

UScan: Towards Fine-Grained Urban Sensing

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Abstract.

We have recently seen rapid advancement in wireless sensor networks. They are expected to be used for measuring temperature and weather information in a fine grained resolution. Particularly in urban areas, there are various factors to determine the environment; the existence of buildings, parks, and trees along streets affect the flow of wind and shaded areas. We extract the real-world information in urban areas for more comfortable lives by utilizing the fine grained sensed information. In this paper we describe a system of urban sensing and effective placement of sensors based on our experiment in downtown Tokyo. We also speculate the correlation between the trend of temperature and the environment.

Key words: Urban Scanning, Fine Grained, Placement of Sensors

1. Introduction

Basic technologies of wireless sensor networks^[1] have been established and various applications^[5] of wireless sensor networks are currently under investigation. Our group is exploring an application that can help urban lives. One can find an ambient walking route and an "oasis" spot, a windy and low-temperature location in hot summer.

However, the distribution of temperature and the strength of wind is complicated among tall buildings in a city. To enable such applications for ambience, weather-related sensors need to be placed in a fine grained manner.

We have created a system called UScan by which temperature in fine resolution was measured in downtown Tokyo. The UScan consists of a server to collect temperature data, wireless bridges, and uParts^{[3][4]}. We used approximately 200 uParts and collected data during July and August, 2007.

This paper is a report of the experiment using UScan and discusses the relationship between the structure of the environment and observed temperature.

The rest of the paper is organized as follows. Section 2 introduces the architecture of UScan. Section 3 discusses the actual placement of UScan sensors. Sections 4 and 5 show the results of experiments and the analyzed remarks. Finally, Section 6 describes the conclusion.

2. System Architecture

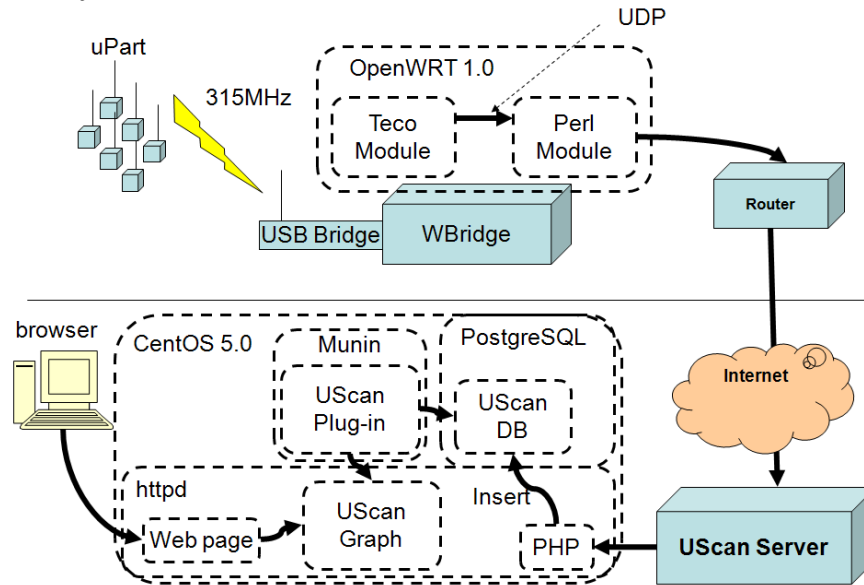


Fig. 1: System Architecture

UScan system architecture is shown in Fig. 1. First, uParts, sensing devices, obtain temperature values and send them to a receiver called WBridge at intervals of 30 seconds. OpenWRT is installed on the WBridge and contains two processes: Teco and Perl modules. The Teco module transfers the data to the Perl module using a UDP socket. Once the Perl module receives the data, it extracts temperature and send it to UScan server. UScan server receives the data and insert that to UScan Database(DB). Munin Plug-in monitors the Database and create a graph. The graph is visible on a Web server.

3. Installation of Sensors

In urban areas such as downtown Tokyo, there are various factors to determine the environment; the existence of buildings, parks, and trees affect the flow of wind and shaded areas. In this section, we explain how we consider installation of sensors.

