# Real-time Mobile Microclimate Monitoring System Using LabView RT

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***Abstract*— Currently air-conditioning units use millions of Watts of energy for stabilizing and providing a comfortable environment temperature to consumers, and the volume keeps on increasing from year to year. It is caused by thermal discomfort phenomenon named as urban heat island. The phenomenon can be measured and identify but required intensive data collection and special temperature sensing devices with detail data analysis. Therefore, this report proposed a new sensitive real-time mobile environment temperature sensing and measurement system for detecting and characterizing the microclimate of the observing location. Moreover, the Labview Real-Time has been used to interface and control the data collection and measurement system from two integrated real-time sensitive temperature sensors. The complete system has been tested and calibrated with the digital environment temperature test meter for accuracy and sensitivity. Four different streets with different land used activities have been used to test and validate the performance, and sensitivity of the system with the new developed town area produced the highest reading at an average of 36.7°C. As a conclusion, the proposed mobile system is achieving the objective as a sensitive mobile device for characterizing the environment thermal condition and microclimate for any types of land used.**

***Keywords- Microclimate, Environmental Temperature, Mobile Monitoring***

## I. INTRODUCTION

Recently, urbanization rate is rapidly increasing, and more buildings have been built up in response to the rapid growth of industries and populations. As a result, millions of trees and millions hectare of lands are cleared to be replaced with buildings, residential area and roads [1]; named as deforestation. This scenario keeps on rolling day by day to cater the demand of the new development and modernization of the country [2] without notice, it will provide the effect to the environmental including increasing of 15% of global warming pollution worldwide as reported in [3].

Lacking continuous observation and enforcement over development or construction industry are the most highlighted issues in recent years, which in return lead to less vegetation and reduction of trees as reported by [4] and [5]. Despite, the rules and act to preserve the environment from unethical and disorder development was highlighted in Environmental Impact Assessment (EIA), but it cannot provide the guarantee for the environment to be protected as reported and highlighted in [5]. Several factors have been identified which influence the failure including the political, technical, legal, social and environmental factors as reported by [5].

On the other hand, the effects of heat retain in buildings and surroundings is studied and focused individually and not for the entire cities as emphasis in [6]. Esthetic is the most highlighted elements during the tree or planting material selection process without considering the shading effect and cooling elements produces by the trees or planting material when it matched. Therefore, the effects of microclimate always occurred in improper planning area and a new township, which is not in the concerns of green city practice. Besides that, fewer spaces between buildings are one of the factors contributing to the effects of microclimate [7]. It will remain until the cooling solutions for the environment are placed properly in the surrounding area, and the issues are highlights by [8] and [9] in their studies case.

Observation of microclimate is a complex process which requires intensive data collection in every specific location before the plotting of thermal variation can be obtained. This process involved days and nights data collection with the highest accuracy data collection through special environment temperature test meter reported in [8]. Sometimes, the timing and weather are the obstacles during the data collection with the consistency of the result are the other elements should be put more on focused.

Continuous reading from specific locations and time frames are the limitation in manual data collection for microclimate due to the high thermal release occurs at specific times from 12.00pm to 2.00pm daily. On top of that, mobile data collection has been proposed to overcome the limitation by [10] and the detail concept and basic knowledge of urban heat island identification has been intensively discussed in [11][12].

The complexity and costs are the two variables that restricting the implementation of mobile data collection for microclimate. Therefore, we proposed a cost effective real-time mobile monitoring system for monitoring and characterizing microclimate in the tropical climate. Design and development of the proposed system would be detailed discussed in the following sections. Implementations and monitoring results are explained in specific subsections III. Section IV will conclude the findings from this study.

## II. METHODOLOGY

This project has been implemented through four phases of development. It was first started with the development of sensor arrays integrated with an electronic system, continued with the development of mobile monitoring facility. The third phase involved the development of host interface (GUI) through Labview. Finally, the last phase involved monitoring process and data collections. The details of each development phase are explained in its respective sub-sections.

