Final Report

Intelligent Mobile Disaster Monitoring and Early Warning Unit with Information System for Administrative Management

Assoc. Prof.Chuwong Phongcharoenpanich (Project leader)

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Supported by King Mongkut's Institute of Technology Ladkrabang (KREF085701)

Fiscal year of 2014

Faculty of Engineering

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Supported by the annual government statement of expenditure

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แหล่งเงิน กองทุนวิจัยสถาบันเทคโนโลยีพระจอมเกล้าเจ้าคุณทหารลาดกระบัง

ประจำปีงบประมาณ 2557 จำนวนเงินที่ได้รับการสนับสนุน 994,000 บาท

ระยะเวลาทำการวิจัย 1 ปี ตั้งแต่ 1 มิ.ย. 2557 ถึง 31 พ.ค. 2558

ชื่อ-สกุล หัวหน้าโครงการ และผู้ร่วมโครงการวิจัย พร้อมระบุ หน่วยงานต้นสังกัด

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บทคัดย่อ

จุดประสงค์

สืบเนื่องจากปัญหามหาอุทกภัยที่เกิดขึ้นในประเทศในปี พ.ศ. 2554 และยังรวมถึงปัญหาซ้ำซากที่เกิดขึ้นเป็นประจำเช่น ปัญหาน้ำป่าไหลหลากและดินโคลนถล่มที่เกิดขึ้นในเขตพื้นที่ภาคเหนือและภาคใต้ ในช่วงฤดูฝน โครงงานนี้จึงมีเป้าหมายเพื่อประยุกต์ใช้ ICT ในการบริหารจัดการเพื่อการป้องกันและแจ้งเตือนในกรณีก่อนและหลังเกิดภัยพิบัติ ซึ่งระบบบริหารจัดการนี้ได้พัฒนาสถานีต้นแบบสำหรับการตรวจวัดแบบเคลื่อนที่ โดยจะมีการเฝ้าระวังการเกิดน้ำท่วมและดินถล่ม การป้องกันและแจ้งเตือน พร้อมระบบสารสนเทศ ระบบบริหารจัดการป้องกันภัยพิบัตินี้สามารถนำไปใช้ประโยชน์ในการจัดการข้อมูลและบรรเทาภัยพิบัติของกรมป้องกันและบรรเทาสาธารณภัยศูนย์เตือนภัยพิบัติแห่งชาติ และกรมชลประทานแห่งชาติด้วย

จุดประสงค์ของโครงการ มีดังต่อไปนี้

ก) พัฒนาต้นแบบระบบเฝ้าตรวจภัยพิบัติและแจ้งเตือนอัจฉริยะแบบเคลื่อนที่พร้อมระบบสารสนเทศเพื่อการบริหารจัดการซึ่งประกอบไปด้วยชุดเซนเซอร์ในการตรวจจับการเกิดน้ำท่วมและดินถล่ม

ข) ออกแบบและนำระบบแจ้งเตือนอัจฉริยะไปติดตั้งเพื่อวิเคราะห์ข้อมูลที่ได้รับจากเซนเซอร์หรับพื้นที่ที่เสี่ยงกับการเกิดภัยพิบัติลักษณะต่างๆ รวมทั้งการกระจายสัญญาณเตือนภัยและแจ้งเตือนภัย

ค) สร้างเซิร์ฟเวอร์ส่วนกลางในการจัดเก็บข้อมูลสำหรับการบริหารจัดการ

ง) ติดตั้งและทดสอบระบบต้นแบบในพื้นที่เสี่ยงภัยในประเทศไทย เช่น พื้นที่ราบลุ่มภาคกลางกับการเกิดปัญหาน้ำท่วมซ้ำซาก

จ) สร้างความร่วมมือด้านการวิจัยระหว่างมหาวิทยาลัยและหน่วยงานเอกชน ในการพัฒนางานวิจัยเพื่อนำมาใช้ประโยชน์ในการป้องกันและรับมือกับสถานการณ์การเกิดภัยพิบัติในลักษณะต่างๆ ของประเทศ

ความสำเร็จของโครงการ

โครงการนี้ประสบผลสำเร็จในการสร้างระบบแจ้งเตือนภัยพิบัติล่วงหน้าซึ่งมีการบูรณาการการจัดการในรูปแบบของ unified platform ซึ่งเป็น platform ที่มีความยืดหยุ่น โดยสามารถเปลี่ยนแปลงตามความต้องการและลักษณะของพื้นที่และงบประมาณเนื่องจากโมดูลในระบบสร้างให้อยู่ในรูปแบบ plug-in module นอกจากนี้สถานีเคลื่อนที่นี้ยังสามารถเคลื่อนย้ายและติดตั้งได้สะดวก รวมทั้งยังเป็น stand-alone unit เนื่องจาก ระบบสามารถส่งสัญญาณแจ้งเตือนภัยพิบัติล่วงหน้าโดยไม่ต้องเชื่อมต่อกับระบบจัดการข้อมูลส่วนกลาง อย่างไรก็ตามเพื่อให้มีการบูรณาการข้อมูลแจ้งเตือนและเซิร์ฟเวอร์เก็บข้อมูลส่วนกลาง ระบบยังสร้างการแจ้งเตือนและตอบกลับที่ครอบคลุมทุกพื้นที่ในประเทศด้วยการเฝ้าระวังแบบไร้สายและสามารถแลกเปลี่ยนข้อมูลระหว่างองค์กรภาครัฐที่เกี่ยวข้องอย่างทันท่วงที

ระบบต้นแบบสำหรับสถานีเฝ้าระวังภัยพิบัติเคลื่อนที่ประกอบไปด้วยอุปกรณ์เซนเซอร์สำหรับตรวจจับการเกิดน้ำท่วมและดินถล่ม ซึ่งในระบบนี้จะแบ่งออกเป็น ส่วนควบคุม, ส่วนจ่ายกระแสไฟฟ้า, ส่วนอุปกรณ์เซนเซอร์และโมดูลสำหรับการเชื่อมต่อสื่อสาร 2 รูปแบบ โดยโมดูลสื่อสารจะทำการส่งข้อมูลที่ได้รวบรวมไว้ถึงระบบจัดการข้อมูลส่วนกลางและส่วนของการตอบกลับที่เกี่ยวข้องเมื่อเกิดภัยพิบัติ โดยจะทำการสื่อสารผ่านระบบเครือข่ายเซลลูลาร์ในโหมดการทำงานปกติ และสื่อสารผ่านเครือข่ายดาวเทียมเมื่อช่องสัญญาณการสื่อสารอื่นๆ ไม่สามารถใช้ได้เนื่องจากการเกิดภัยพิบัติ

สำหรับการเฝ้าระวังการเกิดน้ำท่วมนั้น อุปกรณ์เซนเซอร์จะตรวจวัดระดับน้ำ, อัตราการไหลและทิศทางของน้ำ และข้อมูลทางภูมิอากาศอื่นๆ โดยสถานีเฝ้าระวังภัยพิบัติเคลื่อนที่ได้รับการติดตั้งและทดสอบ ณ กรมชลประทานในพื้นที่ จ.ชัยนาท ประเทศไทย ระบบประสบผลสำเร็จในการส่งข้อมูลที่ได้จากการวัดของเซนเซอร์ถึงระบบจัดการข้อมูลส่วนกลาง นอกเหนือจากการรวบรวมและเก็บข้อมูลแล้ว ระบบจัดการข้อมูลส่วนกลางนี้ยังเป็นศูนย์กลางในการวิเคราะห์ความเสี่ยงและส่งการแจ้งเตือนให้แก่หน่วยงานที่เกี่ยวข้องในกรณีที่อาจเกิดภัยพิบัติได้ และยังทำหน้าที่เป็นเว็บเซิร์ฟเวอร์ที่เก็บรวบรวมข้อมูลสำหรับการสืบค้นจากสาธารณชนอีกด้วย

โครงการนี้ยังพัฒนาอัลกอริธึมใหม่สำหรับการวิเคราะห์ความเป็นไปได้ของการเกิดน้ำท่วมจากข้อมูลที่ได้รับจากเซนเซอร์โดยการใช้ระบบ neuro fuzzy inference แบบปรับค่าได้ (adaptive neuro fuzzy inference system) กฎในการทำนายการเกิดภัยพิบัติ (disaster inference rules) ได้รับการออกแบบโดยใช้ข้อมูลในพื้นที่ท้องถิ่นนั้นๆ อัลกอริธึมนี้เป็นอัลกอริธึมแบบ fully automated ซึ่งการส่งสัญญาณเตือนเริ่มต้นนั้นถูกส่งมาจากสถานีเคลื่อนที่ในขณะเดียวกันก็รอสัญญาณยืนยันจากระบบจัดการข้อมูลส่วนกลางในการแจ้งกระบวนการต่างๆ

สำหรับสาธารณชนเมื่อเกิดภัยพิบัติ อัลกอริธึมนี้ได้รับการทดสอบว่าสามารถทำนายเหตุการณ์การเกิดน้ำท่วมได้ล่วงหน้าถึง 24 ชั่วโมง

สำหรับการแจ้งเตือนและเฝ้าระวังการเกิดดินถล่มนั้น เซนเซอร์จะทำการวัดค่าความชื้นของดินและอัตราการตกของปริมาณน้ำฝน ค่าปริมาณน้ำฝนที่วัดได้นี้จะถูกนำไปวิเคราะห์ร่วมกับแผนที่แสดงพื้นที่เสี่ยงที่จะเกิดดินถล่มได้เพื่อตรวจจับความเป็นไปได้ที่จะเกิดดินโคลนถล่มและมีการแจ้งเตือน โดยแผนที่แสดงพื้นที่เสี่ยงที่จะเกิดดินถล่มนี้สร้างขึ้นจากวิธีการ the weighting factor method ซึ่งเป็นค่า critical antecedent precipitation index นอกจากนี้ โครงการนี้ยังสร้างชุดแบบทดสอบการตรวจจับดินถล่มขนาดเล็กเพื่อจำลองการแจ้งเตือนเมื่อเกิดดินโคลนถล่มได้ด้วย 2 วิธี โดยระบบจะใช้เซนเซอร์วัดระดับความชื้นในดินเพื่อทำนายโอกาสที่จะเกิดดินเลื่อนตัวหรือดินถล่ม และในอีกกระบวนการหนึ่ง จะใช้ reed switch ในการตรวจจับว่าดินมีการเคลื่อนตัวแล้วหรือไม่

คำสำคัญ: การแจ้งเตือนภัยพิบัติ, การเฝ้าระวังการเกิดน้ำท่วมและดินถล่ม, การบริหารจัดการข้อมูล

Research Title: Intelligent Mobile Disaster Monitoring and Early Warning Unit with Information System for Administrative Management

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ABSTRACT

Objectives

Motivated by the mega flood of 2011 and the annual recurrences of landslides in northern and southern provinces of Thailand during rainy seasons, this project aims to apply ICT in disaster management, including disaster preparedness and recovery efforts. This is to be achieved by developing a prototype for intelligent mobile disaster monitoring, in particular flood and landslide monitoring, detection, and early warnings. The system is useful for Thailand's National Disaster Warning Center and Thailand's Royal Irrigation Department.

