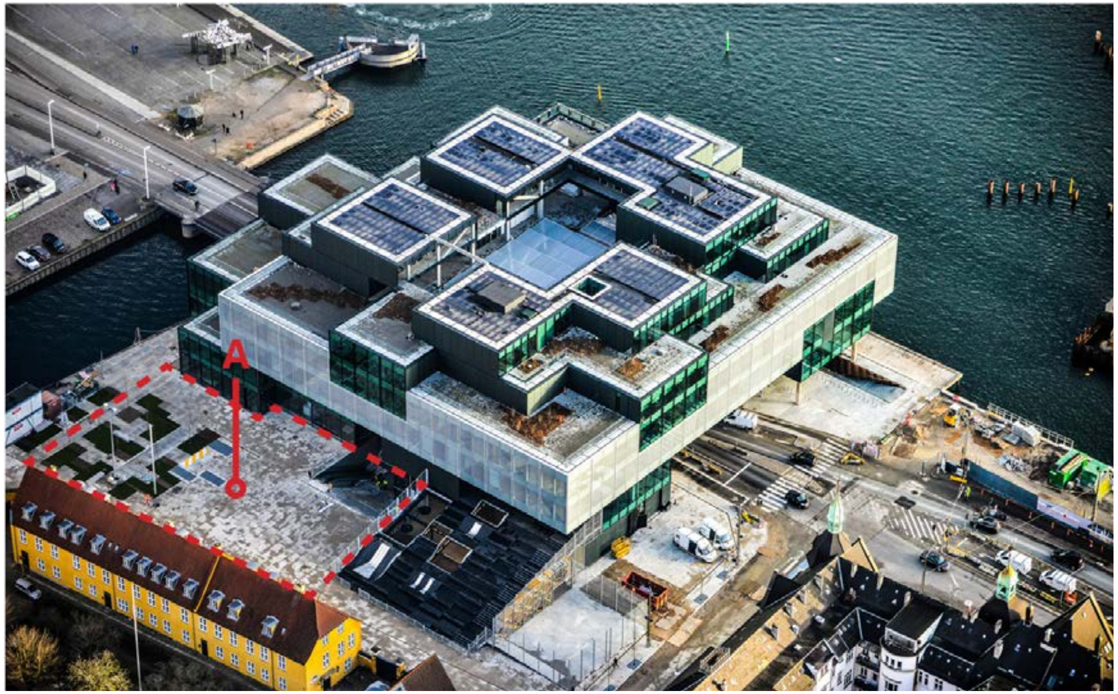
Sunlight Hour Analysis

Red:	**> 6 hours**
Yellow:	**6 hours**
Green:	**3-6 hours**
Turquoise:	**1-3 hours**
Blue:	**0-1 hour**
Purple:	**0 hours**



4/ PROPOSITION FOR AN URBAN SITE

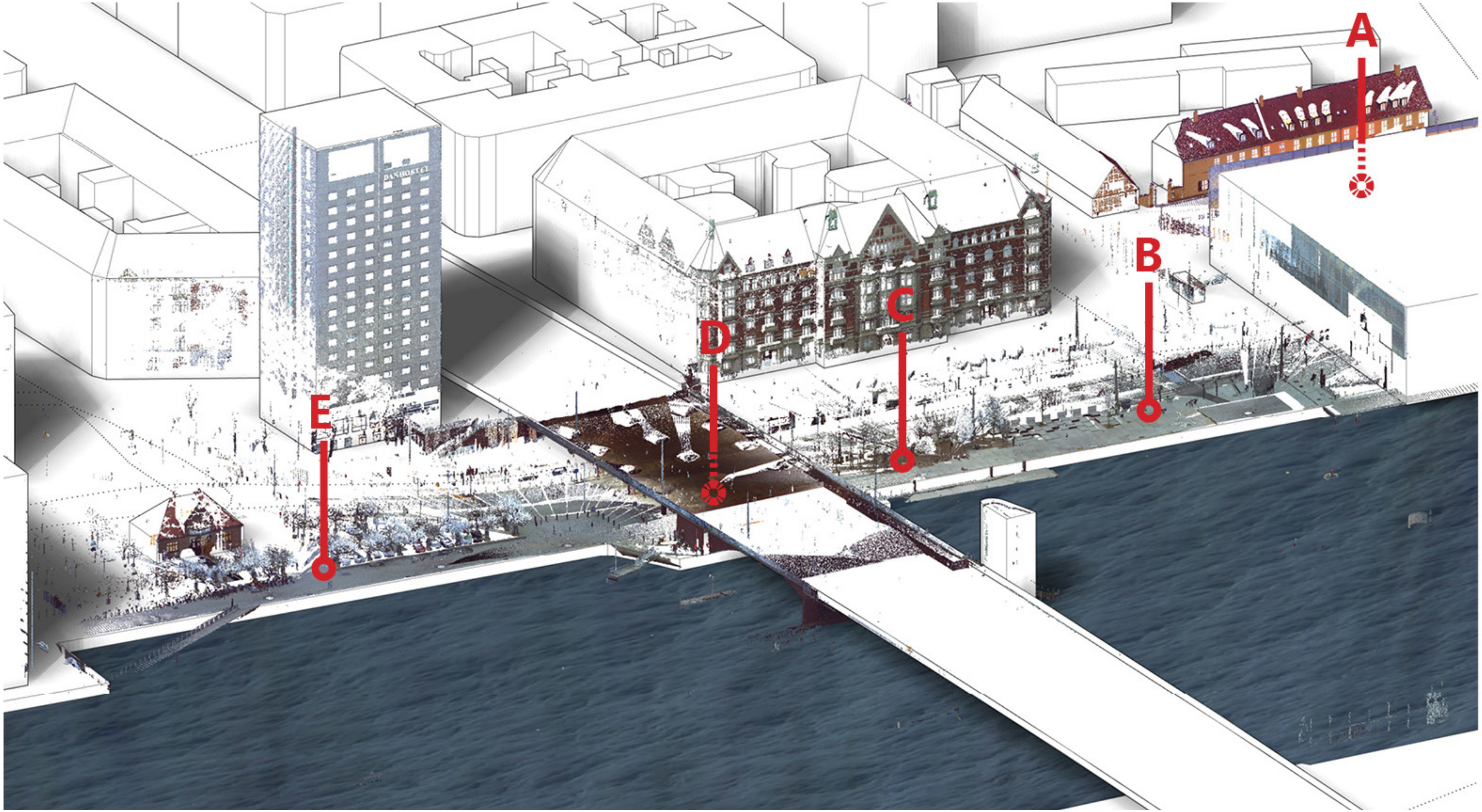
In this section we present an indicative proposal for the deployment of flora robotica technologies within an external and public urban context.



