Ambient Terrain

The generation of large-scale landscape site data for design applications

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Abstract. *'Ambient Terrain' explores the application of large-scale, sensor-based site analysis. The research develops various techniques dealing with the logging, storage, retrieval, analysis, and representation of sensor and image-based data. These techniques could be utilized in concert with traditional site preparation and site information gathering processes, and could arguably serve to reevaluate the site preparation process altogether in a manner which not only focuses on terrestrial data, but also on metrics which are dynamic and multidimensional.*
The research proposes direct applications for urban space and the built environment, in the modes of site appraisal, design and the generation of new spatial strategies.
Keywords. *Unmanned Aerial Vehicle; sensor data logging, ambient site analysis, UAV data collection; photogrammetry, stereophotogrammetry.*

BACKGROUND

The research implements the previous findings of the peer-reviewed paper 'Synchronous Horizons' (Girot et al., 2012) and develops strategies for the deployment of large-scale, spatial sensory data capture with the use of Unmanned Aerial Vehicle (UAV) technology. The techniques have been further developed to improve the nature and ease of capture of these datasets.

A site-based workshop marked the beginning of the advanced visualization module of the Master of Landscape Architecture course at the Institute of Landscape Architecture ETH in 2012. Facilitated by access to UAV technology and low cost electronics, the workshop utilized various environmental sensors, mounted onto the UAV of the Landscape Visualization and Modelling Laboratory (LVML). Sensors such as temperature and humidity were mapped at ground level, carried by the students, and at various altitudes to form a complete spatial dataset. The resulting data was combined in collaboration with the students in order to visualize and understand the characteristics of the non-visible site. The results and implications for spatial design were presented at the ACADIA 2012 conference in San Francisco (Girot et al., 2012).

The workshop had several pedagogic as well as investigative objectives dealing with the quantification and qualification of site data. The exercise was designed to make accessible common site data (such as topography, slope, viewshed), via photogrammetry, but also to look beyond the visual spectrum of site data collection to metrics which are spatial and volumetric, dynamic and subjective. The nature of the research was formulated deliberately to challenge accepted notions of 'spatial design' and 'spatial planning' which often do not consider truly

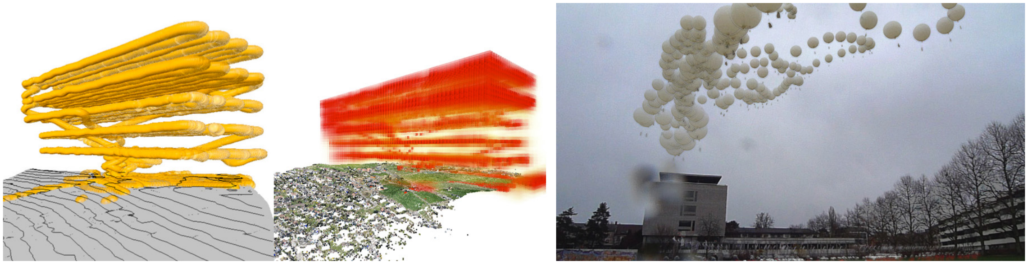


Figure 1
UAV and Balloon - Sensor movement and density mapped over time.

three dimensional data sets, and refer rarely to non-visual site environmental site metrics. The resulting multi-dimensional data sets present novel opportunities and challenges. With such methods, a designer can have immediate access to topographic and air strata data without necessarily needing to carry out a full site survey. On the other hand, representing the multi-dimensional data sets and thus drawing meaningful conclusions presented a unique and challenge, and as such a clear outcome of the research was that novel documentation and representation methods would need to be developed.

The study aimed to emphasize non-visual sensors, in order to heighten extra-sensory data capture, and understanding of site. A minimum density of sensor readings was acheived, in order to allow for reasonable interpolation of captured data (Figure 1 left). While compelling in their nature, they remained relatively abstract from the experience of the site occupant, or detached from a particular temporal sequence.