The specific aims of this project are as follows.

a) Develop a prototype mobile disaster monitoring station and communications system with integrated sensors for flood and landslides monitoring

b) Design and implement an intelligent early-warning algorithm which analyzes the sensing data and broadcasts warning of potential disasters to local communities, as well as alerts authorities

c) Build a central information server for administrative management.

d) Install and test the prototype in actual disaster-prone areas in Thailand. For example, central-region provinces for flooding.

e) Encourage research collaborations between universities and private organization to develop the research for disaster early-warning system.

Accomplishments

As the results of the collaboration between partner institutions, the project completes an early-warning system integration for disaster management in the form of a unified platform. The platform is flexible. It is customizable based on local needs and budget because all modules are plug-in. In addition, the mobile unit itself is portable and is easy to install. It can also be a stand-alone unit because it can send out early disaster warning even without any communications with the central data management system. With the integration of the central data server, however, the system provides a complete nation-wide disaster warning and response system that can be monitored wirelessly and can exchange information among corresponding governmental units promptly and seamlessly.

A system prototype for mobile disaster monitoring station with integrated sensors for floods and landslides monitoring and detection has been developed. The mobile monitoring unit includes the control unit, power supply unit, sensing components and two-mode communication modules. The communications modules send all collected data to the central data management system and corresponding response units in case of the detected disasters. The communications is via cellular network in normal operation mode and via satellite link when all other communications channels are down from disaster.

For flood monitoring, the sensors measure water-level, water flow rate and direction, and weather parameters. The mobile station has been installed and tested at the Royal Irrigation department in Chainat province, Thailand. The measured sensor data have been successfully transferred to the central data management system. Besides collecting and storing the data, the central management system houses the risk analysis algorithm and sends warning alarm to corresponding official response units in case of a predicted disaster. It also serves as the web server that hosts information accessible to the public.

The project develops a new algorithm for analyzing potential floods from measured sensor data using the adaptive neuro fuzzy inference system. The disaster inference rules are designed using local information about the disasters. The algorithm is fully automated; the preliminary early warning alarm is sent from the mobile unit promptly while waiting for the official confirmation at the central data management system about proper protocol that the public should follow. This two-step warning (preliminary-official) allows the public to be informed and prepared for the potential disaster in a timely manner. The algorithm has been tested that it is able to predict events of floods 24 hours in advance.

For landslides warning and monitoring, the sensors keep track of soil moisture and rainfall rate. The rainfall data can be analyzed concurrently with the landslide hazard map to detect possible landslide occurrence and issue warning. The hazard map may be generated using the weighting factor method, the critical antecedent precipitation index, or other criteria. In addition, a small-scale landslide detection demonstration kit has been

built to demonstrate two alternative methods for warning. The system uses soil moisture level to predict a possible landslide. Alternatively, a reed switch is used to detect a landslide when it occurs.

Keywords : Disaster warning, flood and landslide monitoring, data and administrative management

Acknowledgement

This project was partially supported by the funding from the King Mongkut's Institute of Technology Ladkrabang (KMITL). We were thankful to our collaborators from ThaiCom PCL, Thailand, Tokyo Metropolitan University, Japan, and Tokai University, Japan for friendly advice, information and knowledge sharing, and other supports during the project work.

We would like to express our gratitude to APT (Asia-Pacific Telecommunity) for funding of this project in parts of equipment and device including travel expenses for our researchers to visit Japan to discuss this project topic with the experts in Japan, and also for Japanese experts travelling to Thailand for valuable comments and suggestions for our prototype testing.

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Chapter 1

System Design Overview

The overview of our system design is given in Fig. 1.1. Different mobile monitoring stations containing various types of sensors suitable for disaster monitoring of choice are placed at disaster-prone locations across the country. During normal situation, the mobile stations communicate via mobile networks, sending sensor data and other relevant information to the central data management system. During or after disaster, stations within the vicinity of the affected areas where mobile network is down send the data alternatively using satellite link. The central data management system contains the information server, monitoring data during normal operations and during disaster. It also houses the risk analysis algorithm using fuzzy expert system and sends warning alarm to corresponding official response units. Lastly, it serves as the web server that hosts information accessible to the public.

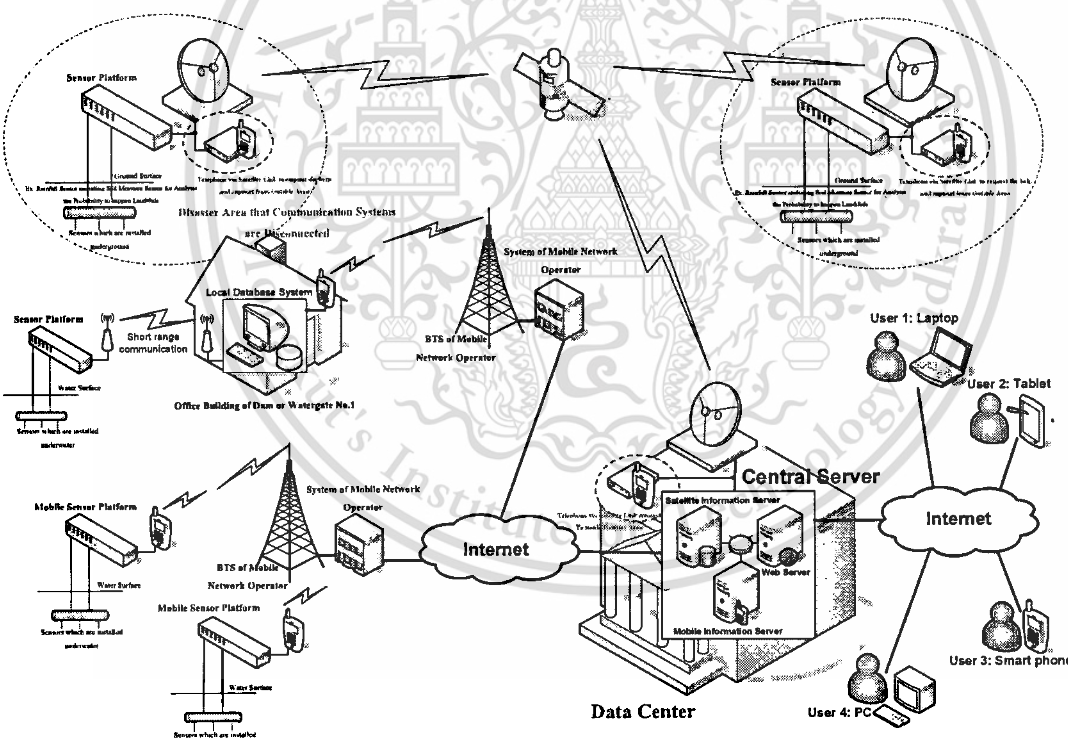


Figure 1.1: Overview of our concept for disaster monitoring system.

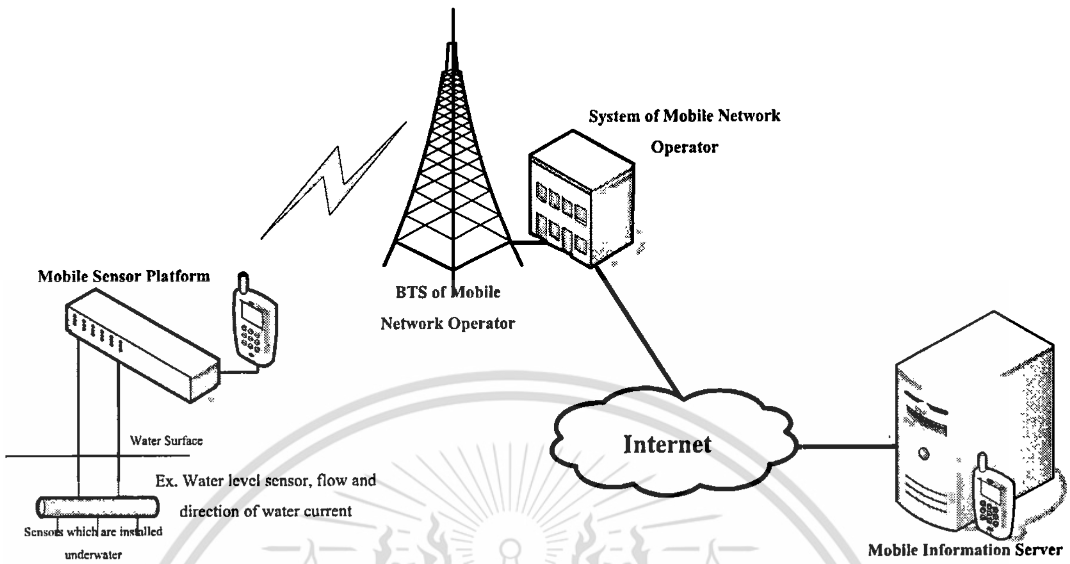


Figure 1.2:Communications via mobile network during normal situation.

Figure 1.2 depicts the communications during normal situation. The sensor data and the location of the mobile station is routed to the mobile information server through the country's existing mobile network. In the cases that the mobile station is installed in the area where mobile network is not available, e.g. inside the jungle, in the valley, or in the disaster area where the terrestrial communication is disconnected, all measured data will be sent to the server using the satellite communication link, as shown in Fig. 1.3.

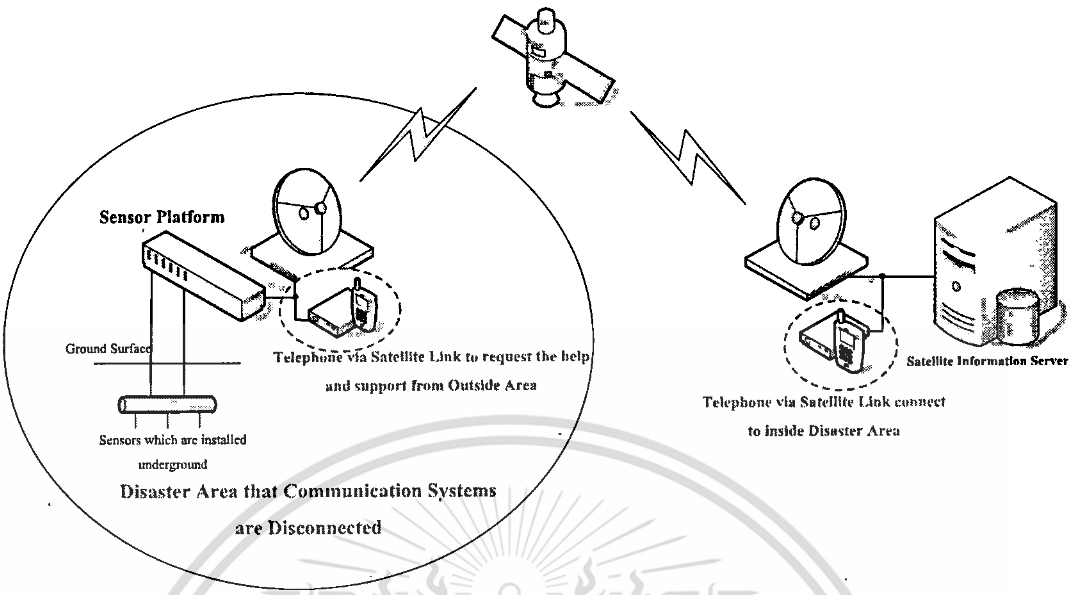


Figure1.3: Communications via satellite link when the mobile network is not available.