3.1 Placement of Sensors

In this environment, we have selected eight observation points as shown in Fig. 2. We have set the following policy: each observation point characterizes an environmental feature. For instance, both points G and A are located at a pedestrians' path of a broad street. But they differ in whether or not trees of

creating shaded areas exist

Since tall buildings can block sunlight, direction of observation points is also an important factor for temperature. Thus, our observation points include every direction; North, East, West and South.

In this way, urban area has many environmental factors complexity. Every observation point has different environmental factors. The result of this experiment is described in Section 4.

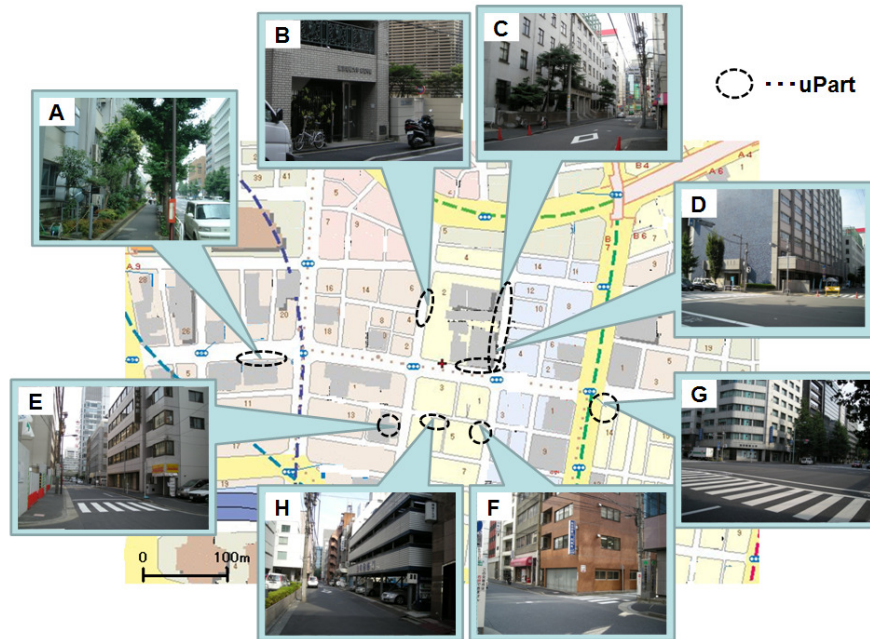


Fig. 2: Overview of sensor installation

For actual installation, we need to adjust the setting point of sensors to conduct correct experiment. Since every building differs in its size and height, walls, plants, and windows.

Since direct sunlight affects the temperature sensor of uParts, sensors need to be set to shadow area all day. For example, Point **b** and **c** are affected by direct sunlight as shown in Fig.3. Hence, these points cannot be candidates for setting sensors. Point **a** is the most suitable place for setting sensor in Fig.3. Similarly, Point **d** is irrelevant for setting sensors in Fig. 4. Therefore sensor is set at Point **f**. In this way, we set 200 uParts with these policies for the experiment.

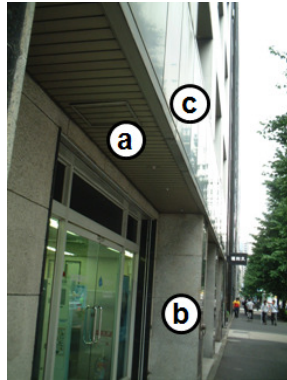


Fig. 3: Setting Example 1

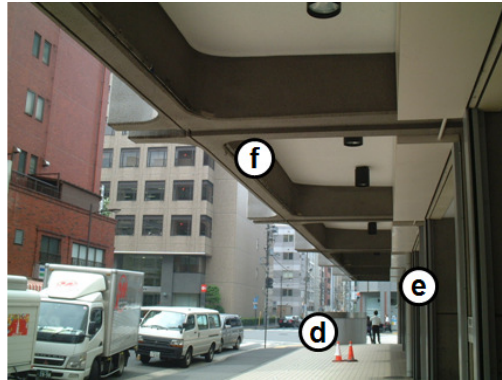


Fig. 4: Setting Example 2

3.2 Package of Sensors

To enable fine grained urban sensing, we need to set many sensors in the observation points. However, as shown in Fig. 3 and 4, setting points of sensors are restricted. Therefore, we made two types of packages for setting sensors as shown in Fig. 5.