4/ indicative site & surroundings

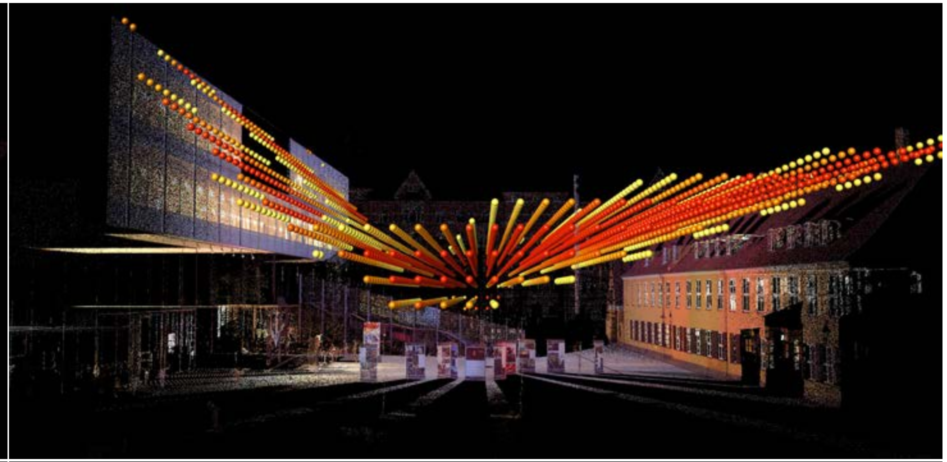
The surrounding external urban plazas of the recently completed Bloxhub have been chosen as a hypothetical site for our proposal. We concentrate design efforts on an area located behind the building (A), but have identified further sites of interest along the harbour front (B-E) that could be colonised by *flora robotica*.

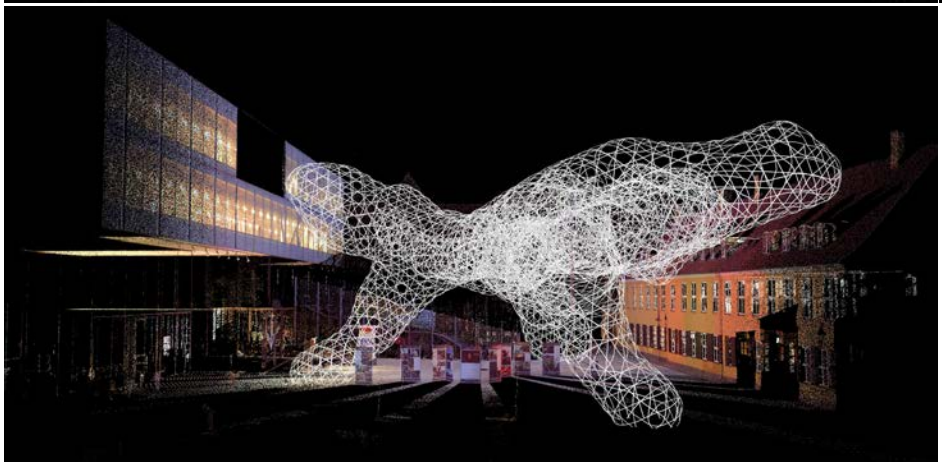
For site A, we propose a canopy structure to provide a porous cover for the winter and natural shading through leaf cover in the summer.

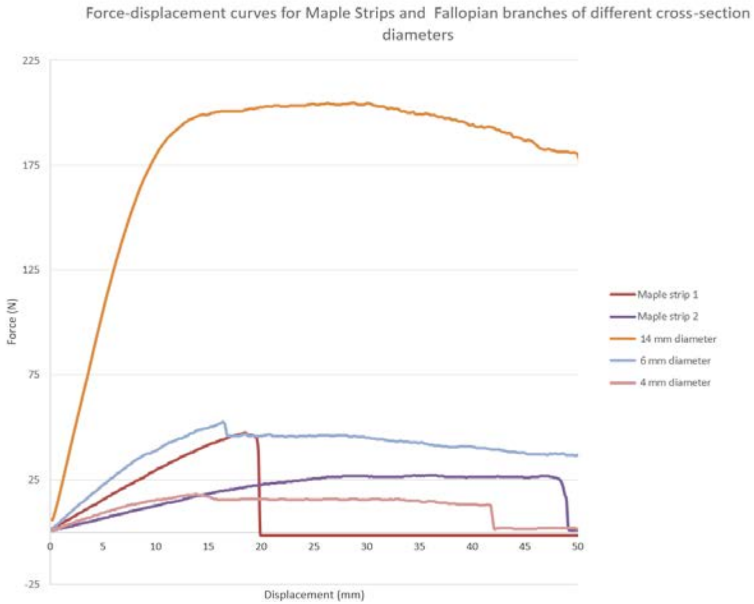

A
B
C
D
E

4/ combining intention & emergent self-organisation

The character of the proposal develops out of the pre-determined intention of providing a lightweight canopy that can be colonised by plants and produce habitats for other species. The geometry of the canopy is derived through a preliminary sunlight analysis to determine an ideal growth plane. Once established, we generate connecting structure using a growth algorithm. The algorithm takes the plane as an 'environmental input' to drive branching and connecting conditions. This is grown as a graph which is then skinned with the Kagome weave pattern. The weave pattern generation provides fabrication information and is used as input into subsequent simulation and analysis steps to determine necessary and ideal growth paths and assess the growth career of the bio-hybrid system.