Chapter 2

Mobile Monitoring Station

The mobile disaster monitoring station consists of two main parts—the control unit and the power supply unit. Sensor data received at the control unit are subsequently sent out to the central data management system to be analyzed for possible disasters either via a mobile network (normal situation) or a satellite link (during disasters). Components of the mobile monitoring station are displayed in Fig. 2.1.

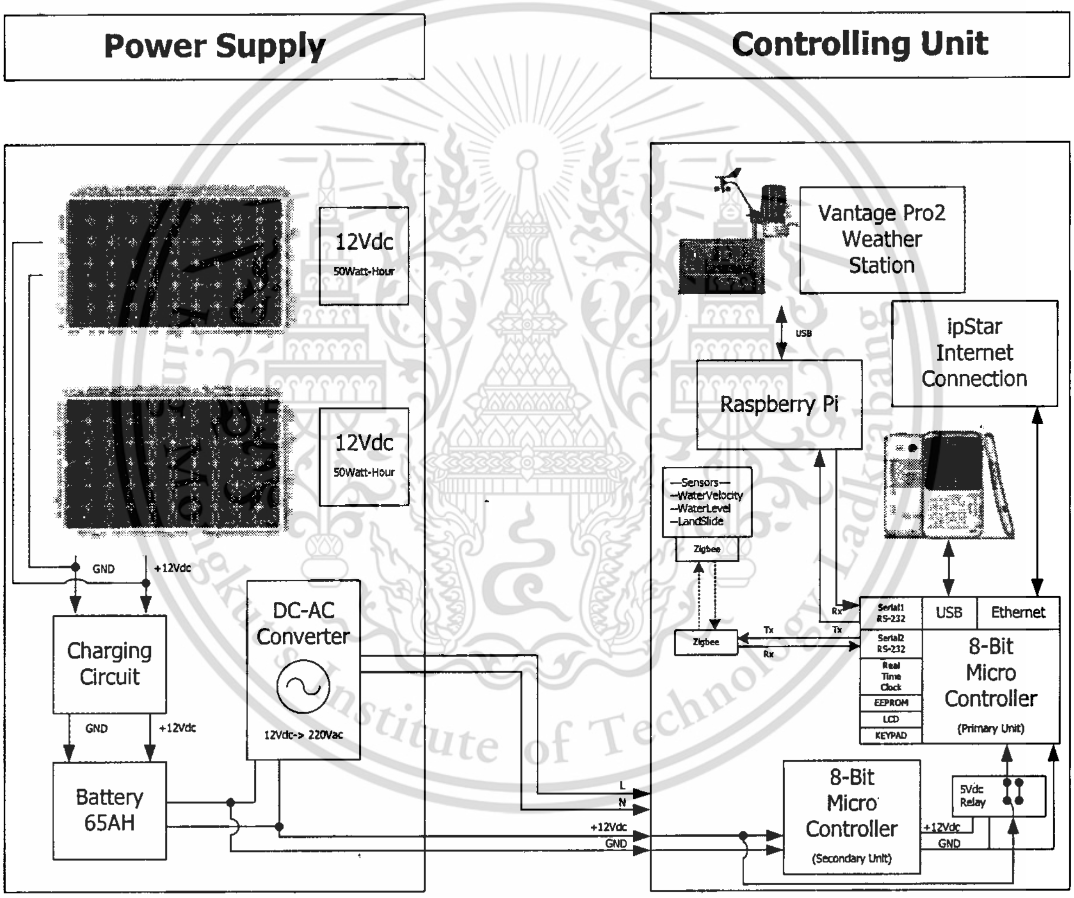


Figure 2.1: Block diagram of the mobile disaster monitoring station.

The mobile monitoring station can be powered two ways—using regular power outlets or using solar cells. For the units located in the city area, for example, units installed for additional measurements away from fixed-point monitoring stations, the units can use regular power outlets. Solar cells power will be used for mobile units that are installed in the rural areas or difficult terrains without electricity, or used in the case that the electrical system is down due to disasters. For both power systems, inverter for charging reserve battery will also be provided. For usage, the user can choose the power supply manually.

2.1 Designing the power supply unit

We rely on solar power as the main source of power so that the mobile station can be installed in remote areas where access to electricity may be limited, such as in the forests or mountains. The solar power is converted to electricity by the solar photovoltaic system. Two solar panels are connected in parallel to the charging circuit. Each can produce 50 Watt-hours of power, so the system can produce 100 Watt-hours. In Thailand, the peak hours of sunlight are between 11am to 3pm (4 hours per day), so the base station should have the maximum amount of 400 Watt for daily use. Factor in the efficiency at around 80%, the actual amount of power generated is 320 Watt per day, or 13.33 Watt per hour. Consider the equation $P = IV$, If the voltage of 12 V is used, the maximum load that the power supply can support is $I = P/V = (13.33)/(12) = 1.11$ A per hour. For two consecutive days of operation the current usage is 1.11 A/hr * 48 hrs = 53.28 A. Hence, the battery should have the capacity more than 53.28 AH. In practice, the load should be approximately 80% of the battery capacity, so we select a battery with the capacity of 65 AH for the supply unit. There is also a DC-AC converter (12 Vdc – 220 Vac) in the power supply system that can produce the power between 0-150 Watts according to the actual load. However, the real maximum is 100 Watt because the solar panel can only produce that much power.

The hardware of mobile station built from the design in Fig. 2.1 is depicted in Fig. 2.2. The station has a weather station installed above two solar panels. The remaining hardware are housed inside a waterproof case in the middle. The picture of the power supply unit (not including the solar panel) in Fig. 2.3.

Figure 2.2: Hardware of mobile monitoring station.

Figure 2.3: Actual hardware of the power supply unit.

Table 2.1 compares the current usages between the design and the actual amount during system operation.

Table 2.1: Comparison of designed and actual current usages.

	Designed	Actual usage
Voltage (Volt : V)	12	12
Current(A/Hr)	1.11	0.81
charged -Battery hours from fully (Hr) to depletion	58	80

2.2 The sensors

Different types of sensor can be integrated into the mobile monitoring station as plug-in modules. Specifically, to use the monitoring station for floods monitoring we use the following sensors:

2.2.1 Water level sensor

To detect water level, we built a water level measurement unit using ultrasonic sensors as shown in Fig. 2.4 located on shore close to the river bank. The first ultrasonic sensor measures the distance between ground of river bank and transducer, while the second one measures the distance between a water surface and transducer. Since two transducers are deployed in the same height above the ground, the different of these distance values is the water level with respect to the river bank level.

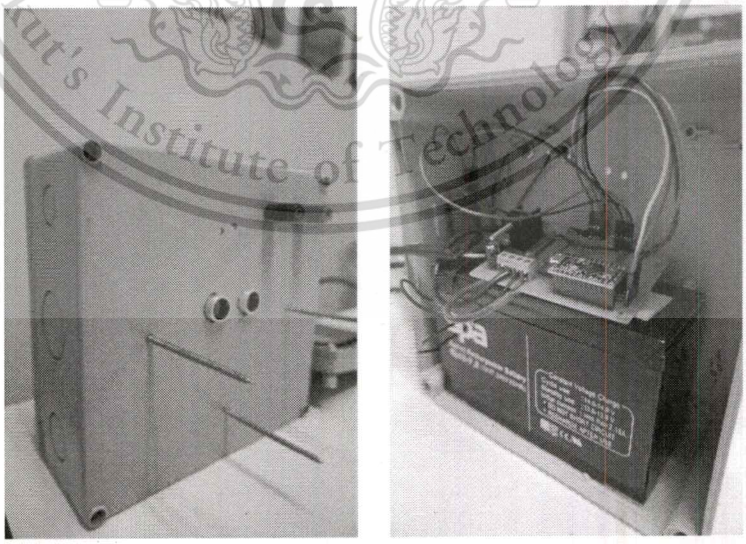


Figure 2.4: The ultrasonic sensors for water level measurement. Left: outside. Right: inside.

For data communications, data measured from the two transducers are sent tothe mobile station via Zigbee module. All data received at the mobile station are calculated by the microprocessor to get the water level. Then, the water level is transmitted to the central data management system via a GPRS module.

2.2.2 Water flow sensor

We use a current flow meter with a 60-mm diameter propeller shown in Fig. 2.5 in this project. The water flow rate is calculated from the number of its rotor blades rotations using Eq. (1).

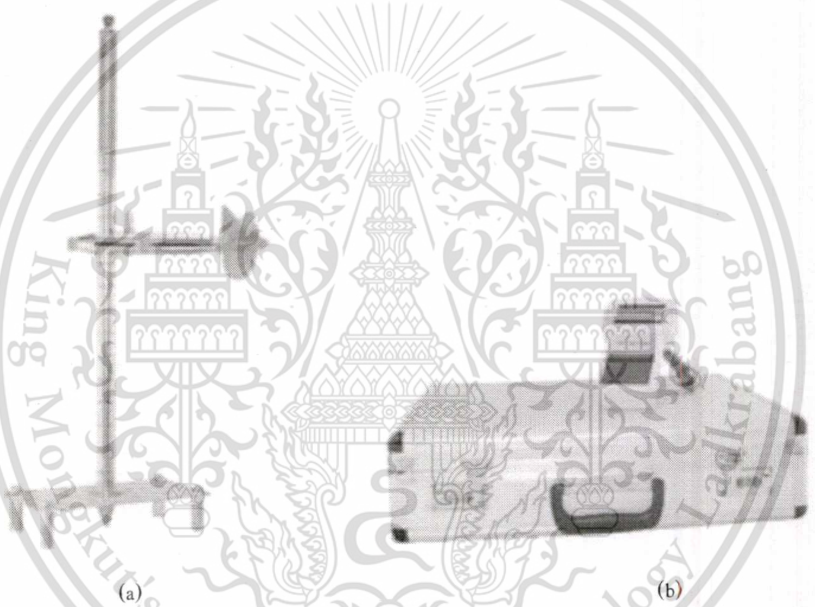


Figure 2.5: (a) LS1206B propeller. (b) HT-B type portable current flow meter.

The sensor measures the signal from the rotor blades rotations and then sends the pulses to the microprocessor in order to compute the flow rate as

$$V = \frac{(k/b)N}{T} + C/a \quad \text{m/s,} \qquad (1)$$

where V is the average velocity, T is lasting time, N is the number of signal in T times and k/b and c/a are constants. This equation is based on the theory of area of open channel's velocity; the flow can be obtained from $Q = VS$, where S is the sectional area.

2.2.3 Weather station

The project uses the Vantage Pro2™ Weather stations (Davis Instruments), as shown in Fig. 2.6. The weather station is capable of measuring six weather parameters—atmospheric pressure, temperature, wind speed, wind direction, humidity, and rainfall rate. The data are sent wirelessly to a weather station console.