### *A. Integration of Sensors into Electronic System*

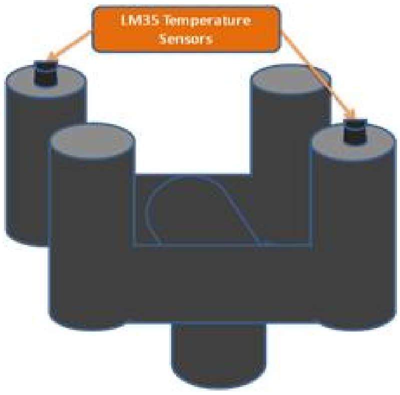


Figure 1. Concept design of the sensors

The first phase has been carried out by integrating temperature sensors in embedded system. Fig.1 shows the conceptual design of the sensors. The sensors used are temperature sensors, LM35 which are placed in inexpensive Polyvinyl Chloride (PVC) pipes and were designed systematically to maximize absorption of heat during the monitoring process.

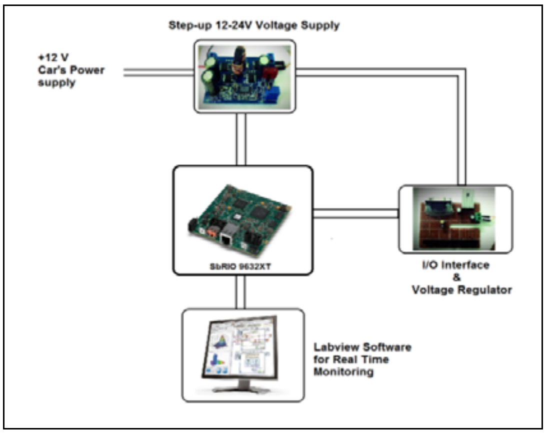


Figure 2. Block diagram of the monitoring system

The main controller circuit consists of a National Instrument SbRIO 9632XT FPGA board, a step-up 12-24 volt power supply, an I/O interface module with integrated voltage regulator circuit, connect to the temperature sensors LM35.

Fig. 2 shows the block diagrams of the completed circuit system as a whole. From the figure, the voltage for the controller circuits supply from the car's power supply (cigarette lighter), by which the voltage is shifted up from 12V to 24V by the step-up voltage supply module. The SbRIO board is powered up from the shifted 24V voltage supply since it needed at least 0.2mA current supplies for Ethernet communication between the board and the host interface (laptop). The sensor communication interface is through the I/O interface self-designed module that consists of a 5V regulator circuit. The prototype of the controller circuits is as shown in Fig. 3.

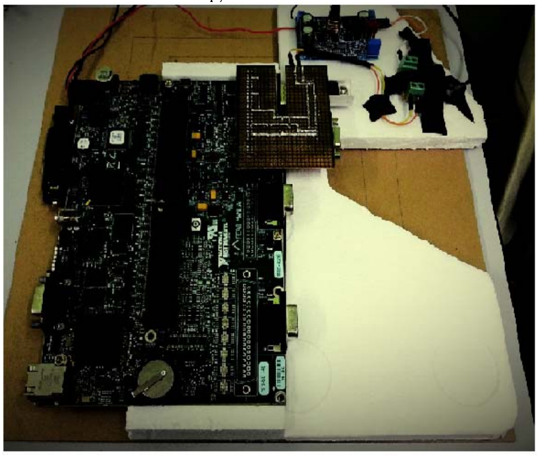

Figure 3. Prototype of the controller circuits

### *B. B. Development of Mobile Monitoring Facility*

The second phase of development involved the mobile monitoring facility as shown in Fig. 4 which was used during measurement and data collection process. The designed sensors are placed 1.5 meters tall from ground level as shown in Fig. 5 to avoid ambient temperatures from the ground and the monitoring vehicle from affecting the readings during measurement.

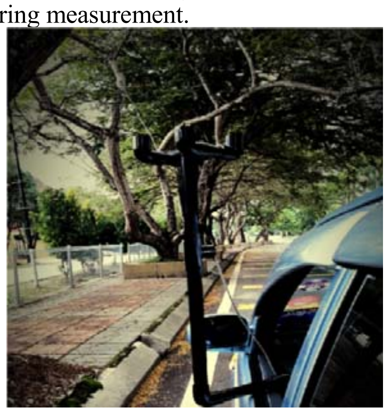

Figure 4. Sensors placed on the mobile monitoring facility

Figure 5. Mobile Monitoring Facility

Fig. 6 shows the inside of the monitoring vehicle and how the measurements have been conducted. From the figure, both the host interface (laptop) and the controller circuit are placed on the monitoring vehicle during measurement, and it is monitored in real-time.