The research also integrates the results of the 4 day workshop 'Asynchronous Streams', conducted as part of the SmartGeometry 2013 conference held at the Bartlett, UCL in London (Workshop leaders: Dubor A., Fraguada, L., Pacegueiro-AC, F.). In contrast to the previous research, this marked the reintegration of visual data inputs via streaming video, in order to generate a true 'ambient' or sensorially contextual understanding of site. This second workshop, combined the concept of a spatial dataset with two additional aims, namely a streaming database, consisting of visual and abstract data over time, capable of realtime capture, relay, processing and visualization; and the choice of helium balloons to carry the moving sensors, allowing sound spatial readings and generating distinct patterns of movement based on local air movement.

The re-integration of visual input, via site video, facilitated the capture of site movement, and ambient visual information, such as site colours, light levels, and environmental changes.

TECHNIQUES

The research consists of 4 overlapping yet distinct phases, which shall be documented within the scope of this project; site strategy, capture processes, processing, and applications.

SITE STRATEGY

The test sites were chosen for their open, uncluttered nature, and strong spatial dynamics. In both workshop cases, this was accompanied by strong seasonal change, redevelopment potential or flexible program and use. These specific characteristics were chosen in order to highlight the spatial applications of the ambient datasets.

Additional considerations apply for air-bound sensors. Light to moderate winds typically provide a hindrance to the efficient function of the UAV used. In the case of the Asynchronous Streams workshop, the balloons, however sensitive they appeared to moving air, responded surprisingly well as a grid to the moderate winds experienced on site. The specific strategy regarding the anchoring and chosen sensor height of the balloons was adjusted on site accordingly, the tethers spread relatively wide (30° to ground minimum), and the balloons tethered to one

Figure 2
Photogrammetry positions from a) UAV campaign (MAS LA 2013 project site, Erstfeld, CH) and b) Asynchronous Streams (SG2013, London).

another in order to provide additional grid-stability, and resistance to gusting winds.

CAPTURE PROCESSES

The data capturing phase is undertaken with processes which implement several different software and hardware tools. This premise then supposes that the captured data is of multiple resolutions that can be understood as a whole set, or as the discrete data streams from which they originate.

The tools utilized during this phase range in cost and accessibility, though the objective was to identify low-cost and accessible tools for each phase of the capture process. Two main techniques are utilized for data capture: Photogrammetry and Sensor Data Logging. Both techniques are implemented through the aid of moving platforms, through public transportation, and traversing the site on foot. Moving data capture platforms allow for a wide coverage area for the data capture, while at the same time posing challenges in obtaining a sufficient data resolution in a particular area.

Each capture process is designed to cover specific volumes of the site (as opposed to only considering 'areas'). For large scale terrain generation through photogrammetry, the UAV drone is guided by a path perpendicular to the ground that allows a seamless set of images to be captured which in turn results in a seamless three dimensional point cloud (Figure 2 left). When the UAV is utilized for sensor data logging, several vertical 'horizons' are plotted to guide the drone to capture a specific volume of data. On foot, on bicycle, and on public transportation, the capture process is designed to complement the UAV campaigns. The 'terrestrial' campaigns are then supplemented in the same manner as the UAV campaigns, increasing data density as the target study area becomes clear. Specific additional paths are drawn in order to cover the site area and to ensure appropriate resolutions where it is necessary, and previous paths are retraced where the data is deemed to have 'expired' in its applicability.

The data capture process of the Asynchronous Streams workshop extended photogrammetry and mobile sensors with static, sporadic sensors (Smart Citizen) and database streaming (Figure 3). This al-

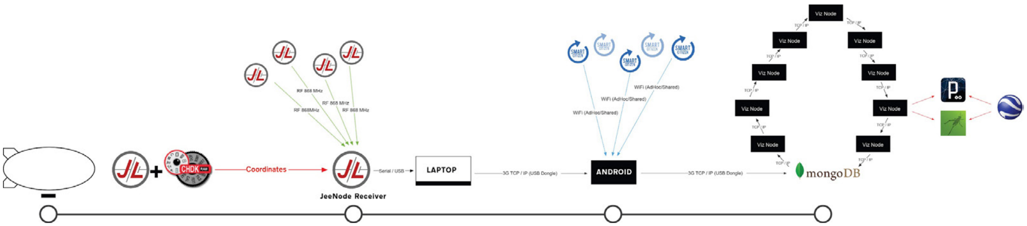


Figure 3
Data capture process of the Asynchronous Streams workshop.