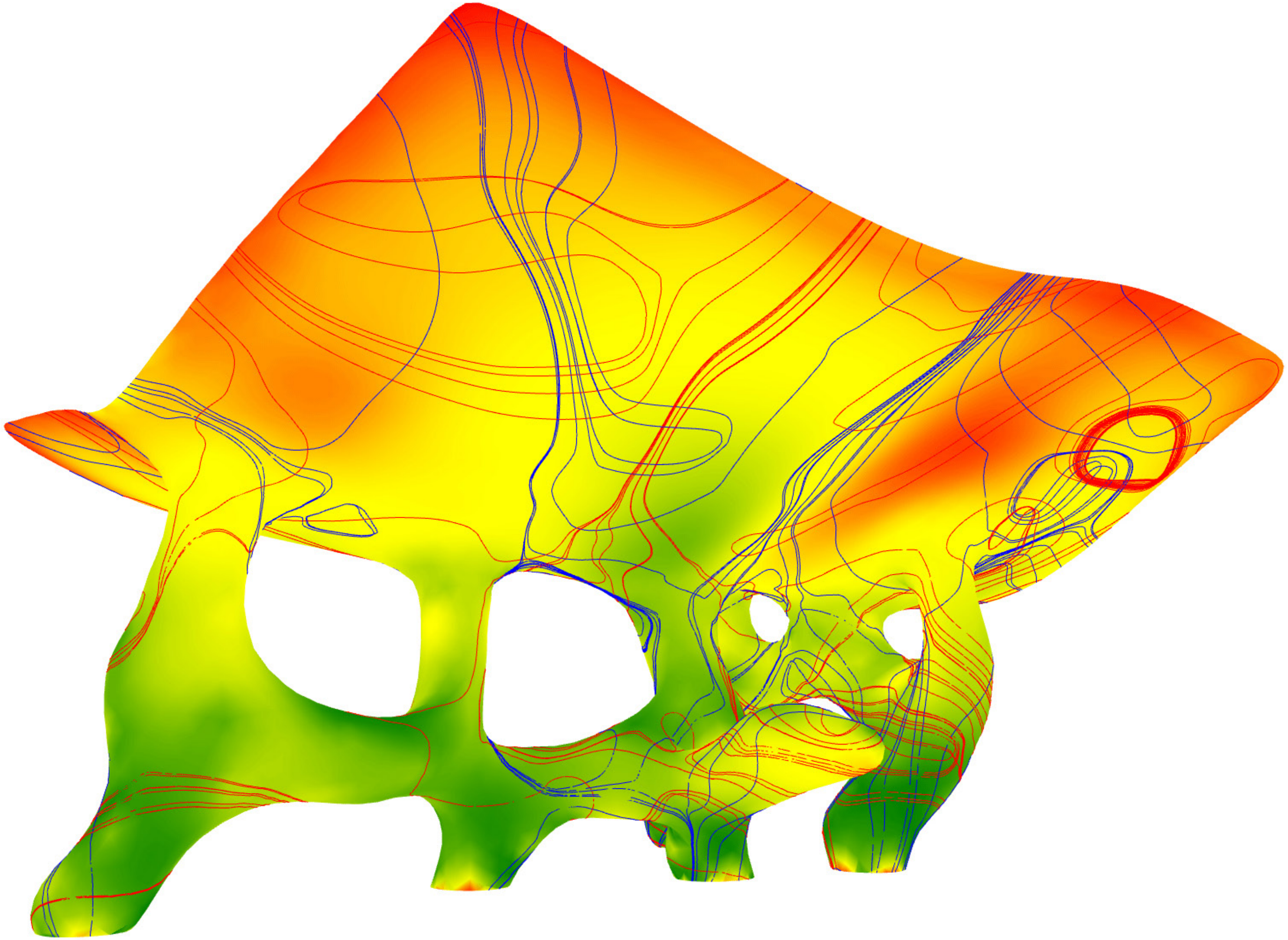


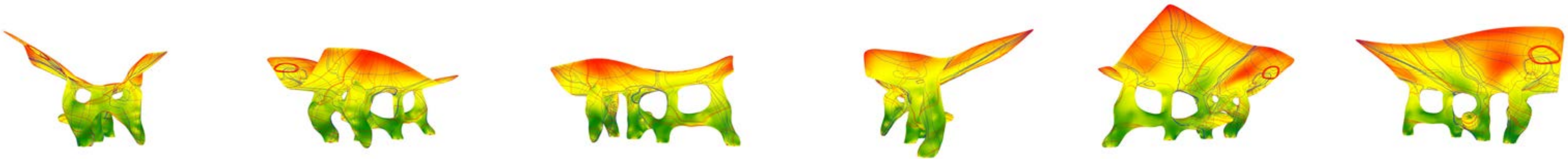
4/ pathways for plant growth

Structural analysis of the weave identifies stresslines which can be interpreted as ideal plant growth pathways. These can be mapped to 'nearest weave elements' - the elements to be replaced by plant growth.

Branches vary in strucutral capacity according to cross-sectional area. A coarse approaximation can be made to determine minimum growth requirements for target areas.