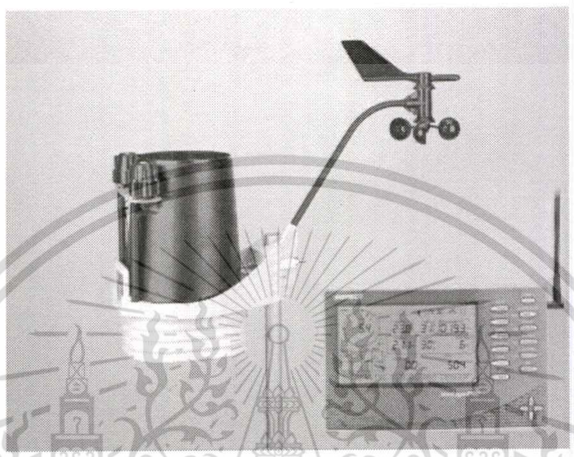


Figure 2.6: Vantage Pro 2 Weather Station. Left-the ISS system; Right-the console.

A tipping bucket rain gauge (Fig. 2.7) is located inside the weather station as part of the integrated sensor system (ISS). When tipped, a magnetic touches the contact of a reed switch, sending an electrical pulse.

Figure 2.7: Tipping bucket rain gauge inside the Vantage Pro 2.

A USB data logger specifically made for the Vantage Pro 2 weather station (by Davis Instruments) is needed to transfer the data out of the console. An included software WeatherLink can be used to download the data to a computer. An example of the data file received from the weather station console is depicted in Fig. 11. Alternatively, in this project we reconfigure the data logger for serial communications and connect the weather station console to the microcontroller directly. The microcontroller is programmed to send download commands directly to the console.

Date	Time	Temp Out	Hi Temp	Low Temp	Out Hum	Dew Pt.	Wind Speed	Wind Dir	Wind Run	Hi Speed	Hi Dir	Wind Chill	Heat Index	THW Index	Bar	Rain	Rain Rate	Heat D-D	Cool D-D	In Temp	In Hum	In Dew	In Heat	In EMC	In Air Density	Wind Samp	Wind Tx	ISS Recept	Arc. Int.
11-11-13	15:41	---	---	---	52	---	0.0	---	0.00	0.0	---	---	---	---	760.0	0.00	0.0	---	---	28.1	46	15.4	28.2	9.11	1.1517	22	1	95.7	1
11-11-13	15:42	33.7	33.7	33.7	51	22.1	0.0	NW	0.00	1.6	NW	33.7	38.3	38.3	759.9	0.00	0.0	0.000	0.011	27.9	47	15.5	28.1	9.11	1.1520	24	1	100.0	1
11-11-13	15:43	33.7	33.7	33.7	51	22.2	1.6	WNW	0.03	3.2	WNW	33.7	38.4	38.4	759.8	0.00	0.0	0.000	0.011	27.8	50	16.5	28.2	9.31	1.1518	23	1	100.0	1
11-11-13	15:44	33.8	33.8	33.7	51	22.2	3.2	NNE	0.05	4.8	N	33.8	38.6	38.6	760.0	0.00	0.0	0.000	0.011	27.8	50	16.4	28.1	9.41	1.1517	23	1	100.0	1
11-11-13	15:45	33.8	33.8	33.8	50	21.9	3.2	NNE	0.05	3.2	N	33.8	38.2	38.2	760.0	0.00	0.0	0.000	0.011	27.7	51	16.7	28.1	9.41	1.1516	24	1	100.0	1
11-11-13	15:46	33.7	33.8	33.7	51	22.2	3.2	ENE	0.05	4.8	ENE	33.7	38.4	38.4	760.2	0.00	0.0	0.000	0.011	27.7	52	16.9	28.1	9.61	1.1512	23	1	100.0	1
11-11-13	15:47	33.7	33.8	33.7	51	22.2	1.6	ENE	0.03	4.8	ENE	33.7	38.4	38.4	759.9	0.00	0.0	0.000	0.011	27.7	52	16.9	28.1	9.32	1.1524	24	1	100.0	1
11-11-13	15:48	33.7	33.7	33.7	51	22.2	0.0	---	0.00	0.0	---	33.7	38.4	38.4	759.9	0.00	0.0	0.000	0.011	27.7	53	17.2	28.2	8.92	1.1532	19	1	82.6	1
11-11-13	15:49	33.8	33.8	33.7	52	22.5	0.0	---	0.00	0.0	---	33.8	38.9	38.9	760.0	0.00	0.0	0.000	0.011	27.6	51	16.6	27.9	8.82	1.1542	23	1	100.0	1
11-11-13	15:50	33.8	33.8	33.8	51	22.2	1.6	NE	0.03	3.2	NE	33.8	38.6	38.6	759.9	0.00	0.0	0.000	0.011	27.6	49	15.9	27.8	8.62	1.1549	23	1	100.0	1
11-11-13	15:51	33.8	33.8	33.8	51	22.3	0.0	---	0.00	0.0	---	33.8	38.7	38.7	759.9	0.00	0.0	0.000	0.011	27.5	48	15.5	27.6	8.92	1.1544	23	1	100.0	1
11-11-13	15:52	33.8	33.8	33.8	51	22.3	0.0	---	0.00	0.0	---	33.8	38.7	38.7	760.0	0.00	0.0	0.000	0.011	27.4	47	15.1	27.4	9.33	1.1539	24	1	100.0	1
11-11-13	15:53	33.9	33.9	33.9	51	22.3	1.6	NNW	0.03	3.2	N	33.9	38.8	38.8	760.0	0.00	0.0	0.000	0.011	27.4	49	15.7	27.5	9.43	1.1534	23	1	100.0	1
11-11-13	15:54	33.9	33.9	33.9	51	22.4	1.6	NW	0.03	4.8	N	33.9	38.9	38.9	760.0	0.00	0.0	0.000	0.011	27.3	51	16.3	27.6	9.63	1.1533	23	1	100.0	1
11-11-13	15:55	34.0	34.0	33.9	50	22.1	3.2	NNE	0.05	6.4	NNE	34.0	38.7	38.7	760.2	0.00	0.0	0.000	0.011	27.3	52	16.6	27.7	9.75	1.1526	23	1	100.0	1
11-11-13	15:56	34.0	34.0	34.0	50	22.1	3.2	N	0.05	6.4	N	34.0	38.7	38.7	760.0	0.00	0.0	0.000	0.011	27.3	53	16.9	27.7	9.85	1.1522	22	1	95.7	1
11-11-13	15:57	34.0	34.0	34.0	50	22.1	4.8	NNE	0.08	8.0	NNE	34.0	38.7	38.7	760.0	0.00	0.0	0.000	0.011	27.3	54	17.2	27.8	9.85	1.1521	24	1	100.0	1
11-11-13	15:58	33.9	34.0	33.9	50	22.1	3.2	NNE	0.05	4.8	NNE	33.9	38.6	38.6	760.0	0.00	0.0	0.000	0.011	27.3	55	17.5	27.9	9.85	1.1519	23	1	100.0	1
11-11-13	15:59	33.9	33.9	33.9	51	22.3	1.6	N	0.03	4.8	N	33.9	38.8	38.8	760.0	0.00	0.0	0.000	0.011	27.3	55	17.5	27.9	9.85	1.1515	24	1	100.0	1
11-11-13	16:00	33.9	33.9	33.9	51	22.3	1.6	NNE	0.03	3.2	NNE	33.9	38.8	38.8	760.0	0.00	0.0	0.000	0.011	27.4	55	17.5	28.0	9.75	1.1519	23	1	100.0	1
11-11-13	16:01	33.8	33.9	33.8	50	22.0	1.6	NNE	0.03	3.2	NNE	33.8	38.3	38.3	759.9	0.00	0.0	0.000	0.011	27.4	55	17.6	28.1	9.42	1.1527	24	1	100.0	1
11-11-13	16:02	33.8	33.8	33.8	50	22.0	3.2	NE	0.05	4.8	NNE	33.8	38.3	38.3	759.9	0.00	0.0	0.000	0.011	27.4	54	17.3	28.0	9.32	1.1535	22	1	95.7	1
11-11-13	16:03	33.8	33.8	33.8	50	21.9	1.6	NE	0.03	3.2	NE	33.8	38.2	38.2	759.9	0.00	0.0	0.000	0.011	27.4	53	16.7	27.8	9.42	1.1531	23	1	100.0	1
11-11-13	16:04	33.8	33.8	33.8	50	21.9	0.0	NNE	0.00	1.6	NNE	33.8	38.2	38.2	759.9	0.00	0.0	0.000	0.011	27.4	51	16.4	27.7	9.42	1.1526	24	1	100.0	1
11-11-13	16:05	33.7	33.8	33.7	51	22.2	1.6	W	0.03	3.2	NW	33.7	38.4	38.4	759.9	0.00	0.0	0.000	0.011	27.4	52	16.7	27.7	9.85	1.1518	23	1	100.0	1
11-11-13	16:06	33.7	33.7	33.7	51	22.2	0.0	W	0.00	1.6	W	33.7	38.4	38.4	759.9	0.00	0.0	0.000	0.011	27.4	53	17.0	27.8	10.05	1.1518	23	1	100.0	1
11-11-13	16:07	33.7	33.7	33.7	51	22.2	0.0	W	0.00	1.6	W	33.7	38.4	38.4	759.9	0.00	0.0	0.000	0.011	27.4	55	17.5	28.0	10.05	1.1518	23	1	100.0	1
11-11-13	16:08	33.8	33.8	33.8	51	22.2	0.0	---	0.00	0.0	---	33.8	38.6	38.6	760.0	0.00	0.0	0.000	0.011	27.3	56	17.8	28.0	10.05	1.1518	23	1	100.0	1
11-11-13	16:09	33.8	33.8	33.8	51	22.2	1.6	W	0.03	3.2	W	33.8	38.6	38.6	760.0	0.00	0.0	0.000	0.011	27.3	56	17.8	28.0	10.05	1.1518	24	1	100.0	1
11-11-13	16:10	33.8	33.8	33.8	51	22.2	1.6	W	0.03	3.2	WNW	33.8	38.6	38.6	760.0	0.00	0.0	0.000	0.011	27.3	56	17.8	28.0	10.05	1.1518	23	1	100.0	1
11-11-13	16:11	33.8	33.8	33.8	51	22.3	0.0	---	0.00	0.0	---	33.8	38.6	38.6	760.0	0.00	0.0	0.000	0.011	27.3	56	17.8	28.0	10.05	1.1518	24	1	100.0	1
11-11-13	16:12	33.8	33.8	33.8	51	22.3	0.0	WNW	0.00	1.6	NW	33.8	38.7	38.7	760.1	0.00	0.0	0.000	0.011	27.3	56	17.8	28.0	9.85	1.1523	23	1	100.0	1
11-11-13	16:13	33.8	33.8	33.8	51	22.3	1.6	NW	0.03	3.2	NW	33.8	38.7	38.7	760.0	0.00	0.0	0.000	0.011	27.3	56	17.8	28.0	9.75	1.1527	23	1	100.0	1

Figure 2.8: Example of data file downloaded from the weather station console.