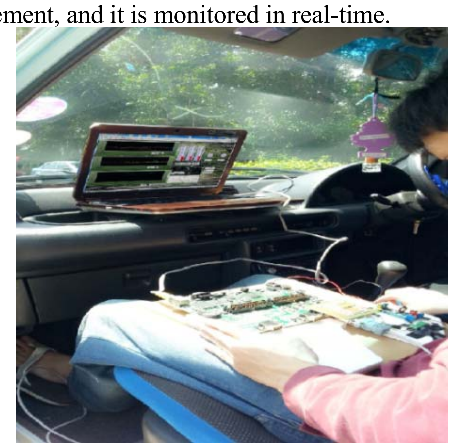

Figure 6. Communication between sensors and users

### C. *Host Interface and Graphical User Interface*

The third phase involved graphical user interface (GUI) using National Instrument Labview software, providing a host interface to the system for easier controlling and monitoring process. Fig. 7 shows the front panel of the GUI monitoring process.

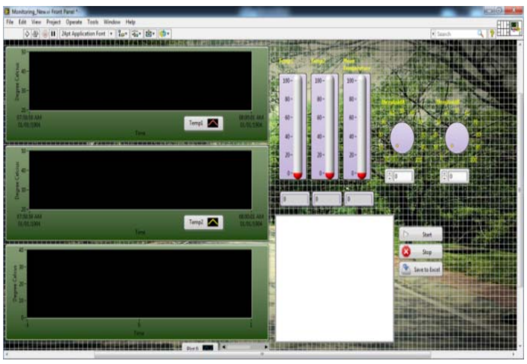

Figure 7. Front panel of the host interface

In the analog data acquisition stage as shown in Fig. 8, the analog outputs of the temperature sensors were received in millivolts (mV), where 1mV of its output corresponds to 1 degree Celsius. All the processes are put in a while loop for a continuous real-time reading, with a button to start and stop to initiate or halt the program, respectively. In addition, the *Date&Time* function was used for a more accurate monitoring which was then displayed and logged in a graph.

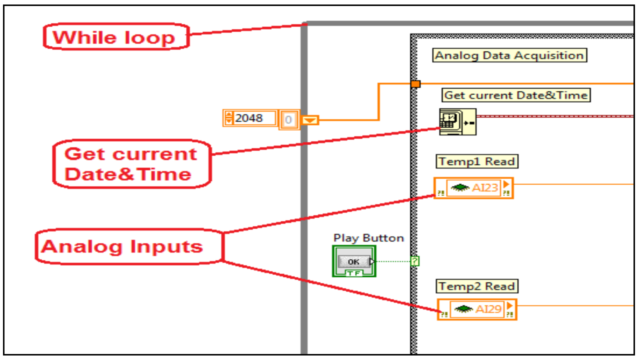


Figure 8. Analog data acquisition

The analog readings, then were processed in more detailed calculations in the signal processing stage as in Fig. 9. This stage is responsible for converting mV into Celsius and displaying the data on its respective graphs where each reading goes into its respective subVIs for calculations. In addition, the *Mean* function was used automatically to calculate the mean of either one temperature which is used for further analysis.

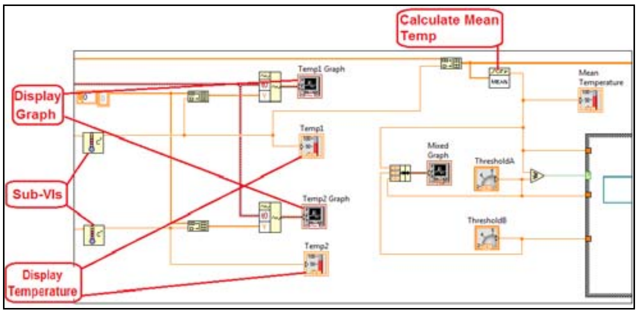


Figure 9. Signal processing

Fig. 10 shows the whole system of the Host Interface, which consists of 3 main parts: the Analog Data Acquisition, Signal Processing, and Data Logging. While, the Fig. 11 shows the third stage of the GUI, which is the data logging. In this stage, all the readings that have been displayed in the graphs were recorded and saved in Microsoft Excel for further analysis.