A package in the right-hand side is utilized for setting to roadside trees or rain pipes. This package focuses on shutting out direct sunlight and can also be waterproof. Temperature sensor is covered with a white roof. Additionally, since the sensor package is placed at a high point, to avoid falling of the sensors, the sensor package must be light. Therefore the white roof is made from waterproof paper.

A package in the left-hand side is a simpler one. This package is utilized for setting sensors on the wall of building. To enable setting on the building wall, this package is very small and light.

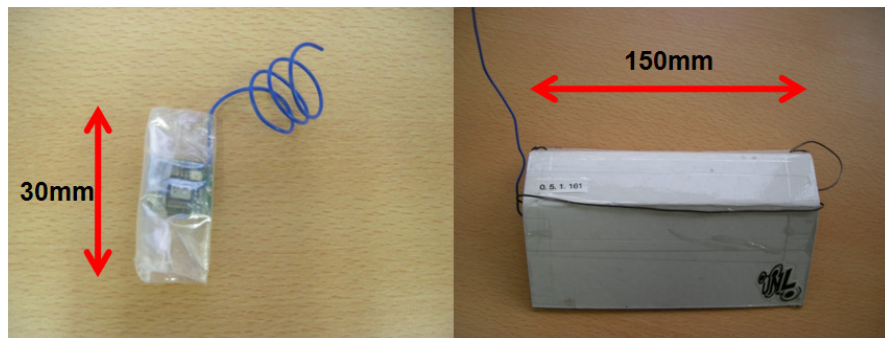


Fig. 5: Sensor Package

4. Experiment Result

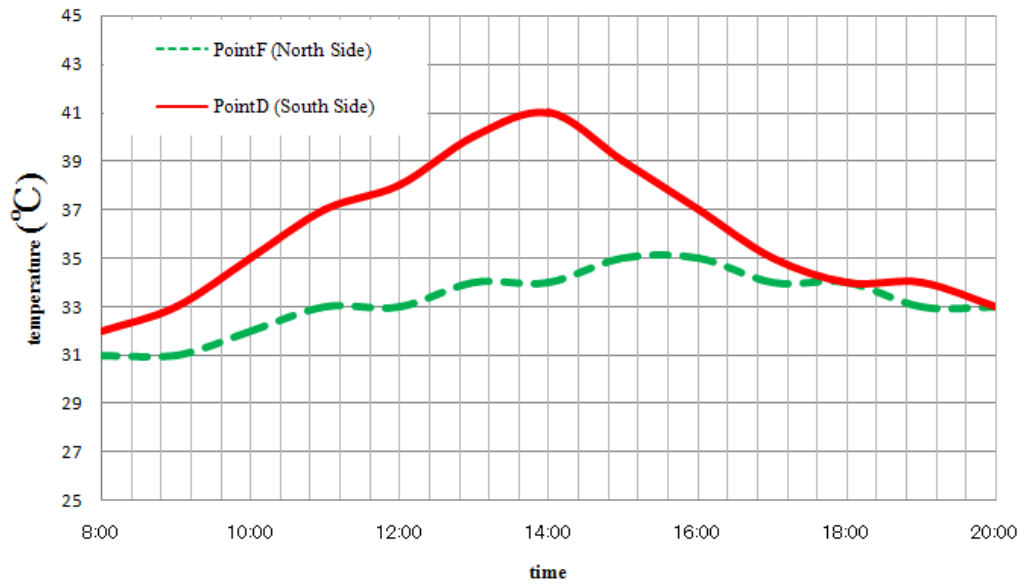


Fig. 6: Broad-Street vs. Alley (August 21, 2007)