The weather station is installed on top of the mobile monitoring station, as shown in Fig. 2.2. Other sensors are installed remotely. The data from the remoted sensors are routed back to the mobile station. The remote sensor units do not use the power from the main power supply unit, but have their own solar panels and batteries.

Because the mobile station and the secondary sensor systems are at some distance apart, a wired connection is not suitable. Therefore, we design the system to send data wirelessly using Zigbee technology through RS-232 port. The Zigbee module used in this project has a transmission distance between 100-300 m, depending on the terrains.

For landslide monitoring we use the Vantage Pro 2 weather station mentioned earlier, along with soil moisture sensor and a reed switch.

2.2.4 Soil moisture sensor

The moisture sensor used in this project is a Grove-Moisture sensor as shown in Fig. 2.9.

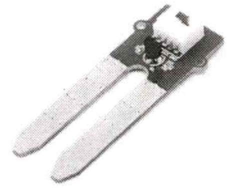


Figure 2.9: The Grove-moisture sensor.

2.2.5 Reed switch

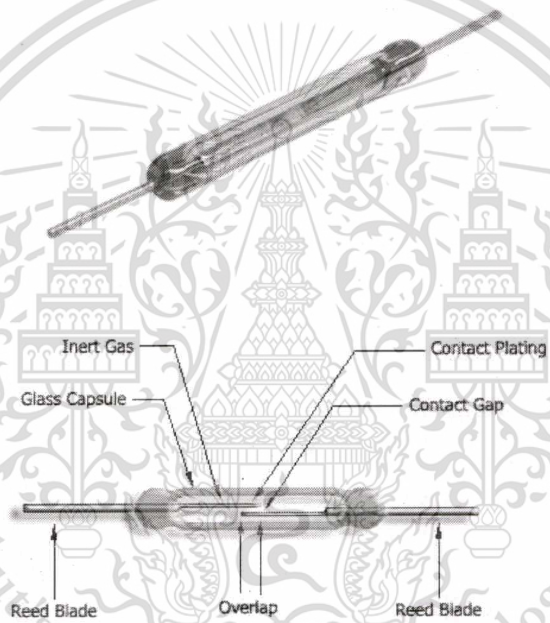


Figure 2.10: Reed switch.

A reed switch (Fig. 2.10) is operated by a presence of magnetic field. The contact plates are normally open; the contact gap is closed when the magnetic field is applied near the glass capsule. For our landslide warning system, a reed switch is used to detect an occurrence of a landslide (details in later chapter).

2.3 Designing the control unit

The control unit on the mobile monitoring station consists of the following components:

1. Two 8-bit microprocessors: A primary microprocessor is ATmega2560, a secondary microprocessor is ATmega328-20PU.

a. The primary microprocessor controls the data reception from all sensors and data transmission processes. In normal operation data is sent to the server via a 3G cellular network. In case of cellular service disruption during disasters or in the location where cellular network is not available, the data is transmitted through a high-speed internet via IPSTAR satellite (details in the next chapter).

b. The secondary microprocessor monitors the primary microprocessor. If the primary microprocessor stops working from any reasons, it will be reset within 24 hours.

2. Real Time Clock (DS1307), EEPROM (24LC512), LCD (20x4), Keypad (4x4), USB (MAX3412E), Ethernet (Wiznet W5100) and RS-232 ports: These are connected to the primary microprocessor.

3. A Raspberry Pi (Broadcom BCM2835) board

4. A Weather Station (Davis Vantage Pro 2) console: The weather station console and its integrated sensor system (ISS) can be installed at separate locations at most 500 meters apart. The ISS, which has its own solar panel with backup battery, sends sensor data to the console.

5. An android phone (HTC chacha)

2.4 System workflows of the control unit

The flowcharts of the control unit are depicted in Fig. 2.11-2.15. Figure 2.11 depicts the data transmission process from the weather station console. Six weather parameters: pressure, temperature, wind speed, wind direction, humidity, and rainfall rate, are sent as a string frame to the primary microprocessor via the Raspberry Pi board. The program is written in Python language. Figure 2.12 depicts functions of the primary microprocessor, programmed using C++. The sub-programs Prg1 and Prg2 are displayed in details in Fig. 2.13 and 2.14, respectively. Figure 2.15 depicts the process of the android phone (written in Java to receive data from the microprocessor and send it out to the central data server. The hardware of the control unit is illustrated in Fig. 2.16.

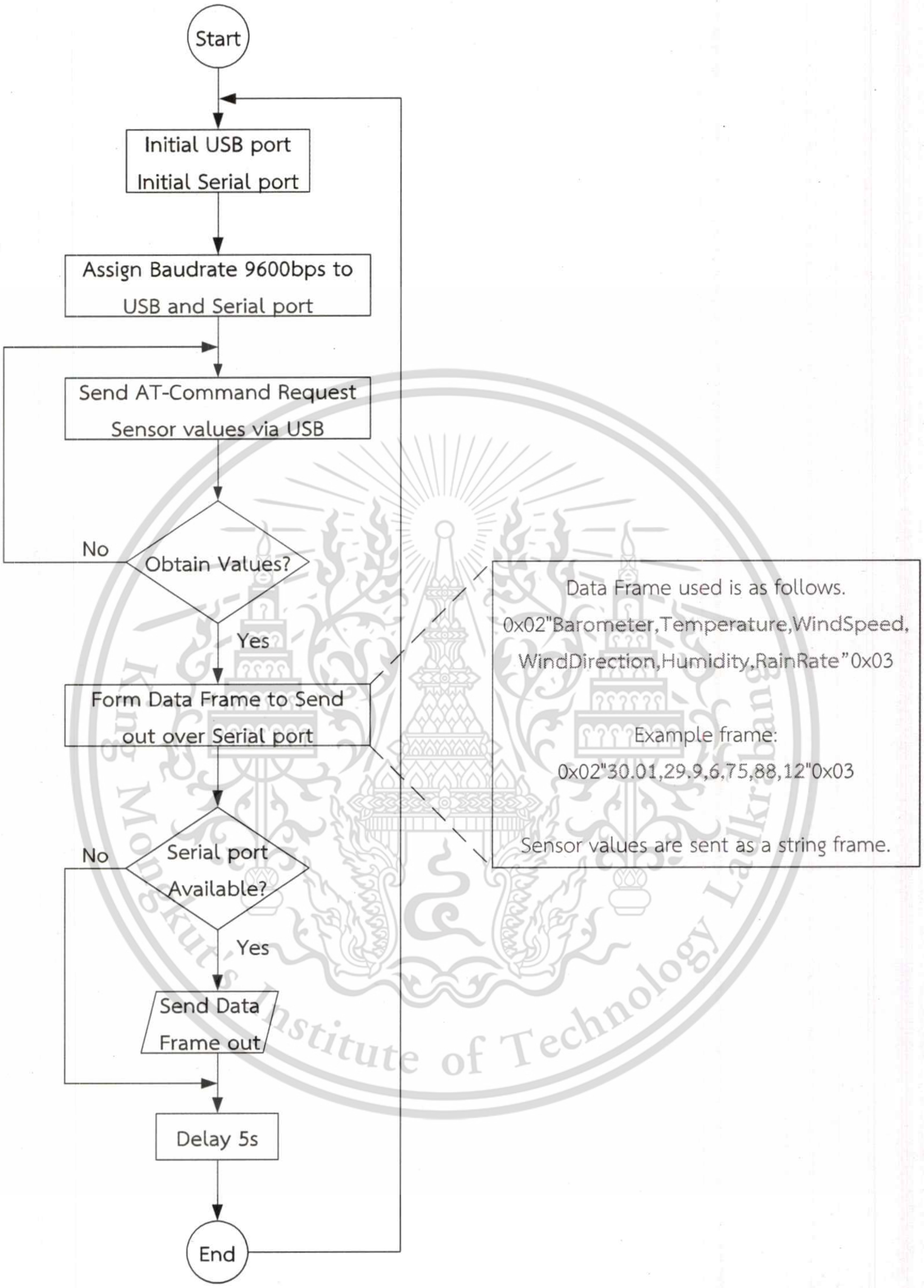


Figure 2.11: Data transmission process from the weather station console.

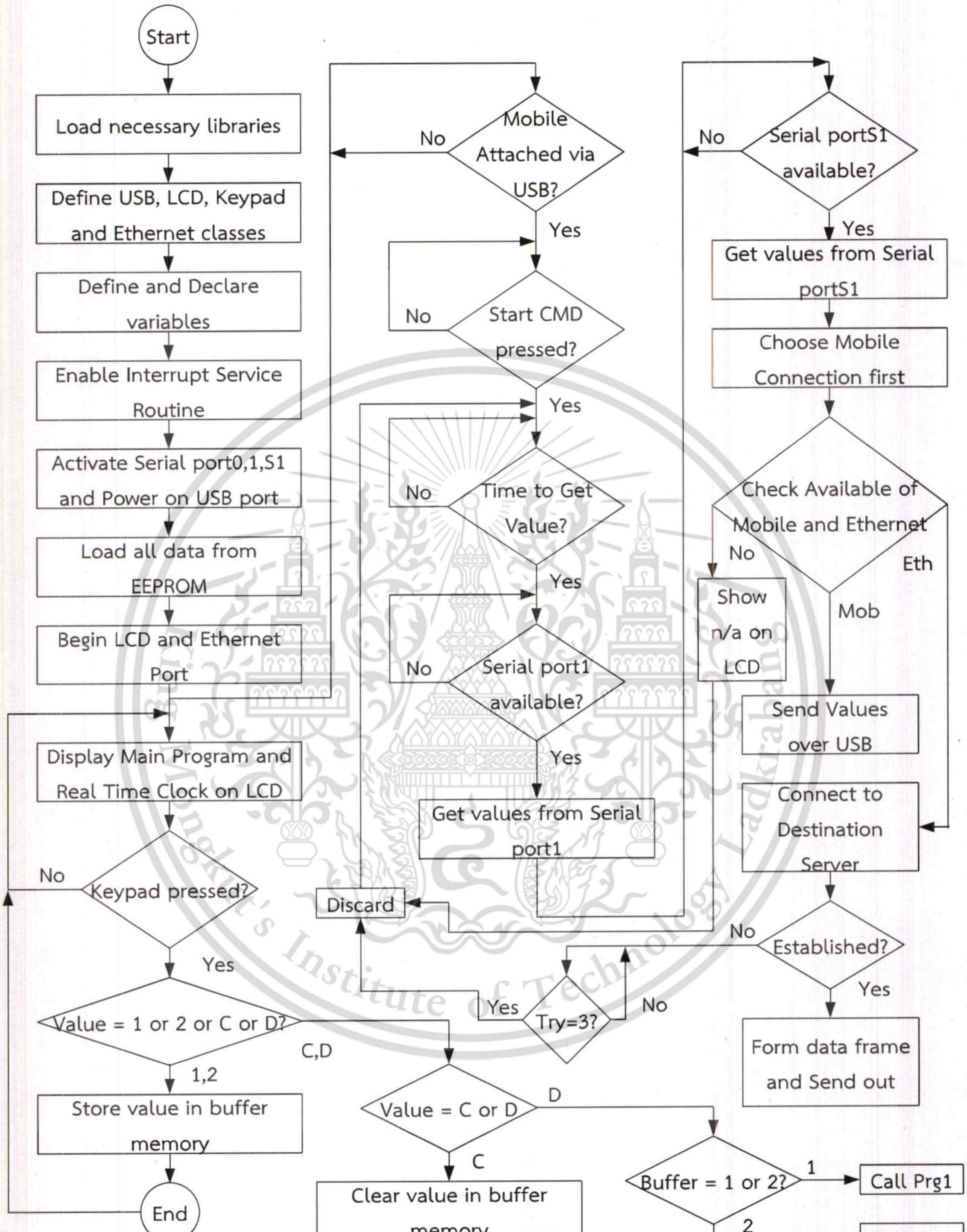


Figure 2.12: Main program on the primary microprocessor.

