DRAFT – Not for wider circulation

Smart City Pilot Project Proposal
Mobile IR street mapping for urban heat island research

TULIP

TULIP is UTS' leading smart city project delivery program. It is a joint initiative from the Institute for Sustainable Futures (ISF) and the Faculty of Engineering and IT (FEIT). TULIP is developing a blueprint for open community smart city project delivery. Our focus is environmental monitoring for urban liveability and climate responsive neighbourhoods.

This proposal is for an R&D project at UTS in collaboration with the car sharing company GoGet. We would further seek to engage a Western Sydney metro council. The core of the proposal is the development of a rapid response road surface monitoring device that can be mounted beneath a vehicle. The device would transmit real-time heat, GPS and time-stamped data packets to the TULIP platform, building up a dynamic real-time picture of urban heat in the city. There is also an urban heat research component a citizen science and community engagement angle.

Heat events, which are themselves intensifying in strength and regularity, are a major concern for Australian cities. The issue received significant attention in the City of Sydney's 2015 publication *Adapting for Climate Change: A long term strategy for the City of Sydney*. The report identifies a series of Action Pathways for adapting to the impacts of heat events, including but not limited to development of a heat wave response plan and communicating and raising awareness of the issue with the public.

Existing locally-specific information about urban heat comes from relatively expensive one-off GIS aerial snapshots of the city. Internet of Things (IOT) technologies such as LoRaWAN or 3G enabled sensor networks now have the ability to provide low cost real-time, high-definition geographical data about urban heat. This is continuous or on-demand data for less than the cost of chartering an aerial survey.

*"**Heatwaves:** Extreme heat days are expected to increase. This means that heatwaves will become hotter, last longer and be more frequent. The heatwave of 37.7°C that Sydney experienced in 2011 would have been considered a 1 in 100 year event in 1995. This is projected to become a 1 in 2 year event by 2070, meaning that heatwaves of such a magnitude could be expected every two years on average. Sydney currently experiences days of extreme heat, that is, over 35°C, 3.7 times a year on average. Our research concluded that by 2030 this is projected to increase to5.8 times a year and is likely to occur 15 days a year by 2070. Such an increase in the occurrence of extreme heat will have a significant impact on our community..."*

- Adapting for Climate Change: A long term strategy for the city of Sydney, 2015

Illustrating the data deficit

Sydney metro councils rely entirely on costly single snap-shot aerial IR maps

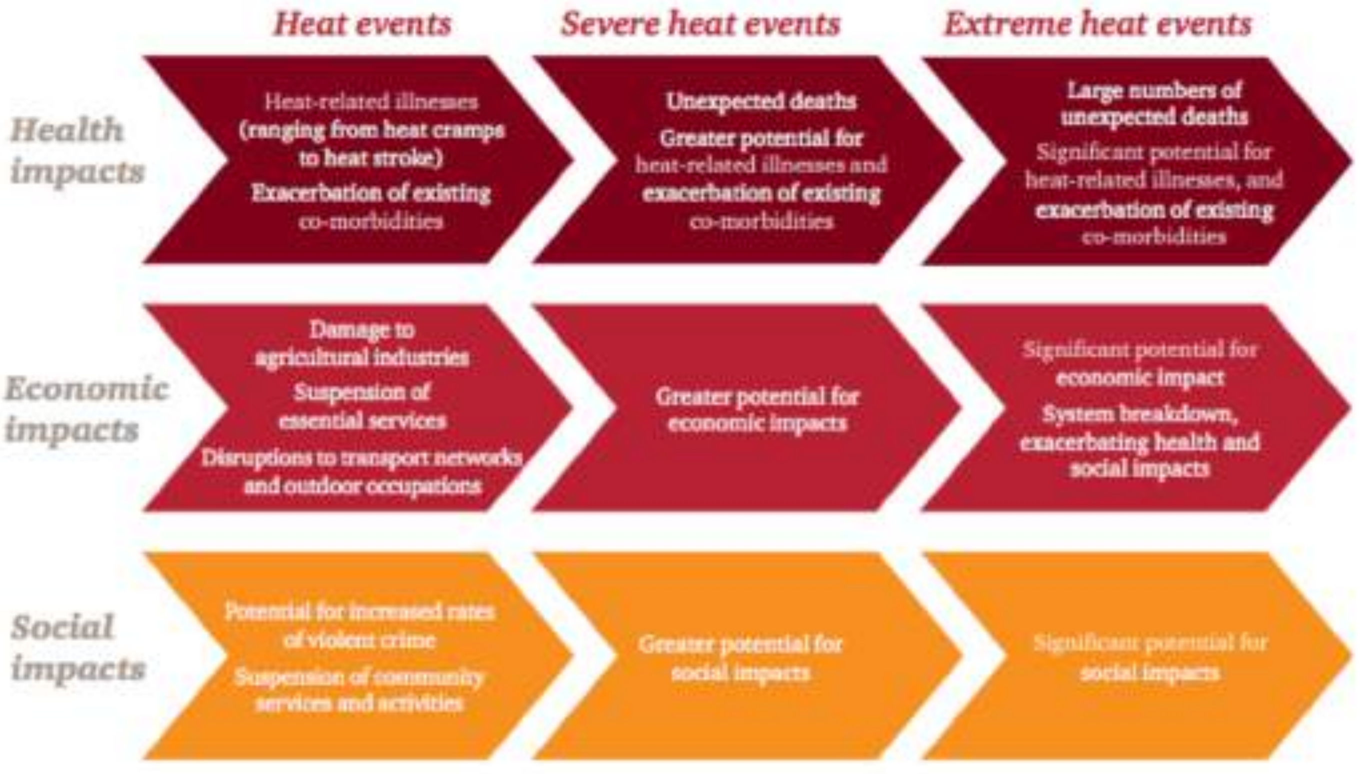
Existing heat map from *Adapting for Climate Change: A long term strategy for the city of Sydney, 2015*