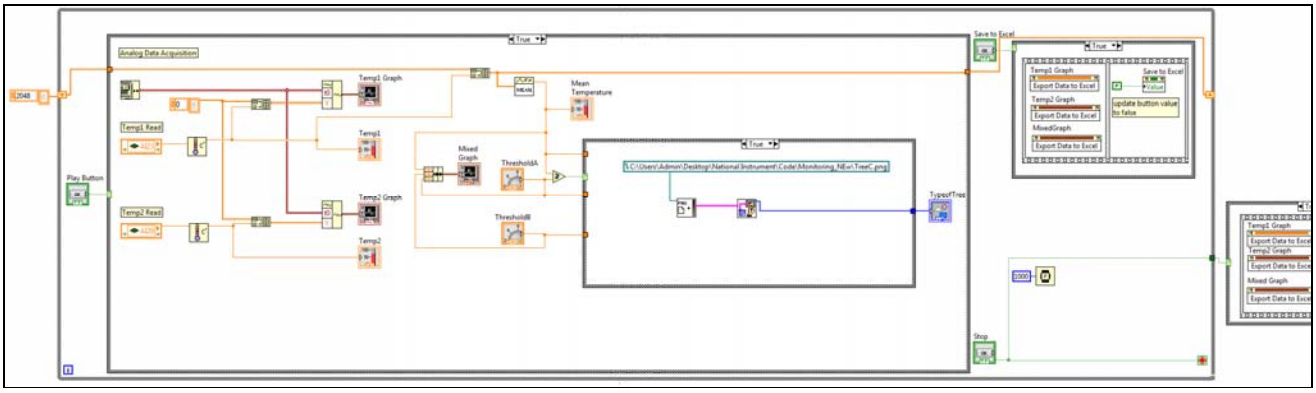

Figure 10. The whole VI of the monitoring system consists of analog data acquisition, signal processing, and data logging

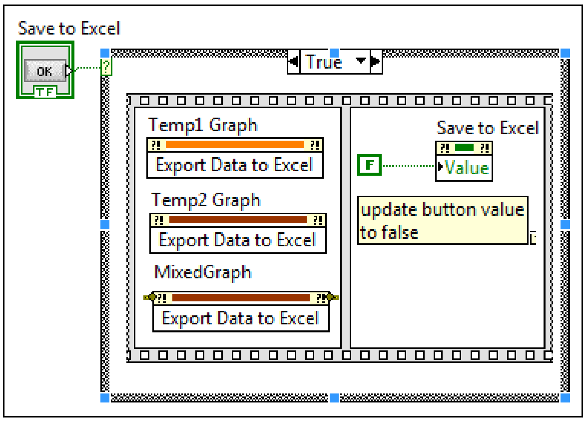


Figure 11. Data logging

### D. *Monitoring Process and Data Collection*

The fourth stage involved monitoring process and data collection. The monitoring process has been carried out in Shah Alam area, to study the thermal difference in residential and industrial area. Moreover, the process has been done for a period of 4 days repetitively at a peak time from 12.00pm to 2.00pm since it is the hottest time in a day and to ensure the most accurate, consistent readings, and reliable data. In addition, the measurement has been done at an average speed of 20-30 kilometers per hour to reduce the wind effect on the sensors. In other words, the measurement is starting from one point location to another point location, with a duration of 2 to 5 minutes approximately, and with an interval of 1 second per readings. The details of the monitoring process are discussed further in the Result section.

## III. RESULT AND DISCUSSION

The results of the monitoring processes consist of 2 main parts: the tabulated temperature measurement of the monitoring area and the thermal mapping profiles, each is discussed in its respective sub-sections.

### A. *Temperature Measurement*

Table I shows a summary of monitoring activity that has been done in 4 particular areas, namely *Seksyen U12*, *Seksyen 11*, *Seksyen 13*, and *Hicom Glenmarie Industrial Park*. From the table, the average temperature readings for temperature 1 at *Sekyen U12*, *Seksyen 11*, *Seksyen 13*, and *Hicom Glenmarie Industrial Park* are 35.6°C, 30.4°C, 35.2°C, and 33.6°C respectively. While, the average temperature 2 readings are 37.9°C, 31°C, 34.9°C, and 36.7°C respectively. Lastly, the average temperature of both sensors for each monitored location are 36.7°C, 30.7°C, 35.1°C, and 35.2°C respectively.

The duration of monitoring at *Seksyen U12*, *Seksyen 11*, and *Seksyen 13* are 4 minutes, 7 minutes and 3 minutes, respectively, while monitoring duration at *Hicom Glenmarie Industrial Park* is 4 minutes. The difference of the duration of monitoring heavily depends on the distance from starting point to the end point. *Seksyen 11* has the longest distance, followed by *Seksyen U12* and *Seksyen 13*, and lastly *Hicom Glenmarie Industrial Park*.