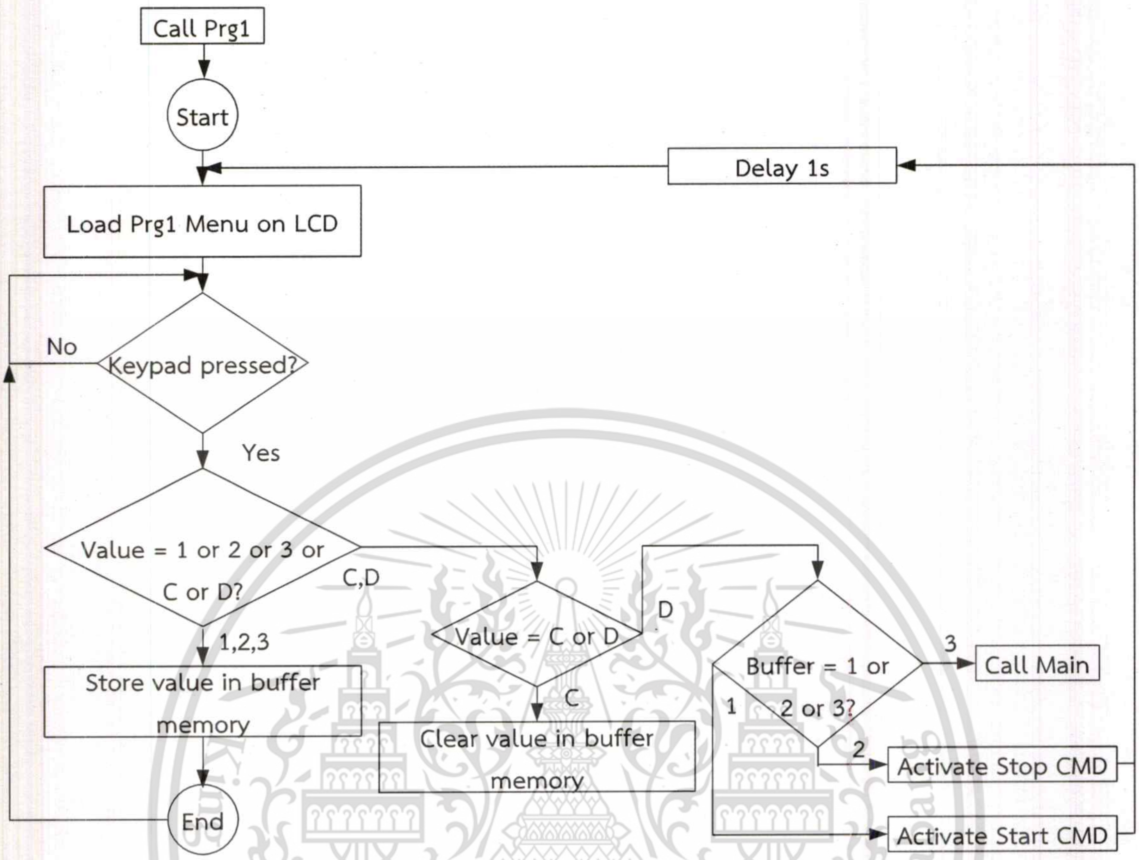


Figure 2.13: Flowchart of Prg1 in the main program.

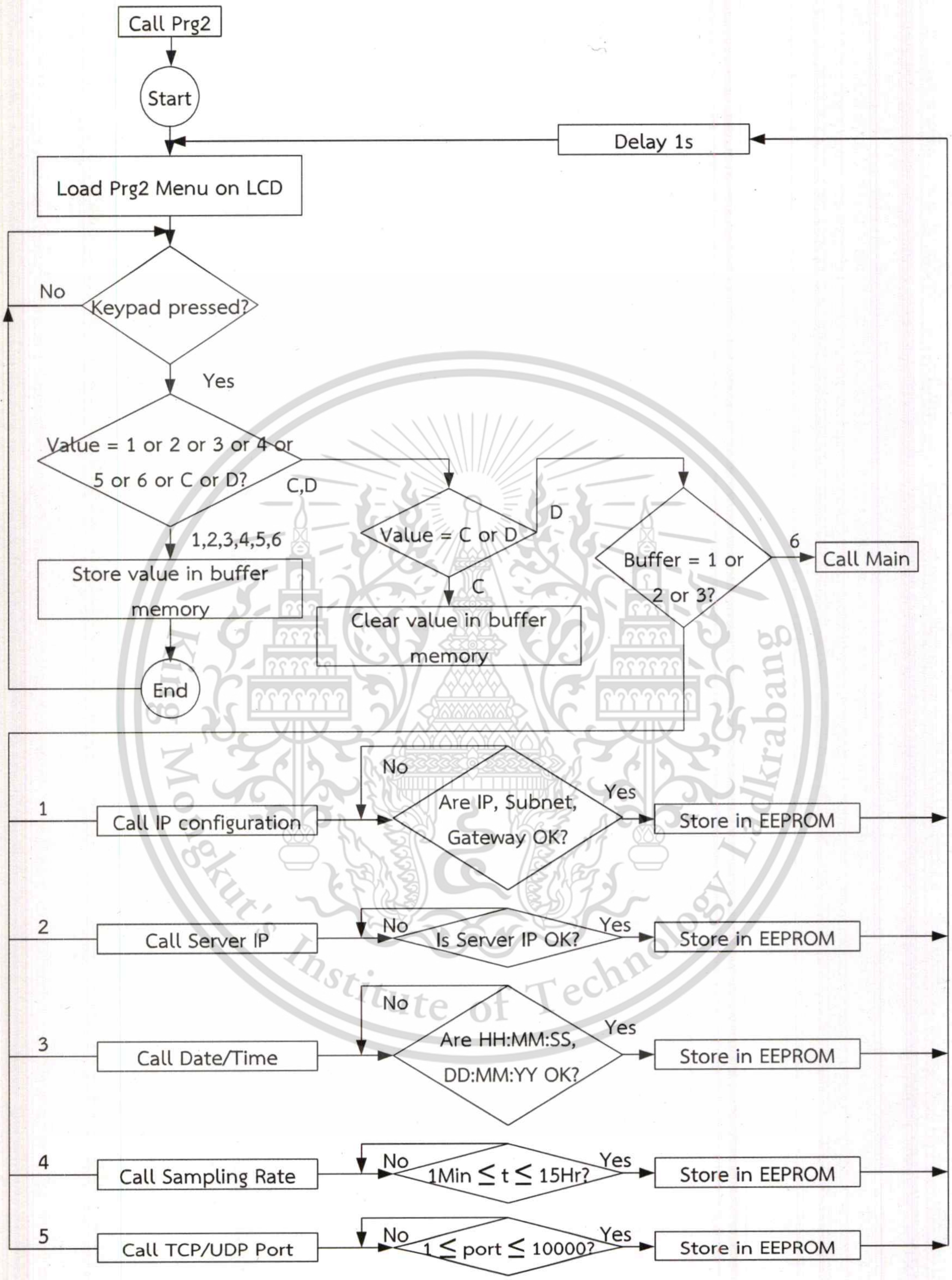


Figure 2.14: Flowchart of Prg2 in the main program.

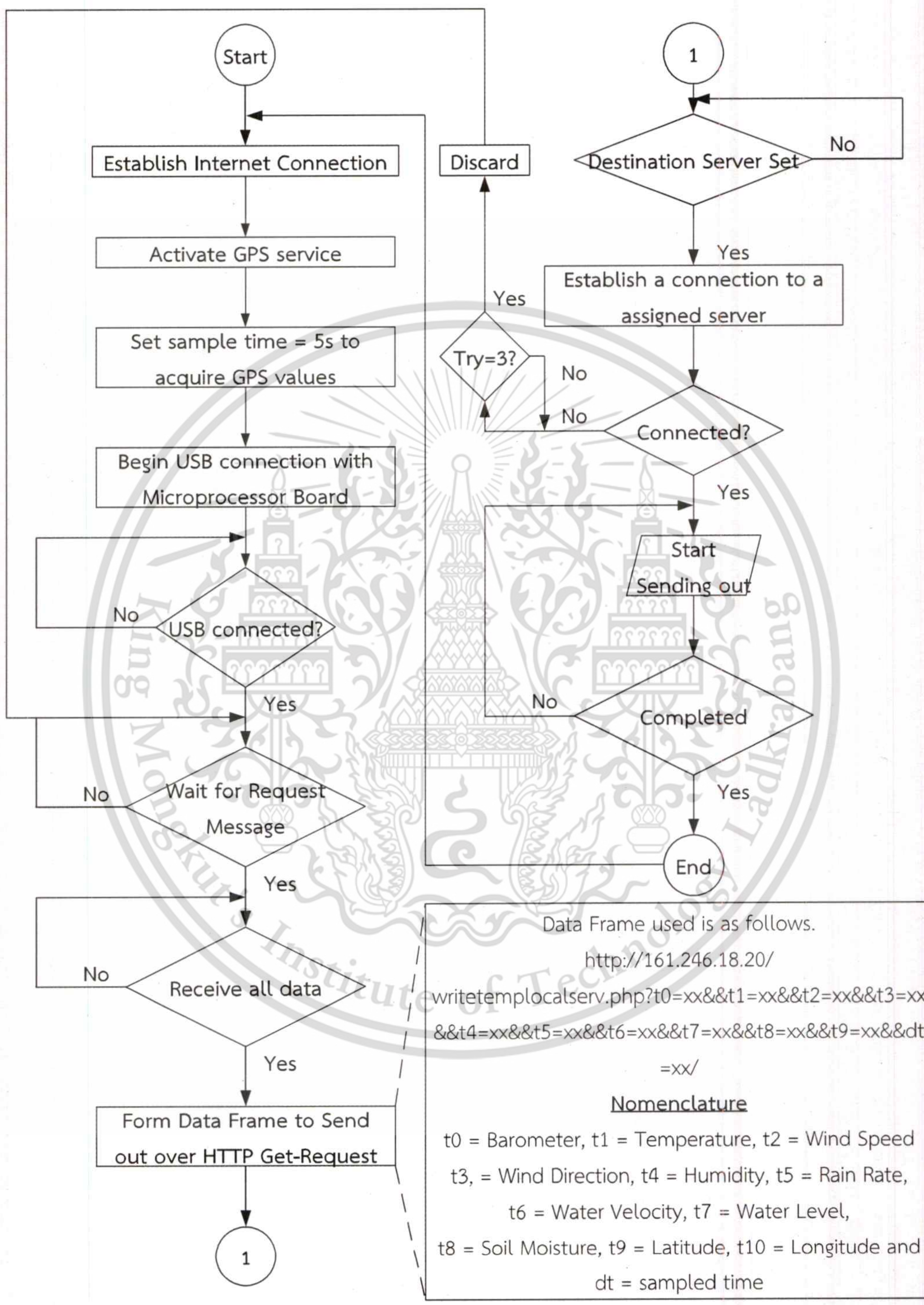
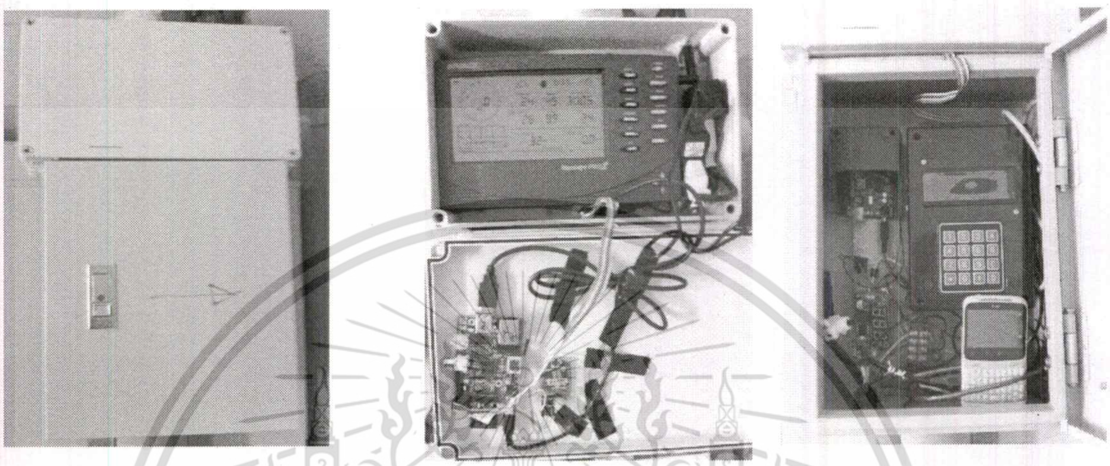