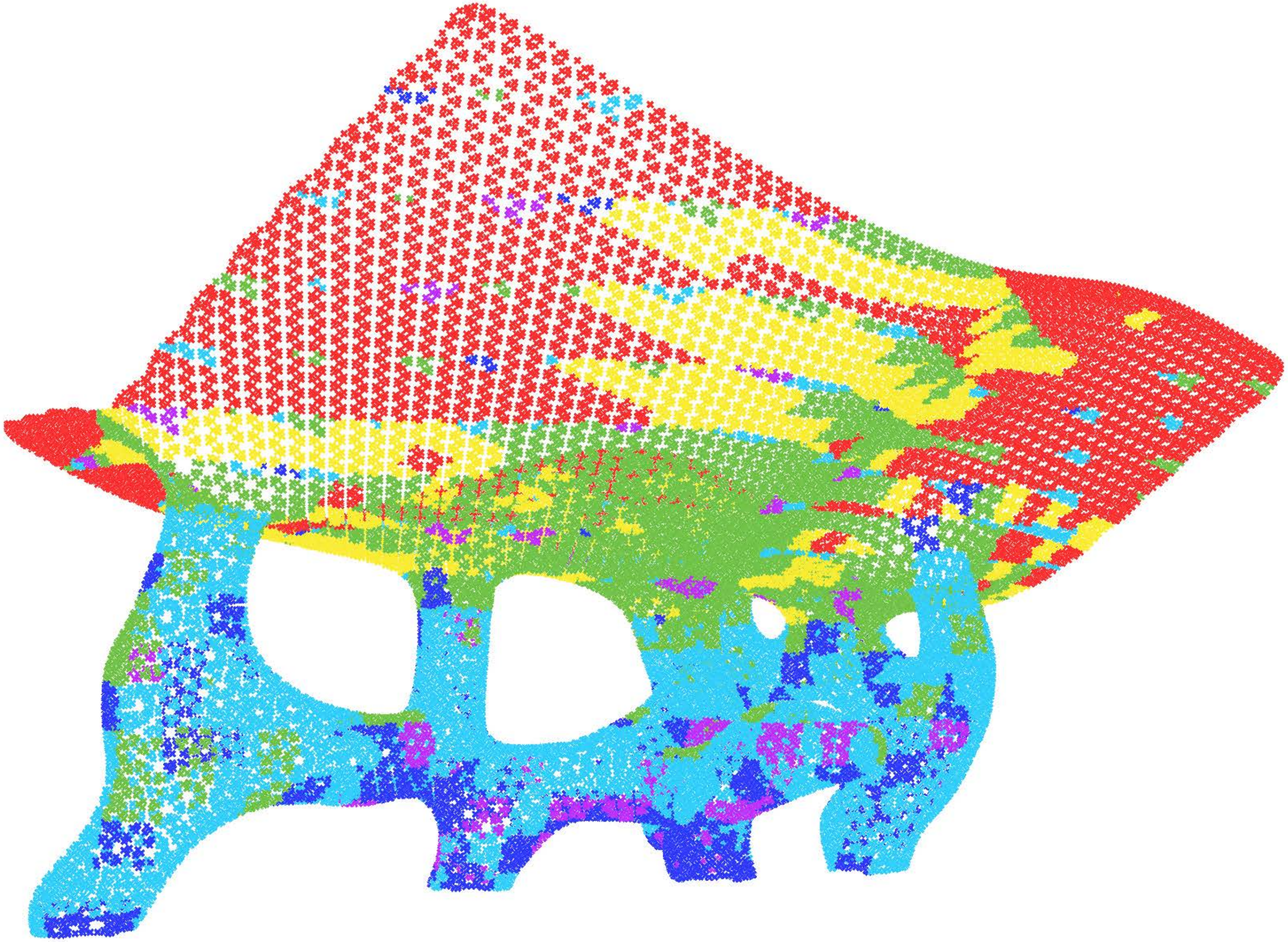
While waiting for plant material to mature to the required performance, temporary supports may have to be used . These can offer temporary architectural opportunity during this phase of the growth career, beofre being relocated or removed as can be seen in the 'anticipated growth career', p.28/29.





4/ **analysing conditions for species diversity**

The weave is also fully analysed to determine the number of sunhours across its surface so that specific conditions can be mapped to ideal species. In combination with the structural analysis this allows a developed understanding of suitable species to achieve specific perfomace requirements and exploit intrinsic conditions created by the weave.