Figure 12. Monitored route at residential area starting from Desa Alam to Cahaya Alam

TABLE I. SUMMARY OF DATA FOR MONITORED AREAS IN SHAH ALAM

| Location | Seksyen U12, Shah Alam | Seskyen 11, Shah Alam | Seksyen 13, Shah Alam | Hicom Glenmarie Industrial Park |
|---|---|---|---|---|
| Time of Monitoring | Afternoon* | Afternoon* | Afternoon* | Afternoon* |
| Average Temperature 1 | 35.6 °C | 30.4 °C | 35.2 °C | 33.6 °C |
| Average Temperature 2 | 37.9 °C | 31.0 °C | 34.9 °C | 36.7 °C |
| Total Average | 36.7 °C | 30.7 °C | 35.1 °C | 35.2 °C |

*measurement done between 12pm to 2pm

Fig. 12 shows the route of the monitoring activity at *Seksyen U12* residential area. It started from point A near the residential area at *Desa Alam*, passed through the commercial area and some empty lots with some vegetation on the side road, and ended at point B near the residential area at *Cahaya Alam*, over a distance of 1.4km.

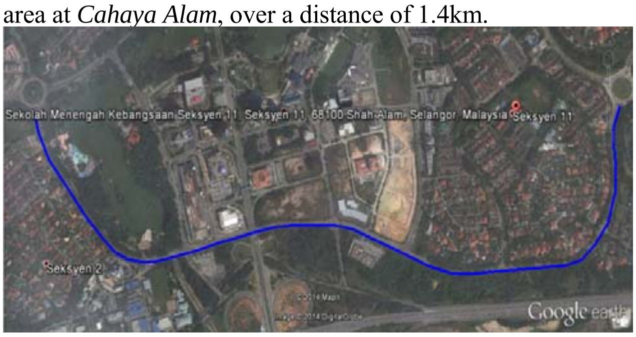


Figure 13. Monitored route at suburban area starting from Seksyen 11 to Seksyen 2

Fig. 13 shows the route of the monitoring at suburban area near *Seksyen 11*. The measurement points started from *Bulatan Kayangan*, passed through the residential area of *Seksyen 11* and ended at *Bulatan Permai*, over a distance of 3.1km.

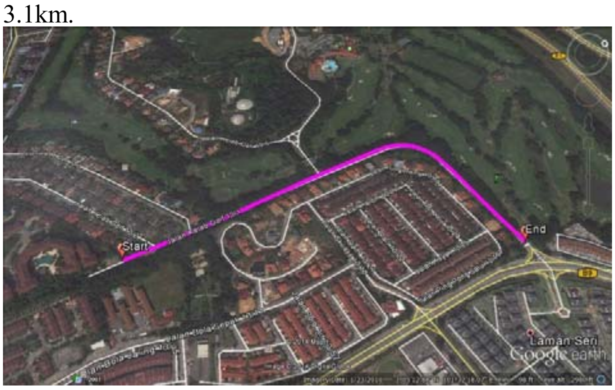


Figure 14. Monitored route at suburban area starting from Sri Alam Condominium to entrance of Kelab Golf Sultan Abdul Aziz Shah

Fig. 14 shows the monitored route at a residential area in *Seksyen 13* near the *Kelab Golf Sultan Abdul Aziz Shah*. The measurement points started from *Sri Alam Condominium* and ended at the entrance to *Kelab Golf Sultan Abdul Aziz Shah*, with a distance of 1.1km approximately.


Figure 15. Monitored route at Hicom Glenmarie Industrial Park near Seksyen 13

Fig. 15 shows the monitored route of one of the industrial areas in *Shah Alam*, named; *Hicom Glenmarie Industrial Park*, with a distance of 1.6km over 3 minutes approximately.

## B. *Thermal Mapping Profiles*

Fig. 16 shows the tabulated data of the average recorded temperatures for all the monitored areas. From the data, the highest recorded temperature is at *Seksyen U12*, followed by *Seksyen 13* with average temperatures up to 37°C and 36°C respectively. The lowest recorded temperature is at *Seksyen 11* with an average temperature of 31°C. The thermal conditions for all the monitored area was recorded and mapped into thermal profiles as shown in the next figures.