Figure 2.15: Flowchart of the data transmission process in the Android phone.



a) b) c)

Figure 2.16: The control unit and sensors installed at the mobile station. a) External of the control unit. b) Internal of the top control unit. c) Internal of the bottom control unit.

The mobile monitoring station for flood warning has been tested on site at the Hydrology Irrigation Center for Central Region in Chinat province during a visit from the Japanese experts. The data (water level, water flow rate, and weather parameters) are successfully transferred to the central data management system.

Chapter 3

Satellite Communications Unit

In case of natural disasters such as floods, landslides, or earthquakes, infrastructures of terrestrial and cellular telephone networks are often damaged. Relief efforts to restore the original networks could take weeks, so communications between stranded disaster victims and other areas are cutoff. To quickly restore communications during or immediately after such disasters, Raspberry Pi, a credit-card sized computer, is used as a server to control and manage sensor data from the weather station. The data is sent to the database on the central server via an Internet network of IPSTAR satellite. This real-time sensor data can be monitored and utilized by people in the disaster areas, as well as other people outside the affected areas. An IP phone is used to send and receive calls between disaster area and safe areas. This satellite communications system is depicted in Fig. 3.1.

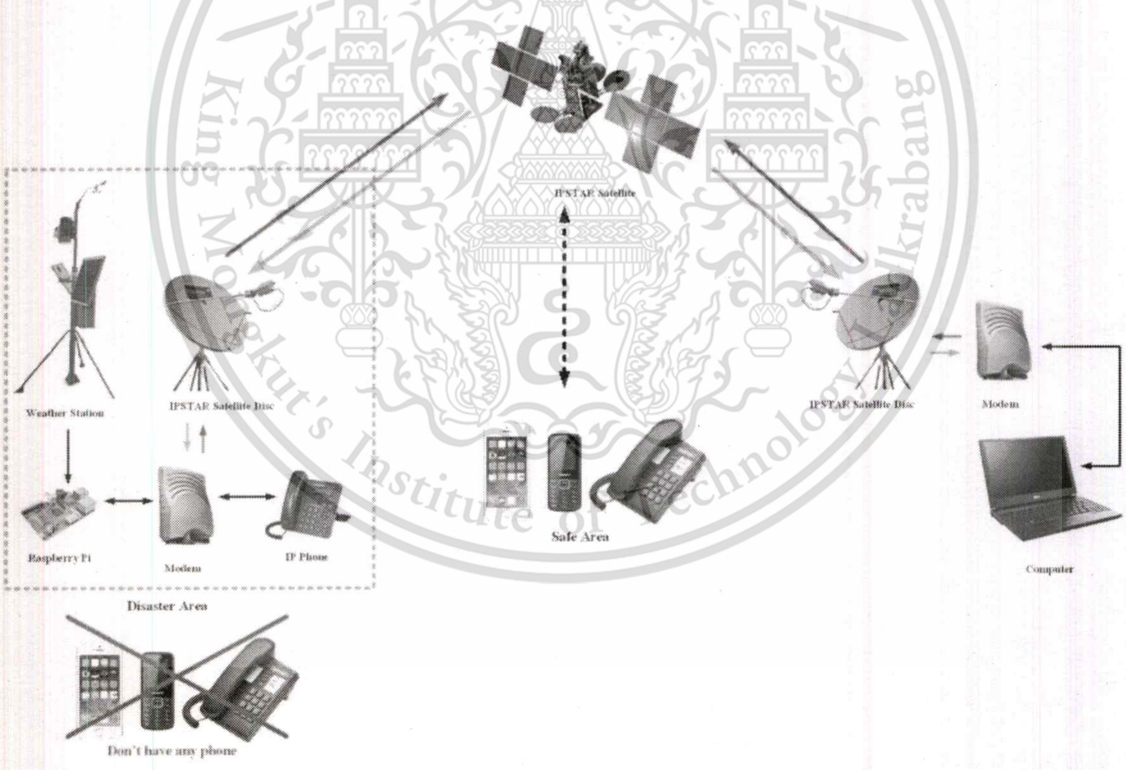


Figure 3.1: Communications system via IPSTAR satellite during disaster.

3.1 Raspberry Pi

Raspberry Pi is a credit-card sized computer first developed as a low-cost computer for kids to learn programming. However, because it is small, has low power consumption, and is programmable just like a regular PC, it is suitable to be used in a small job that does not require heavy computing. Our system has adapted Raspberry Pi to be an embedded system used as a controller. It receives sensor data from the weather station and connects to the satellite via an indoor unit, which is a modem connected to an IP phone.

In this project we opt for Raspberry Pi board (model B), whose specifications are given in Table 3.1.

Table 3.1: Raspberry Pi board (Model B) specifications.

System on a chip (SoC)	Broadcom BCM2835 (CPU, GPU)
CPU	700MHz ARM1176JZF-S core (ARM11 family, ARMv6 instruction set)
GPU	Broadcom VideoCore IV @ 250 MHz OpenGL ES 2.0 (24 GFLOPS) MPEG-2 and VC-1, 1080p30 H.264/MPEG-4 AVC high-profile decoder and encoder
Memory (SDRAM)	512 MB (Shared with GPU)
USB 2.0 Ports	2 (via the built-in integrated USB hub)
Video Input	A CSI input connector allows for the connection of RPi designed camera module
Video Outputs	Composite RCA (PAL and NTSC), HDMI (rev 1.3 & 1.4), raw LCD Panels via DSI 14 HDMI resolutions from 640x350 to 1920x1080 plus various PAL and NTSC standards.
Audio Outputs	3.5 mm jack, HDMI, and as of revision 2 boards, I2S audio (also potentially for audio input)
Onboard storage	SD/ MMC/ SDIO card slot (3.3V card power support only)
Onboard network	10/100 Ethernet (8P8C)

Low-level peripheralsLow-level peripherals	GPIO, UART, I2C Bus, SPI Bus with two chip selects, I2S audio +3.3V, +5V, Ground
Power ratings	700 mA (3.5 W)
Power source	5 Volt via Micro USB or GPIO header
Size	85.0 mm x 56.0 mm x 17 mm
Weight	40 g

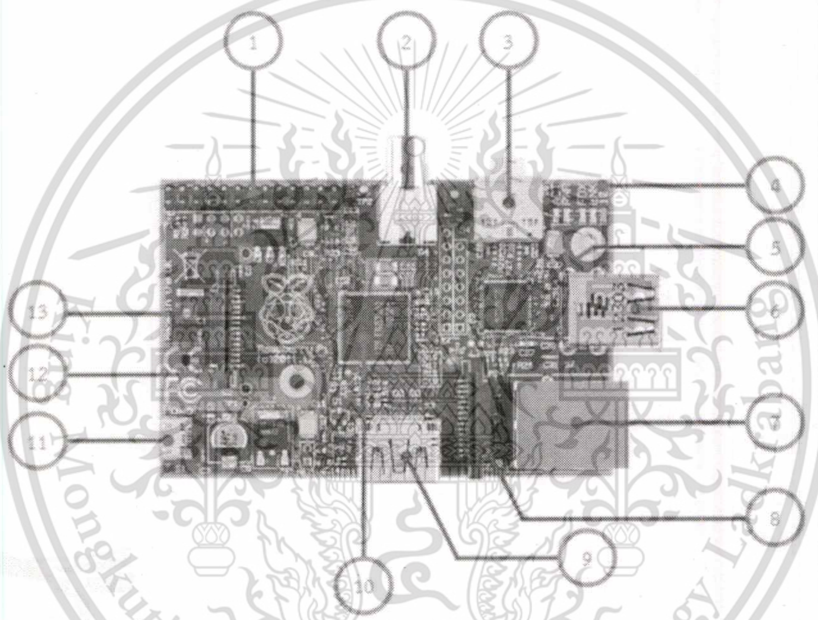


Figure 3.2: Raspberry Pi board (Model B).

Fig. 3.2 depicts the Raspberry Pi board (Model) B. It consists of the following parts.

1 GPIO port. The Pin layout on model A and B (Revision 1) are the same, but it is different in model B (Revision 2) which is given in Fig. 3.3.

3.3V	1	2	5V
I2C0 SDA	3	4	DNC
I2C0 SCL	5	6	GROUND
GPIO4	7	8	UART TXD
DNC	9	10	UART RXD
GPIO 17	11	12	GPIO 18
GPIO 21	13	14	DNC
GPIO 22	15	16	GPIO 23
DNC	17	18	GPIO 24
SP10 MOSI	19	20	DNC
SP10 MISO	21	22	GPIO 25
SP10 SCLK	23	24	SP10 CE0 N
DNC	25	26	SP10 CE1 N

Figure 3.3: Pin layout of the GPIO port on Raspberry Pi Model B (Revision 2).