Note the following:

- The data is six years old at the time of publication and represents the most recent data available to the City.
- The flight details – production of these maps is costly as it involves chartering a survey plane, hence the infrequent data updates.
- Roads are clearly the hottest surfaces in the city and are the main contributors to the urban heat island effect.
- The roads are hotter (33°C) than the maximum temperature for the day (29°C)

Parramatta
Similar scenarios exist across Greater Sydney. Parramatta's *Cool Parramatta* website provides access to aerial IR maps from February 2013 – data that is now five years old, from a single snapshot in time.

Image: Heat map from City of Sydney *Adapting for Climate Change* strategy, 2015



A versatile tool for mapping street heat

We propose trialing a pilot concept designed to allow continuous or on-demand heat mapping of urban streets. This involves the development of a new custom device that makes use of an infrared (IR) temperature sensor and attaching it to the underside of a GoGet fleet vehicle. The system would combine an IR temperature sensor, a GPS device, a digital clock and a connectivity technology (e.g. LoRaWAN, 3G). The IR sensor would provide a continuous reading of street surface temperature as the vehicle drives around the city, with data tied directly to GPS coordinates and time. This data would be sent to the TULIP platform. The output would be a map of the city with data displayed in colour wherever the vehicle has driven.

We propose that this technology might be piloted on a single vehicle, to test practical application of the technology. One vehicle, during the course of its standard duties, might not travel down a significant number of streets on a certain day. It might be sent out on demand to gather heat data, however that is not the final approach we envision. Instead we envision a significant number of fleet vehicles being fitted with this technology, which is small, relatively low-cost and would sit out of sight beneath the body of a car. This would be a system whereby fleet vehicles are not repurposed as data gatherers but gather data as a *secondary* activity to their primary functions. The daily movements of the wider car fleet would cover a significant proportion of the city's streets.

This technology would only provide data for street surface temperatures, however this is certainly of great relevance to strategic planning and communication. Streets are the hottest areas of the urban landscape and the greatest contributors to the urban heat island effect. They also represent a large proportion of the public space for which a city government has direct jurisdiction. An aerial IR survey provides data on all surfaces and so would continue to be of relevance, however this new technology would essentially 'fill the gap' in time between surveys. It may even be possible to calculate a relational factor from aerial data between road surface temperature and other surface types such as roofs and parks, allowing IOT data on road temperature to be extrapolated to model surrounding surface temperatures. The accuracy of this modelling could then be verified and adjusted with a new aerial data set carried out simultaneous to IOT data capture.

Vehicle-mounted environmental sensors: a new data gathering approach for enhancing the power of Geographical Information Systems (GIS)

Digital technologies are increasingly enabling the decentralisation of the fundamental building blocks of our society, perhaps most notably information. IoT in the hands of a city government can provide vast quantities of incredibly rich data about the urban environment, its systems flows and occupants. The cost of IoT hardware and communication networks is dropping all the time, making it not only accessible but increasingly a better value option than the previous approach of contracting GIS surveys. The data becomes dynamic, rather than a static snapshot, and may be used to evolve adaptation strategies and even to provide real-time feedback to automated urban management systems.