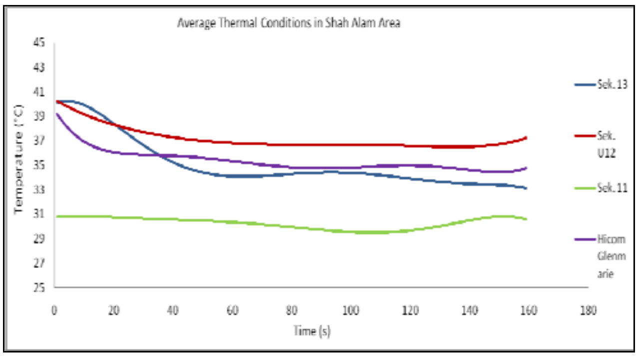


Figure 16. Avarage thermal conditions in Shah Alam area

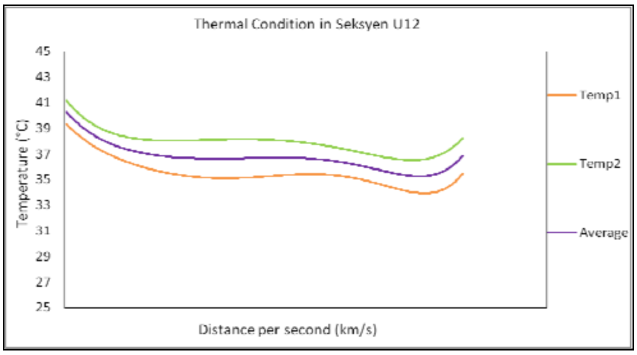


Figure 17. Thermal condition for sensor 1, sensor 2, and the average of both sensors in Seksyen U12

The thermal condition in *Seksyen U12* indicates the highest readings when compared to the other monitored area as shown in Fig. 17. The highest readings of sensor 1 (temp1) reached 42°C and the highest readings of sensor 2 (temp2) reached 39°C.

While in Fig. 18 shows the thermal condition for *Seksyen 13* where the monitored area was done near the residential area. The thermal difference recorded is the highest during the start of measurement, and significantly reduced towards the end of measurement.

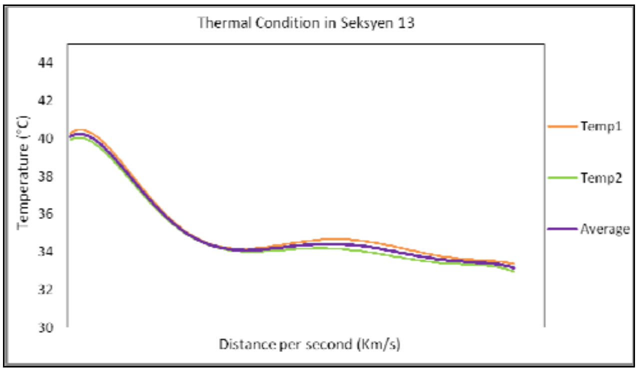


Figure 18. Thermal condition for sensor 1, sensor 2, and the average of both sensors in Seksyen 13

The temperature variations in *Hicom Glenmarie Industrial Park* show an average of constant readings from 38°C to 35°C which can be seen in Fig. 19. However, Fig. 20 shows the thermal variations near the *Seksyen 11* residential area with the lowest temperature readings of 29°C and the highest was 32°C.

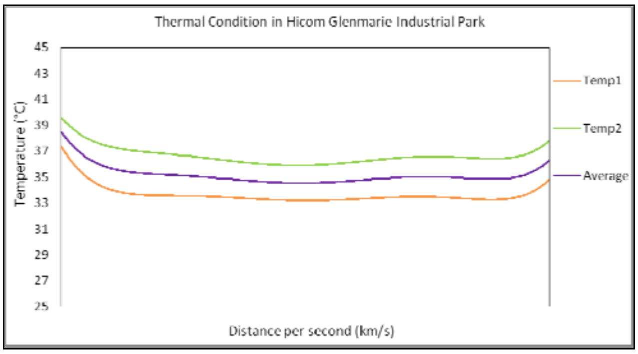


Figure 19. Thermal condition for sensor 1, sensor 2, and the average of both sensors in Hicom Glenmarie Industrial Park area

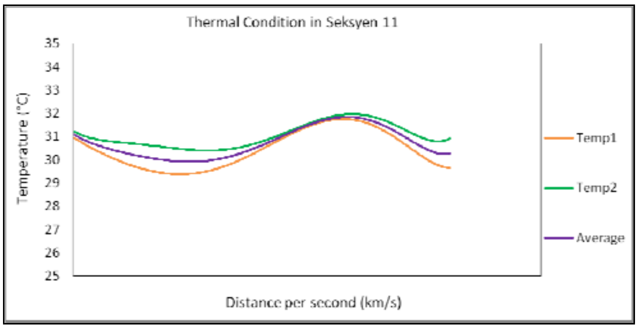


Figure 20. Thermal condition for sensor 1, sensor 2, and the average of both sensors in Seksyen 11

Based on the monitoring activities that have been done in various places, the mobile monitoring system can monitor the surrounding temperature efficiently.