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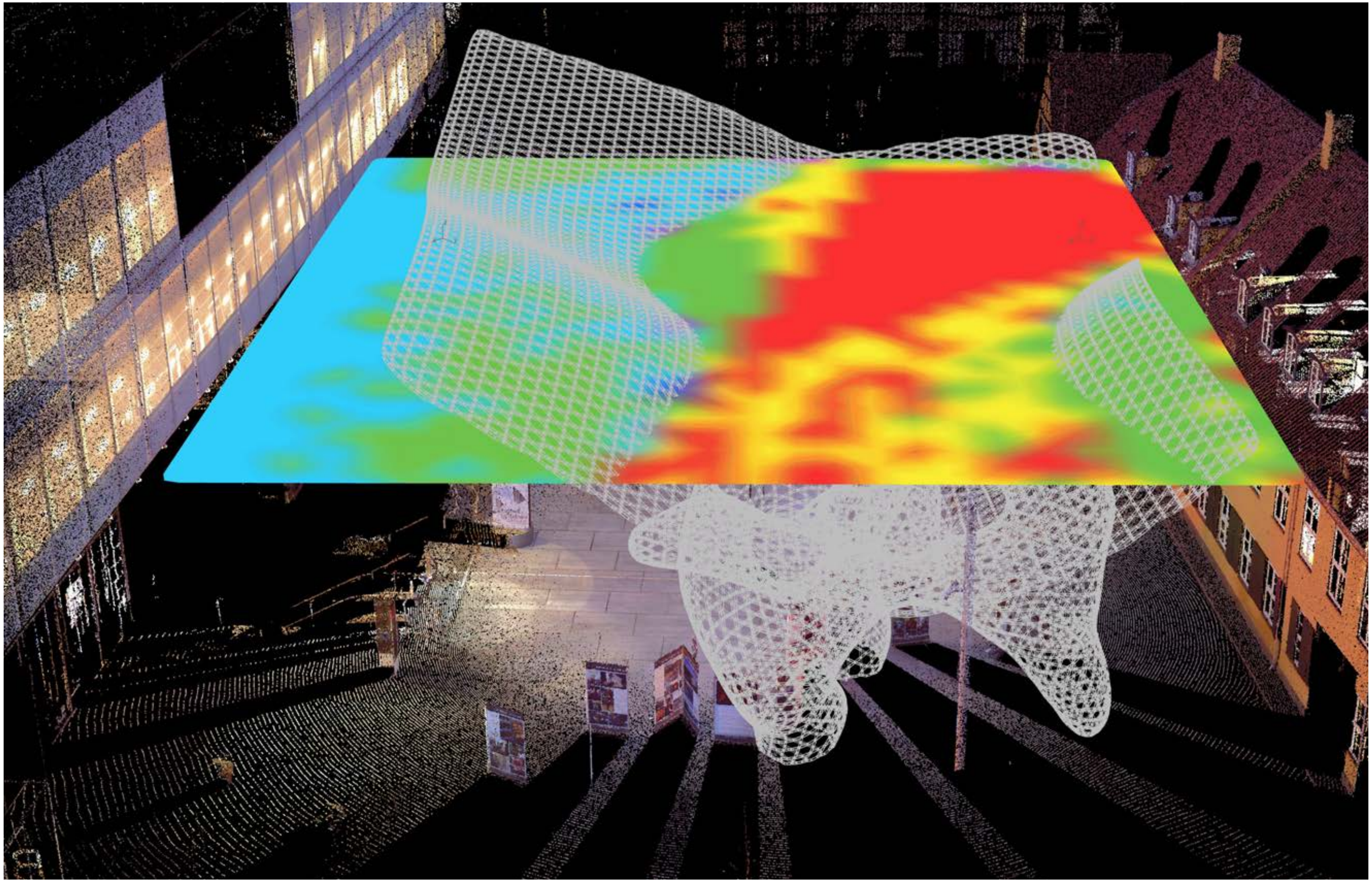
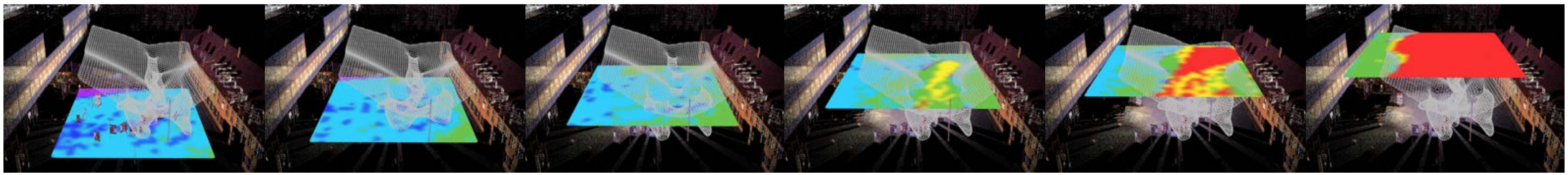
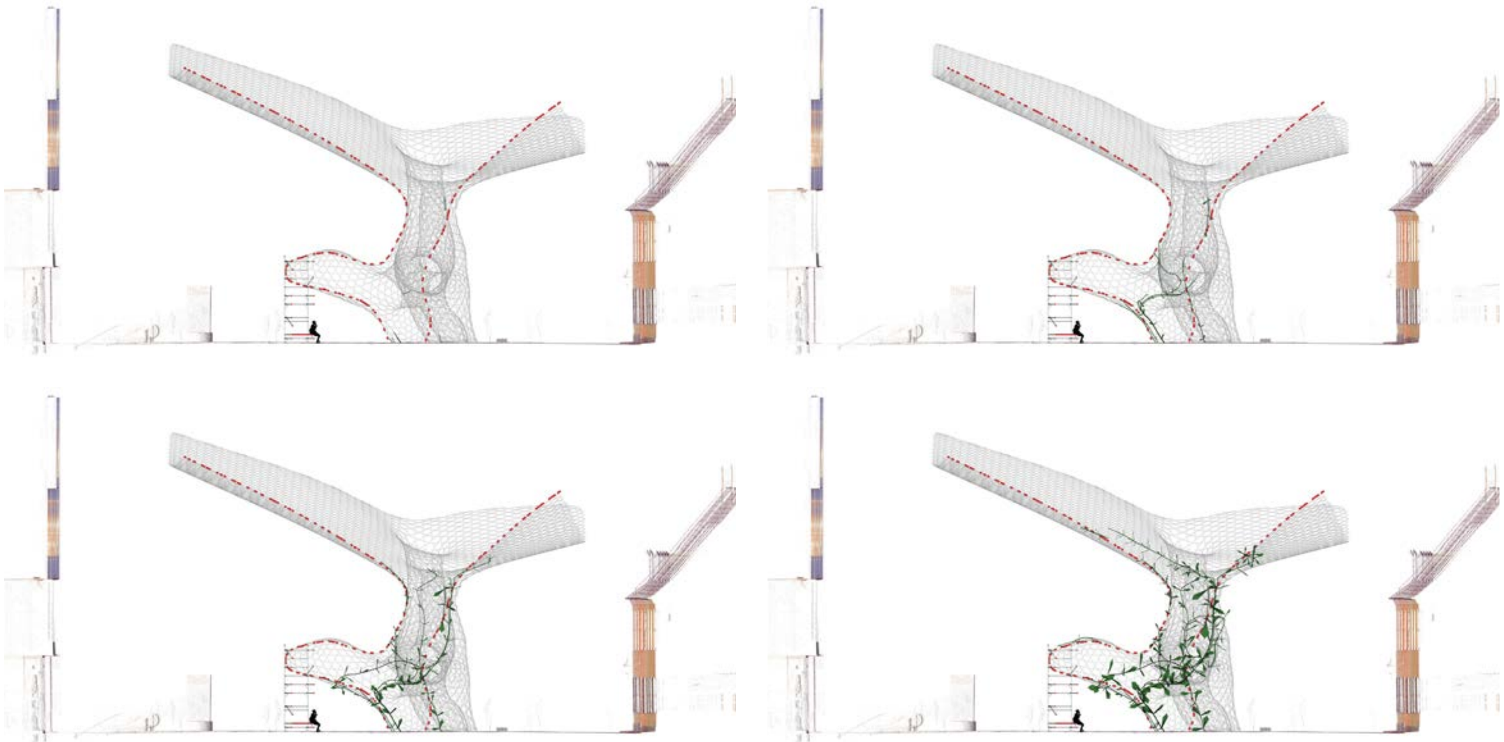
4/ effects on surroundings