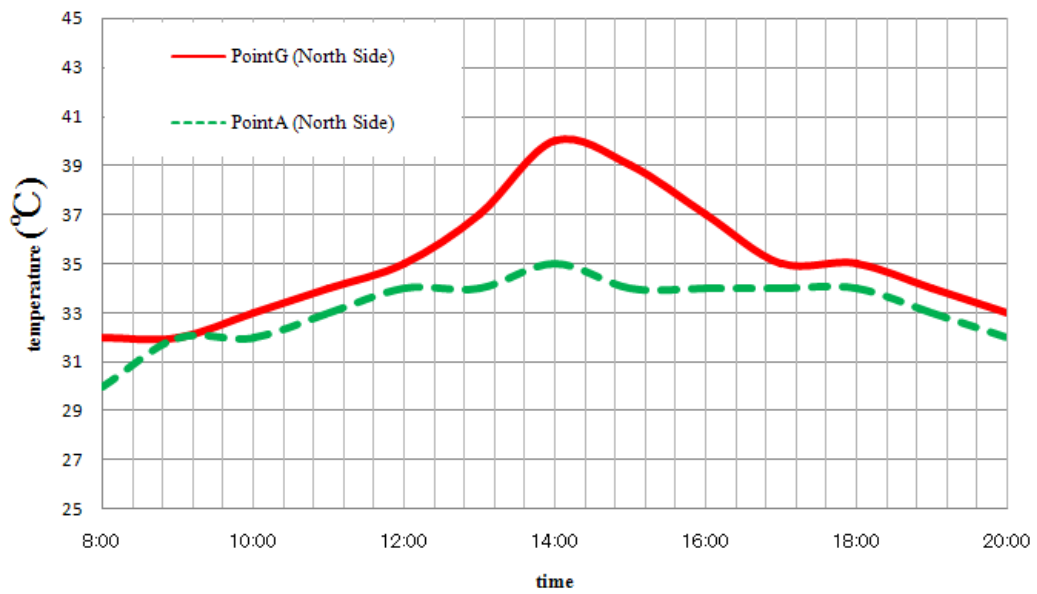


Fig. 7: Effect of Roadside Trees (August 21, 2007)

Our experimental result is shown in Fig. 6 and 7. These graphs show clear difference in temperature with regard to the observation points. For example, Fig. 6 obtained temperature at Point F and D. Although these points are only at 50-meter distance, the maximum difference in temperature reaches six degrees Celsius. Fig. 7 shows effect of roadside trees. While the north side of Point A has many trees, the north side of Point G has no trees. The difference between them appears as the difference in temperature up to five degrees Celsius. These differences validate the importance of fine grained sensing.

This difference of temperature is caused by environmental factors; Roadside trees, width of roads and direction. Therefore, we will analyze these factors in the next section.

5. Analysis

5.1 Parameter organization

In this section, we analyze the obtained data. Let us revisit the factors to affect the environment.

***Direction**

In urban area, buildings are squeezed into a narrow space. Movement of the sun complicates the environment. Many kinds of shade are made by complex buildings and sunlight. Therefore observing points are affected by these factors; due to the morning sunlight, we confirm east-side observing points tend to have higher temperature an hour earlier than west-side points.

***Roadside Trees**

These trees block the direct sunlight to the blacktop road, and release oxygen by photosynthesizing from the sunlight and carbon dioxide. At the same time, they release their water. Since the water draw heat from precincts, these light interception and evaporation make the temperature be reduced up to by five degrees Celsius.

***Broad Street**

(Let us define a broad street as a street with more than 20-meter width.)

Temperature is influenced by reflected heat from the blacktop road. Wider streets can generate more heat. They are also less shielded from the sunlight. Therefore, the width of street also affects the tendency in temperature.

***Weather**

Weather is also an important factor to determine the tendency in temperature. Since this factor is complicated, we analyze only data on sunny days for the first step.