The sensor placement is the key to ensuring a precise recorded data. Hence, it was designed 1.5 meter tall from ground level as to avoid distortion and unwanted noises from affecting the readings such as the emission of heat from cars, as well as surface temperature of the ground.

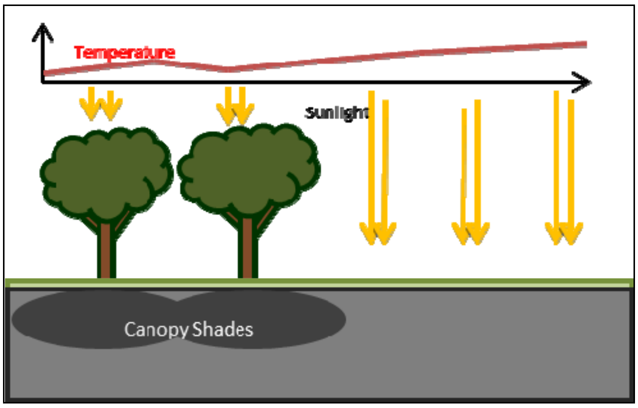


Figure 21. Illustration of the effects of canopy shades of trees to the temperature

As seen in Fig. 12, Fig. 13, Fig. 14, and Fig. 15, the green scapes or the amount of vegetation is different. *Seksyen U12* is a new residential area; it has a lesser vegetation area when

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compared to *Seksyen 11* and *Seksyen 13* residential area. Hence, the evapotranspiration rate of the surrounding trees is smaller, contributing to the accumulated heat in that area as shown in Fig. 17. In addition, the cleared landscapes and paved roads in that area are one of the contributors to the accumulated heat as it reflected less heat from the sunlight.

Besides that, the man-made surfaces and building material absorbed more heat and has lower albedo (ratio of reflected incidental light). This scenario clearly recorded in thermal profile Fig. 18, during the startup measurement and near to the *Sri Alam Condominium*. As a result, the increasing of surface temperature could cause a thermal discomfort to residents as reported in [13]–[15].

Furthermore, human activities such as transportation and manufacturing increases greenhouse and pollutant emission, and anthropogenic which result in the increasing of environment temperature especially near the industrial area as shown in the thermal profile in Fig. 19 for *Hicom Glenmarie Industrial Park*. As a consequence, it increased energy demand for air conditioning in buildings due to the increase of air temperature.

Other the other hand, the already planted roadside trees such as in *Seksyen 11* have significantly affected the readings due to the shading effects of the trees, which cooled down the warmer area. As illustrated in the graph in Fig. 20, the readings constantly decreased due to the cooling effect produced by the trees. It increased slightly when the monitoring vehicle passed through a lesser vegetated area near *Pejabat Pos Laju*, however, started to decrease again when passed through a more vegetated area.

To further understand the relationship of the cooling effect of trees to the temperature, Fig. 21 illustrates the significant effect of canopy shades of trees to its surrounding temperature. From the figure, the heat from sunlight penetrating the trees is reduced due to the dense canopy shape of the trees, hence creating a canopy shade depending on the size of the tree. The creation of canopy shades has significantly reduced the surrounding temperature. It was proved during the monitoring activities, for instances, in *Seksyen 11*, when the mobile monitoring facility moved in a canopy shade, the temperature is greatly reduced and vice-versa

## IV. CONCLUSION

The proposed mobile system based on SbRIO 9632XT FPGA board integrated with high sensitivity temperature sensor LM35 has been successfully developed and capable of characterizing the thermal conditions across the monitored area accurately. Moreover, the functionality of the proposed system has been validated through the monitoring of different land used, and the temperature variations have been efficiently determined for each area. Therefore, this report proposed a new real-time travels/mobile environment temperature sensing system for measuring and characterizing microclimate conditions of the land used area. Furthermore, the implementation cost can be minimized using the open source prototyping platform named Arduino that has been reported used in recently prototyping related research in [16]–[18].