Static smart sensors are starting to be deployed across cities and these will provide more precise environmental readings from single locations over time. This data may be important for calibrating vehicle mounted sensors. It seems likely that both static and vehicle-mounted sensors (and indeed aerial surveys), will work together in helping us to build an accurate understanding of urban heat.

Vehicle-mounted environmental sensors carry a few distinct advantages worth noting:

1. Mobile car-mounted sensors are easy to deploy because they involve working with a single organisation (albeit one with a large vehicle fleet) and the fleets tend to also be standardised (multiple vehicles of the same model), meaning a one size fits all approach with regard to mounting and calibration.

2. Mobile sensors are easier and cheaper to maintain than static sensor deployed out in the urban environment. A technician can visit a single garage to work on all systems in one place or a vehicle can be driven to the facility of a third party without needing to call anyone out to a street or rooftop location and gain all the necessary permissions for elevated access.

3. A vehicle-mounted device is able to draw power directly from the vehicle. This does away with constraints such as battery life, the cost of a small PV panel (such as might be included with static sensor arrays) and indeed the cost of a battery itself. This makes for a smaller and cheaper piece of hardware that does not require annual or bi-annual battery changes.

Image: A Micro-Epsilon thermometer CTfast non-contact IR temperature sensor

Rapid response IR temperature sensors

Non-contact infrared (IR) temperature sensors are able to record the thermal radiation emitted by a specific surface in the same way that a camera lense might focus on a specific spot within the visible light spectrum. The technology may be familiar to many people as a handheld ‘temperature gun’. Standard IR temperature sensors require a little less than two seconds to provide an accurate reading. A vehicle travelling at 40kph covers eleven metres of road a second and 22 metres in two seconds, hence a temperature reading of the road surface would only be possible every 20 seconds or thereabouts, an inadequate resolution. However, new ultra-fast IR sensors have a response time of as little as three milliseconds (0.003 seconds). As a vehicle drives along at speed, this rapid response time will allow for high spatial resolution with a reading at 40kph possible every seven centimetres. The temperature sensitivity is less than 0.5 of a degree.

The resolution that may be attained from this technology is likely to be vastly higher than can be achieved from an aerial survey. This extremely high resolution would be enough to show the presence of shadows across roads, cast by specific trees and buildings. It could in turn provide information that is highly relevant to urban planning and tree policy that is not available from current data sources.

Applications of the data

- Inform urban planning and policy decisions.
- Inform emergency strategies for dealing with extreme heat events.
- Interpret data and place it in the public domain through physical installations or mobile apps.
- Street heat correlates very closely with air quality because hot roads encourage ozone formation. Real-time data about street heat can provide a precise spatial indication of real time risk to public health. This data might then be fed into an automated system such as traffic management. The system would be made aware of literal ‘hot spots’ with a priority to clear those spots of traffic, possibly with reference to additional data such as the location of nearby schools or incoming weather patterns.

Early implementation

Pilot phase:
Work with FEIT to develop a prototype device and data analysis/visualisation platform. Install one device onto one GoGet vehicle. Test the technology in the field using GoGet car(s).

Second phase:
Demonstrate the prototype to local government authorities. Implement multiple vehicle installations. Test how data collection works practically in this circumstance and how the data analysis and visualisation performs over a more extended period, with larger data sets. Work with GoGet and through councils to engage communities with data gathering and data outputs.

Third phase:
Address issues arising from second phase and expand installations across a wider city fleet. Investigate business models for scalability. Also explore ways of expanding the capacity of the technology and its application.

Possible expansion of the concept

- Add multiple IR sensors to a single vehicle array, allowing it to gather temperature data across the width of the road. This might be done by fanning sensor focus points out in front of the vehicle. The result would be a vastly more complex spatial map of data. There may however be practical constraints, such as the presence of other vehicles blocking lines of sight to sensors.

- Certain other types of sensor might be added to the vehicle arrays, such as air quality or noise sensors. Air quality is strongly related to vehicle exhaust emissions particularly Nitrous Oxide and its by-product Ozone and both are hazardous to human respiration. A vehicle carrying these sensors would need to be 100% electric so as not to directly affect the readings. It may be that readings taken in traffic, near the road surface, fluctuate too wildly for accurate readings, or it may be possible to correct for this and possibly to combine such data with data from stationary sensors placed higher above the ground.

- Self-driving vehicle technology is already commercially available and is likely to be incorporated into fleets within the next decade, assuming widespread uptake. This presents further opportunities for vehicle-integrated IoT sensor technologies, which will be free to roam autonomously.

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