*Wind

Flow of wind is becoming important for city planning. Since we have not installed wind sensors, analysis on this factor remains for our future work.

5.2. Classification

To collect fine grained data, we need high cost; power consumption, installation and management of numerous sensors. Thus, we need effective techniques for collecting data to enable an application of fine grained urban sensing. There are many techniques to enable the effective data collection; classification^[2], interpolation and other mathematical one. Here, we clarify the environmental factor from this experiment. Thus, we present the classification techniques in fine grained urban sensor networks. At this moment, we make the simple classification tree^[8]. The tree consists of two environmental factors. Every observation point is graded by tree to four types of street. We will describe features of these types.

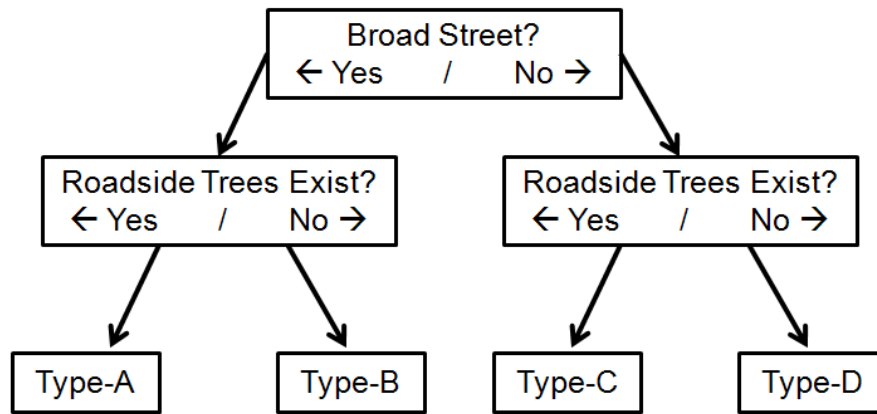


Fig. 8: Classification Tree

*About Type B

Sensing point of type B is south side of Point D and north side of Point G. Graphs of these points shows sensing point of Type B marks the highest temperature than any other point. In the other words, the Type B is the most dangerous point of heat illness.

*About Type A and D

Type A and D have one factor of rising temperature; on the broad-street or no roadside trees. Although environment of these points are difference, graphs are similar. Small differences are caused by amount of the leaves or width of roads.

*About Type C

Sensing Point of type C is east side of Point C. This point is the coolest spot of all sensing points.

5.3. Evaluation

Let us evaluate the classification based on actual data. As our first trial, we extract the highest and the mean value during 10:00 and 16:00 for each measuring point and show the extracted information in a two dimensional graph. Fig. 9 shows the information for August 21, 2007. Types A, B, C, and D have 5, 4, 4, and 13 measuring points, respectively. In the figure, type B is the most distinct from other types. To clarify the difference, we define the following distance in the graph.

$$D(a,b) = ((x_a - x_b)^2 + (y_a - y_b)^2)^{\frac{1}{2}}$$

We apply the distance to each point in Fig. 9. The calculated result is shown in Fig. 10. As seen in the graph, type A and other types are well distinguishable. However, the distance between other types is not meaningfully large.

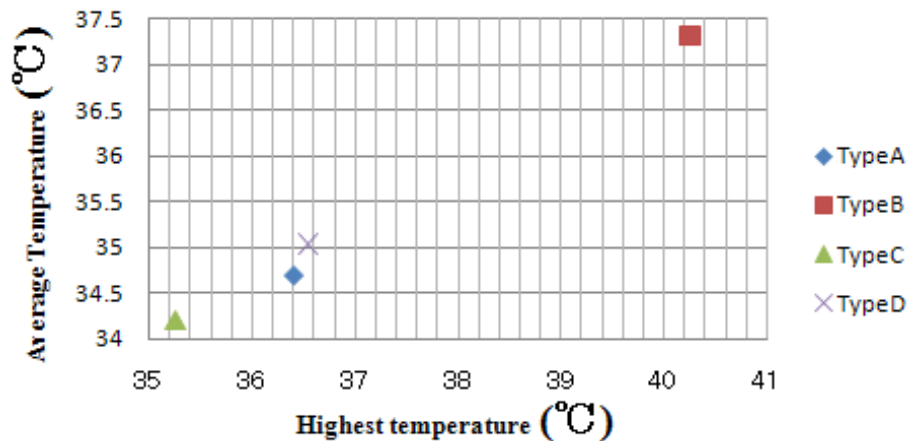


Fig. 9: Overview of Types Correlation (August 21, 2007)