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## REFERENCES

[1] M. C. J. K. Roesnthal, R. Crauderueff, "Urban Heat Island Mitigation Can Improve New York City's Environment: Research on the Impacts of Mitigation Strategies on the Urban Environment," 2008.

[2] R. S. DeFries, T. Rudel, M. Uriarte, and M. Hansen, "Deforestation driven by urban population growth and agricultural trade in the twenty-first century," *Nat. Geosci.*, vol. 3, no. 3, pp. 178–181, Feb. 2010.

[3] D. Boucher and T. Donaghy, "Deforestation Today: It's Just Business," *UCS Trop. For. Clim. Brief.*, vol. 7, 2010.

[4] J. Randolph, *Environmental Land Use Planning and Management*. Island Press, 2004, pp. 534–536.

[5] H. M. Alshuwaikhat, "Strategic environmental assessment can help solve environmental impact assessment failures in developing countries," *Environ. Impact Assess. Rev.*, vol. 25, no. 4, pp. 307–317, May 2005.

[6] Y. Yamamoto, "Measures to mitigate urban heat islands," *Sci. Technol. Trends Q. Rev.*, vol. 18, no. 1, pp. 65–83, 2006.

[7] E. Erell, D. Pearlmutter, and T. Williamson, *Urban Microclimate: Designing the Spaces Between Buildings*. Taylor & Francis, 2012, pp. 143–159.

[8] S. K. S. O. Thani, N. H. N. Mohamad, and S. M. S. Abdullah, "The Influence of Urban Landscape Morphology on the Temperature Distribution of Hot-Humid Urban Centre," *Procedia - Soc. Behav. Sci.*, vol. 85, pp. 356–367, Sep. 2013.

[9] S. K. S. O. Thani, N. H. Nik Mohamad, and S. Norjihan Jamaludin, "Outdoor thermal comfort: the effects of urban landscape morphology on microclimatic conditions in a hot-humid city," in *The Sustainable City VIII (2 Volume Set): Urban Regeneration and Sustainability Volume 179 of WIT Transactions on Ecology and the Environment, Southampton: WIT Press*, 2013, pp. 651–662.

[10] M. Khaikine, A. Koldaev, E. Kadygrov, E. Miller, V. Sokolov, and N. Sokolov, "Mobile system for atmospheric temperature profile monitoring: mobile MTP-5."

[11] J. Voogt, "How researchers measure urban heat islands," in *United States Environmental Protection Agency (EPA), State and Local Climate and Energy Program, Heat Island Effect, Urban Heat Island Webcasts and Conference Calls*, 2007.

[12] L. Gartland, *Heat Islands: Understanding and Mitigating Heat in Urban Areas*. Taylor & Francis Group, 2012.

[13] T. Rashed and C. Jürgens, *Remote Sensing of Urban and Suburban Areas*. Springer, 2010.

[14] M. A. Peña, "Relationships between remotely sensed surface parameters associated with the urban heat sink formation in Santiago, Chile," *Int. J. Remote Sens.*, vol. 29, no. 15, pp. 4385–4404, Aug. 2008.

[15] K. Parsons, *Human Thermal Environments: The Effects of Hot, Moderate, and Cold Environments on Human Health, Comfort, and Performance, Third Edition*. Taylor & Francis, 2014, pp. 1–6.

[16] R. Husin, S. A. M. Al Junid, and Z. A. Majid, "Automatic Street Lighting System for Energy Efficiency based on Low Cost Microcontroller," *Int. J. Simul. Syst. Sci. Technol.*, vol. 13, no. 1, pp. 29–34, 2012.

[17] M. E. M. Ussdek, A. Junid, S. A. Mutalib, Z. A. Majid, F. N. Osman, and Z. Othman, "High-sensitivity gas detection and monitoring system for high-risk welding activity," in *Systems, Process & Control (ICSPC), 2013 IEEE Conference on*, 2013, pp. 256–261.

[18] N. A. M. Tahir, S. A. M. Al Junid, Z. Othman, Z. A. Majid, and S. K. S. O. Thani, *Design Automatic Meter Reading (AMR) Data Logger with Xbee*, vol. 13, no. 1. United Kingdom Simulation Society, 2012, pp. 67–73.