Figure 4
Site capture and remote processing station, SmartGeometry 2013 (Participants: A. Velasco, L. Ghita, S. Jafari, G. Kyriazis, D. Shammas, D. Schildberger, T. Seppänen).

lowed two teams to work simultaneously, one on site, installing and maintaining the sensor arrays, and the other processing the data remotely, and supervising the process and resulting data as it arrived (Figure 4).

DATA PROCESSING

As has been stated, there are a combination of techniques and instrumentation utilized to create a complete and volumetric data set. Cross referencing the data in order compose a unified database is an important issue that needs to be addressed adequately. While photogrammetry and sensor based data give different results, each can be geolocated, time stamped, and tagged with attributes that allow for future queries and data merging. Thus, each piece of data, at its rawest form, can be considered a point in space and time.

The resulting visualizations demonstrated specific spatial understanding of the site, revealing, for example, Synchronous Horizons site variations in humidity in relation to neighbouring forest and infrastructure (Figure 5).

The processing and visualization of streaming data provides new opportunities in data comparison and temporal understanding and site, yet the associated overheads and challenges of interactive visualization proved formidable.

ISSUES

Representation

The data captured has the capability of being understood in various dimensions, thus two-dimensional representations would undermine the efforts of the investigation. Developing adequate documentation and representation standards for such data sets and their applications in spatial design are a primary objective of this research. A unique advantage of working with streaming data sets is the ability to develop visualizations and representations as incoming data is being processed, effectively merging

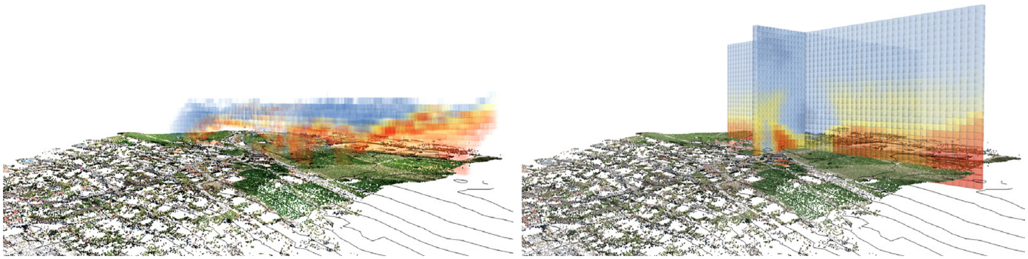
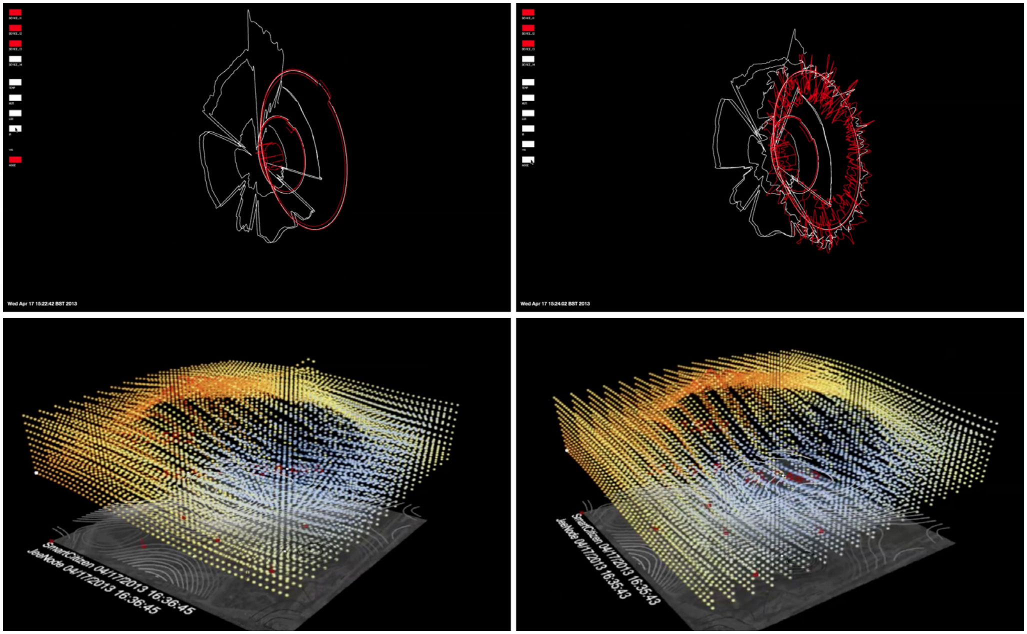


Figure 5
Static humidity data model mapped during the Synchronous Horizons research.