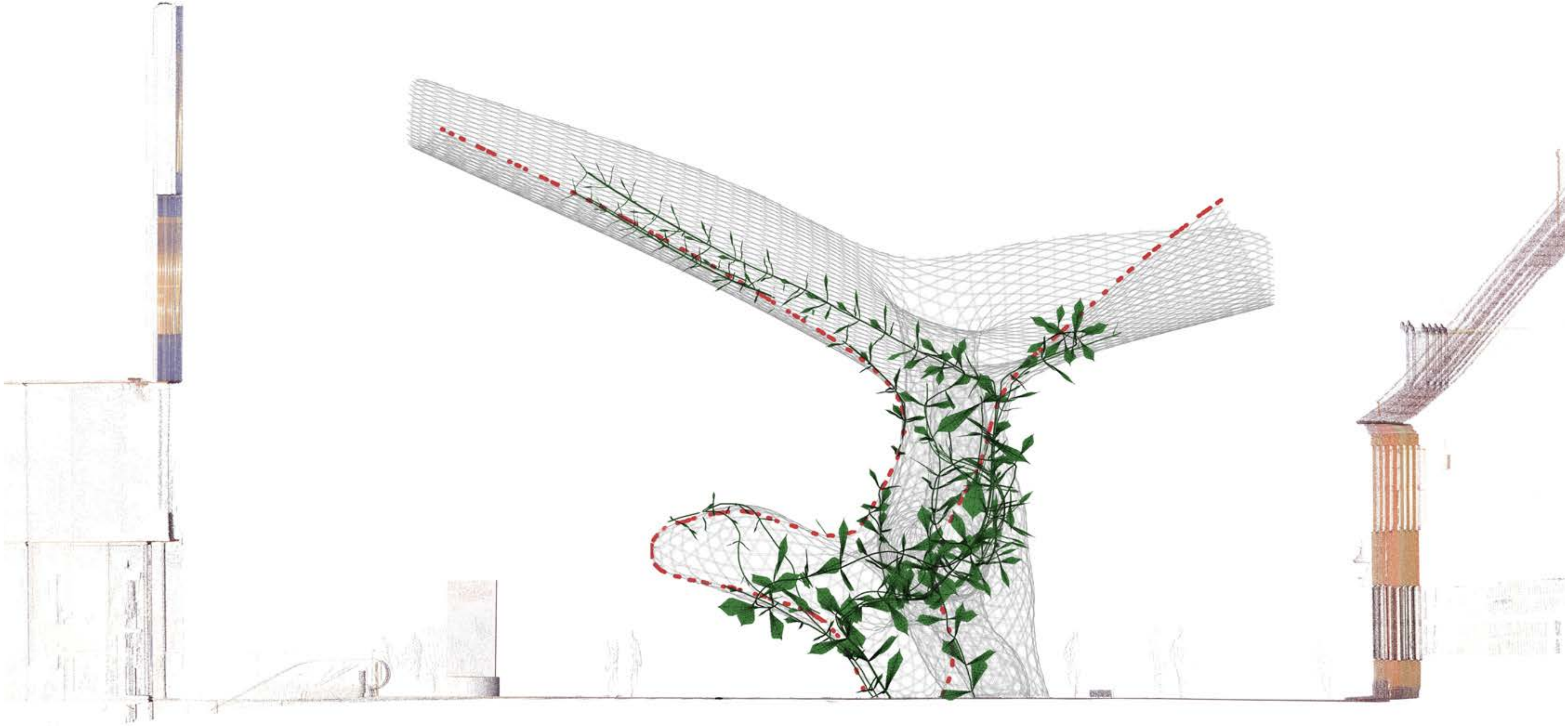
In addition to analysis sunhours on the weave itself, its impact on shading to the surrounding area is also considered. This feedback can be used to modify geometry in the preliminary design phase to ensure ideal conditions for surrounding plantings and anticipated uses.



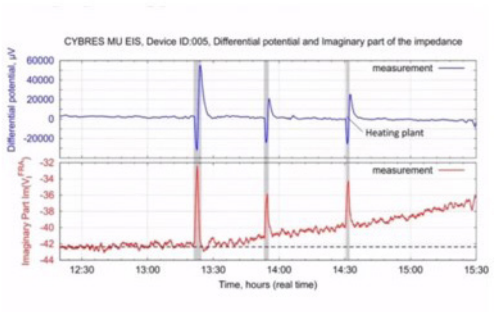


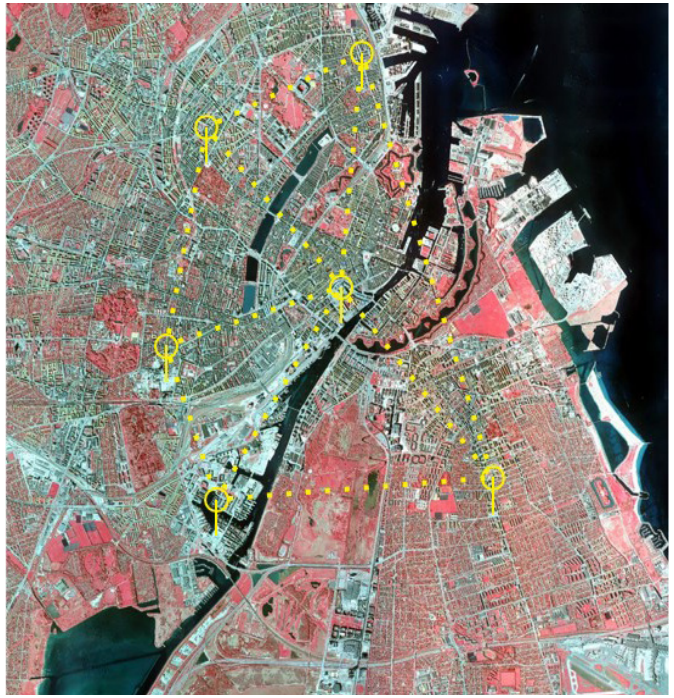
4/ anticipated ‘growth career’