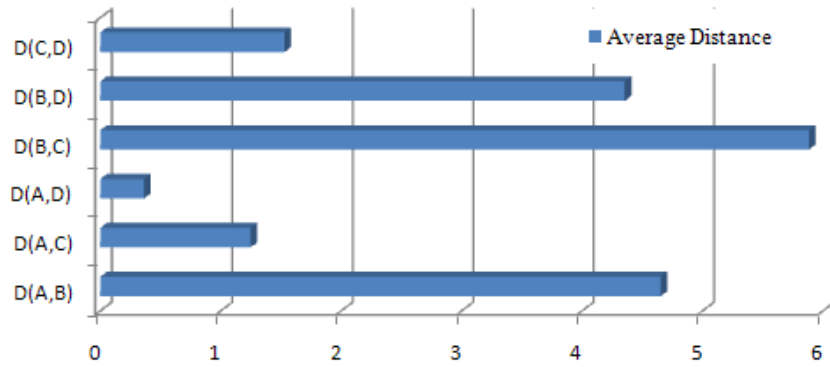


Fig. 10 Average Distance of Types (August 21, 2007)

We also apply this calculation to weekly data during August 21 and 27, 2007. The result is shown in Fig. 11. Compared with the weather shown in Table 1, we can confirm that the distance becomes smaller in cloudy and rainy days.

Table. 1: Weather Information

August, 2007	21	22	23	24	25	26	27
Weather	Fine	Fine	Cloudy & Rainy	Cloudy	Fine	Fine	Cloudy

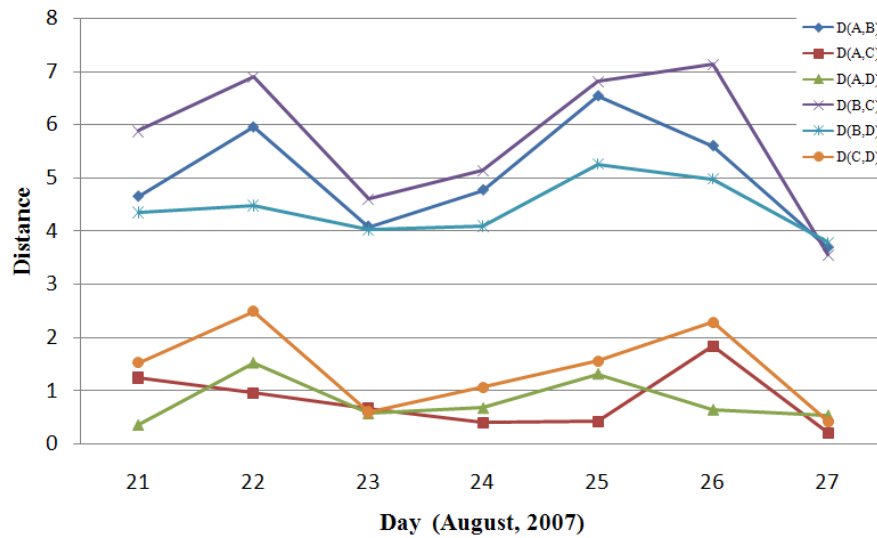


Fig. 11 Details of Distance Shift

6. Conclusion

We conduct the experiment of fine grained urban sensing. From the experiment, we can detect differences of temperature caused with the environmental factors. These environmental factors are utilized for classifying observation points into four types. The classification enables the cost-effective data collection without involving high-complexity algorithm. As our future work, we will analyze the more detail of UScan data for creating efficient fine-grained urban sensing application.

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