Figure 6
a) A large-scale approach to visualization - here the streaming dataset contains all sensors and sensor points are combined in one location (T. Seppänen); b) Dynamic humidity/temperature data model mapped during the Asynchronous Streams research (L. Ghita).



data acquisition with data interaction (Fry, 2007).

Issues of efficient data management, caching, and on-the-fly processing became primary restrictions in the implementation of the streaming data visualization samples developed during the Asynchronous Streams workshop (Figure 6).

Calibration

Many of the instruments proposed are low cost and easily acquired through local vendors. That being said, it is important to understand the difference in readings when utilizing sensors of the same type. Basic temperature and humidity calibrations can be performed, calibration of other instruments, such as air quality and sound are more complicated and require specific environments in order to properly calibrate. Groups such as the Public Laboratory for Open Technology and Science [1] are spearheading open projects which seek to bring down the costs of calibration and instrumentation for more complex and scientific analysis such as mass spectrometry. Also, government entities, such as the Environmental Protection Agency in the United States, have begun programs to study the feasibility of measuring complex metrics such as air quality with low cost sensors [2]. These feasibility studies include the calibration of commonly sourced NO2 and O3 sensors used in citizen science platforms such as the Air Quality Egg or the Smart Citizen. While calibration remains an issue, the data captured can still be analyzed for trends, making use in the changes from one data point to another to understand the dynamics of the site and not necessarily the specific metric.

Data Archiving

Another issue that is a direct result of our combinatorial data collection process is the differing formats in which the data is collected. While it would have been relatively simple to standardize data formats in order to stream directly into a structured query language database (SQL, i.e. MySQL), we opted for a NoSQL solution. This was a deliberate decision as we recognized that the importance was in archiving various formats of data. Because the data is streamed directly to the archiving database as it is being captured, the timestamp becomes the key to correlating data. A NoSQL [5] database (i.e. MongoDB) is able to record data from multiple types of processes and instrumentation, formatted in different manners, so that data can be queried as a continuous stream, or as discrete streams specific to their source and method. The data format need not be known prior to data capturing, and it need not necessarily correlate to formats being used with other instrumentation. The system is not limited by the type of data that is being archived (numerical, image based, or audio based) allowing flexibility for future data formats not implemented initially.

OUTLOOK

Implications

The process offers direct implications for the future construction of buildings and the built environment. Given the speed of deployment and analysis, site-specific microclimate analysis can be generated based on time of day, season, or specific weather event, allowing the quantification of local climate change impact. Despite continual improvements to the efficiencies of the building construction process, the relatively long-term nature of large scale building sites provide perfect grounds for implementation of such sensor networks - where feedback on the impact of changes to the built environment can be recorded as they take place.

Such analysis could continue during the construction process, mapping the true spatial impact of construction projects on the built environment, and bringing new solutions to light, in regards to site-specific adaptive building requirements. The results could generate new models for site-specific and cubic metre-specific opportunities for optimization of ventilation, adaptive facades, air humidity and pressure differentials.

There is a specific lack of research in the area of temporal urban microclimate site analysis, as to support the field of simulation in (Moonen et al., 2012). In this specific field of Urban Physics, which relies predominantly on wind tunnel and CFD simulations, these real-world sensor applications can validate such specific fields of research as pedestrian wind comfort, pedestrian thermal comfort, building energy demand, and pollutant dispersion.

Parallels between environmental flux, (non)usage and ambient context can aid in the re-conception of spatial understanding and potential. Design criteria can be balanced with context criteria, further influencing not only the understanding of the development of space, but the potential evolution of the city.

The technique can be combined with human occupation and movement studies in order to overlay ambient context with use and reaction. This concept has already been tested using the streaming image data, but has not yet been applied in the field.

Within the field of the open space and city development, a fixed, predictive model is no longer relevant in the design of comfortable, durable, and sustainable open space design. A gradually evolving network of public spaces can lever such techniques of re-appraisal in order to optimize existing environments and improve the performance of new urban landscapes.

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