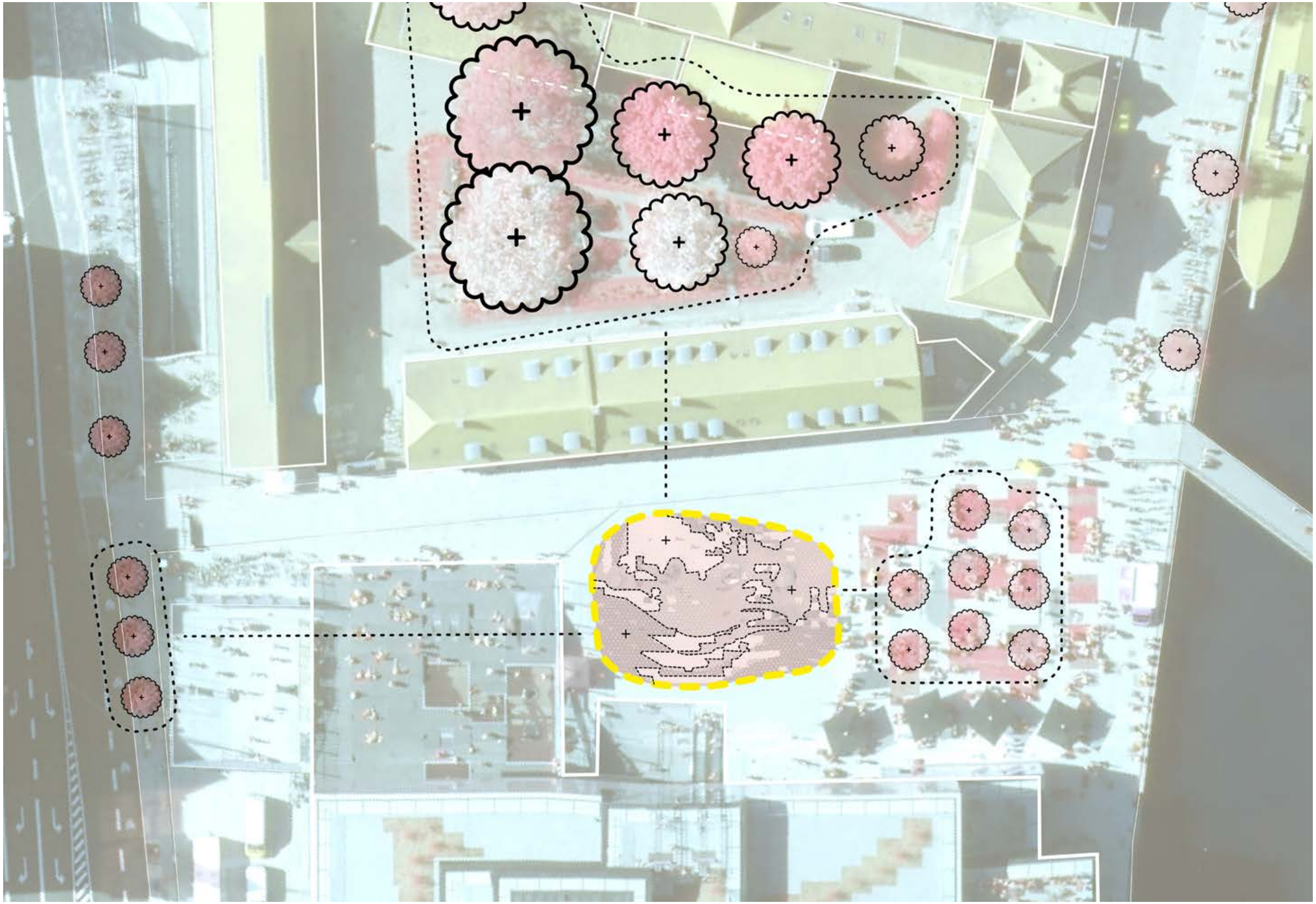
4 / connecting plant communities



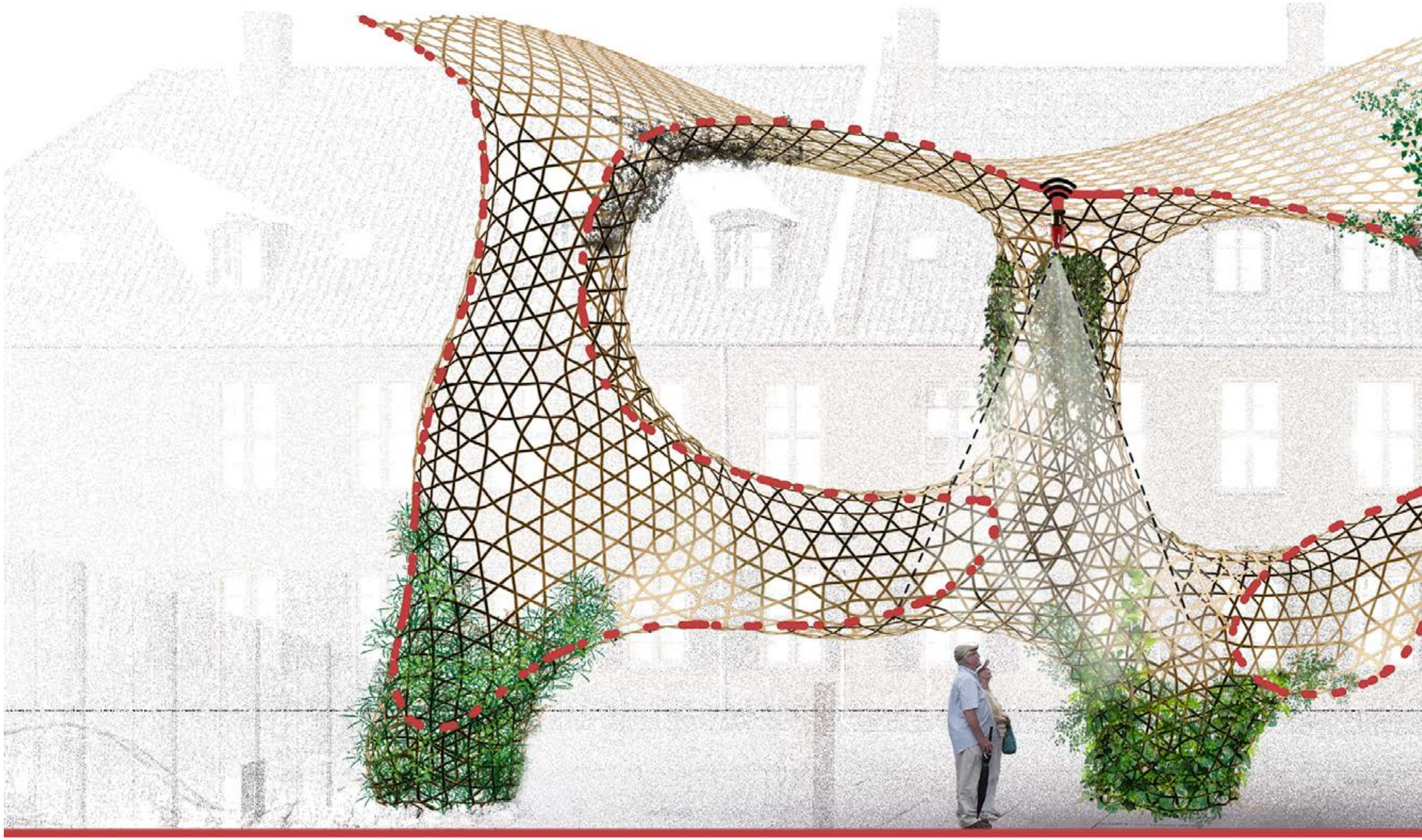


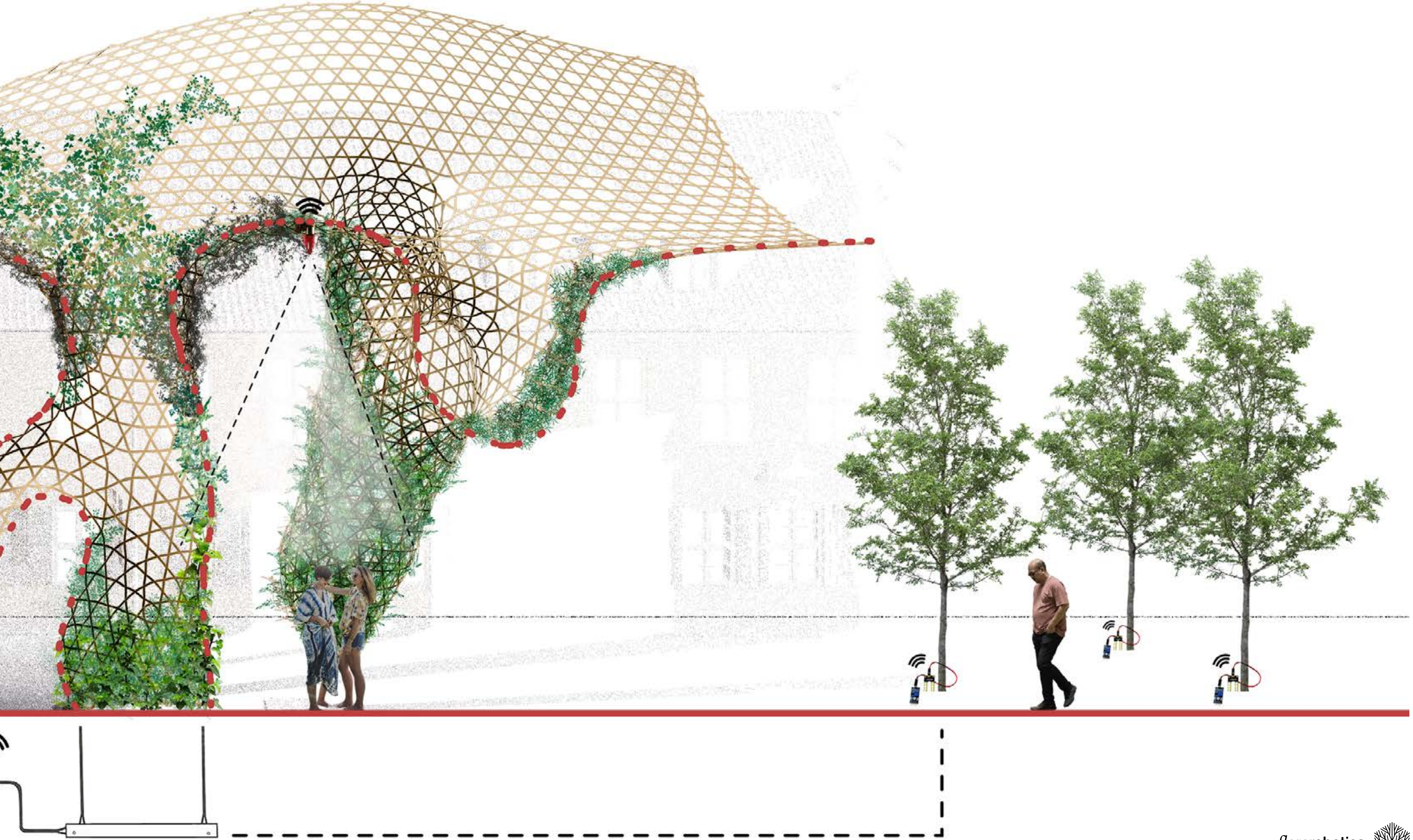
Here we speculate on the possiblity of creating an artificial analogue of the 'wood-wide-web' - the naturally occuring mycellium based network that binds individual plants into a communicating community. Our sensing and mechatronics partner, Cybertronica, have developed a phytosensing device for reading electrophysiology signals of plants. They have demonstrated its use in supporting plant to plant communication through coupled control of environmental stimuli (different coloured lights) and also plant 'learning' where plants can be trained to switch a light source on and off as required.

Deploying this technology in urban contexts would allow the networking of disconnected plant communities to enable environemtal monitoring, regulation of environmetal controllers (such as supplemtary urban lighting and water misting) and promote long-term adaptation and learning. This will create engaging, resilient, adaptive, co-occupied and aethetically potent public spaces aimed at increasing bio-diversity and city liveability for complex living ecosystems. The following spread indicates the connection of existing trees isolated by hard landscape, now connected and contributing to the bio-hybrid system.



4/ **bio-hybrid network**





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