2 Composite RCA video output port.

3 3.5mm audio jack

4 Status LED (Shown in the red square on Fig. 3.4)

ACT: SD Card Access status (green). It flashes during SD card activity.

PWR: Power status. It is steady ON when R-Pi receives 3.3V Power (red).

FDX: Full Duplex status (green). It is ON when Ethernet connection is full duplex.

LNK: LAN Link/Activity status (green). It is ON when Ethernet is connected.

100: 10/100Mbps LAN status (yellow). It is ON when connection is 100 MBps and OFF when connection is 10 Mbps.

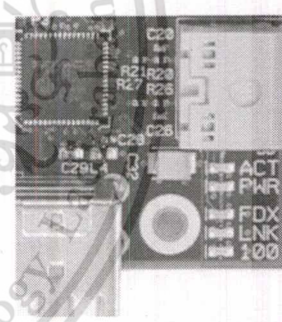


Figure 3.4: Status LED on Raspberry Pi board.

5 LAN Controller.

6 USB 2.0 ports (2 ports).

7 RJ-45 Ethernet LAN port (10/100Mbps)

8 CSI (Camera Serial Interface) for connection to camera module.

9 HDMI video and audio port.

10 Broadcom BCM2835 ARM11 700MHz Chip

11 Micro USB Power port. This is to power the R-Pi board.

12 DSI (Display Serial Interface) port for connection to display monitor.

13 SD Card slot. On the bottom of the board.

3.2 IPSTAR Satellite

IPSTAR system provides a high-speed two-way broadband internet service via satellite connection. The terminal equipment has been specially designed so that it can be used not only with IPSTAR satellite but also other types of satellite. For relief effort during disasters or other emergency situations, the IPSTAR system and service has been developed to meet the users' requirement—to quickly recover the communication networks in the areas that are severely affected by such disasters. It can provide high-speed internet, satellite phone and satellite news gathering (SNG), and acts as a backup broadband communication system for hours, days, or even weeks after disaster until regular services can be restored.

The benefits of using IPSTAR for disaster aids are:

- It acts as a terrestrial infrastructure backup when the regular structure is damaged.
- It serves as a stand-alone system for sending data, voice, and video applications.
- It can be set up quickly in the disaster-affected areas.
- It does not have a limitation on its service areas. It can be used in the business areas, urban areas, or remote areas without landlines. On the other hands, other high-speed internet services, e.g., ADSL and cable modem, can be used in the areas within and around the city limit.
- Its satellite dish for transmitting and receiving signals is compact.

The pictures of IPSTAR satellite dish and the modem are depicted in Fig. 3.5.

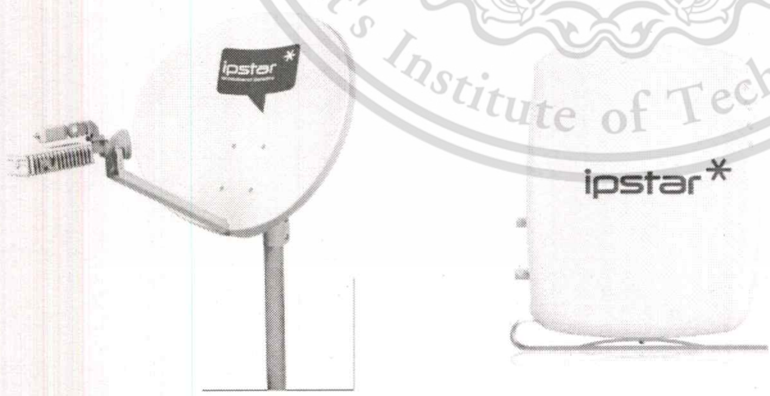


Figure 3.5: 1.2 meter satellite dish with LNB (left) and IPSTAR modem (right).

3.3 IP Phone

Instead of connecting to a traditional public switched telephone network (PSTN), an IP Phone uses voice over IP (VoIP) protocol for sending/receiving calls through an IP network such as the internet. The VoIP telephone network is depicted in Fig. 3.6. Among many standard protocols, Session Initiation Protocol (SIP) is commonly used for voice and video calls. The IP phone compresses 64 Kbps digital voice signals and encodes with low-bit-rate Vocoder so that the signal is down to around 8-10 Kbps. The signals are then arranged into IP packets before being sent through the network to the destination.

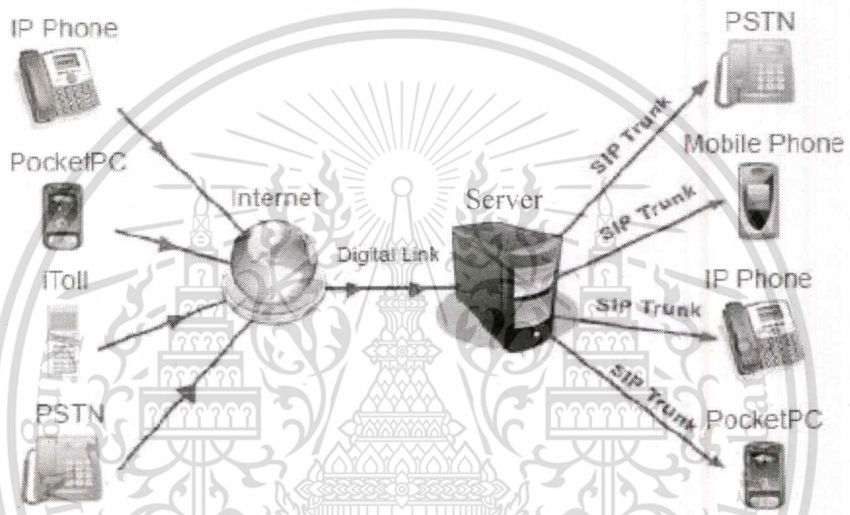


Figure 3.6: VoIP telephone network.

Some benefits of VoIP system for disaster are:

- Extending the telephone network. Any devices supporting over-the-internet operations such as PA, PDA phone, mobile phone, can connect through VoIP into the disaster-affected areas.
- Saving the cost of long distance calls. Networks in different cities can be connected via VLAN on the internet, so that they can communications as if they were close by. The system only incurs the cost of connecting to the internet.
- Saving the cost of network setup. It uses the high-speed internet network from IPSTAR. Besides, network management and maintenance are easy. There is no cost for software copyright as that is part of the IPSTAR service.

3.4 Installation and testing of IP Phone using the IPSTAR system

Fig. 3.7 illustrates the IP Phone system via IPSTAR satellite, which is composed of the antenna, the modem, the IP phone, and the computer.

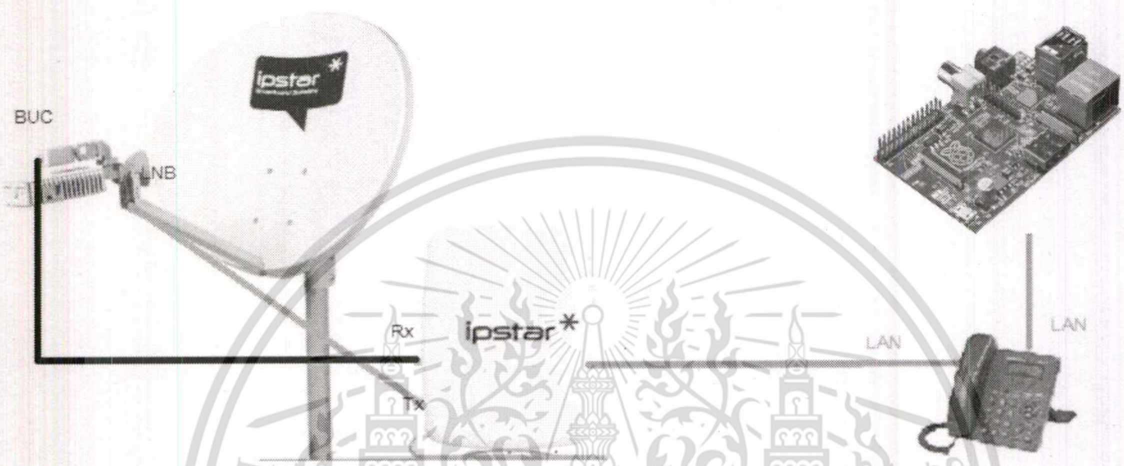
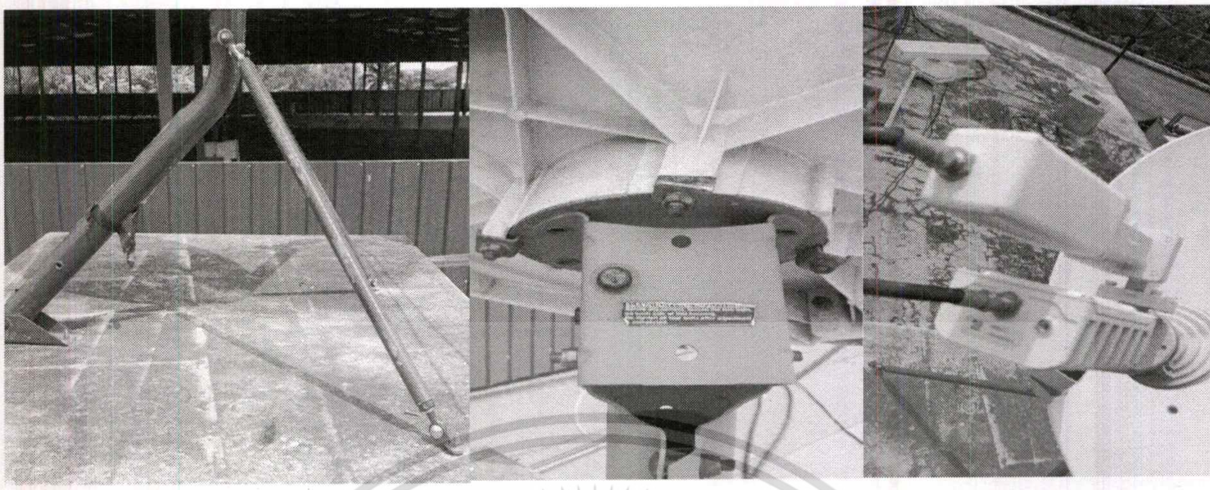


Figure 3.7: Block diagram of the IP phone system via IPSTAR satellite.

3.5 Satellite dish setup

Assemble the 1.2m satellite dish components, as shown in Fig. 3.8. Attach the stand to the cement base, as seen in Fig. 3.8(a). Adjust the stand so that it is perpendicular to the base. Assemble the dish to the stand, as shown in Fig. 3.8 (b). Next, install feed horn into its position (Fig. 3.8(c)), and secure with the nuts and bolts.



(a) (b) (c)

Figure 3.8: Satellite dish setup.

Turn the feed horn to four o'clock and adjust the azimuth angle (AZ) to 120 degrees (SE) so that the dish points to ThaiCom 4 (iPSTAR) satellite. Adjust the elevation angle (EL) to 62 degrees. The installed dish is depicted in Fig. 3.9.

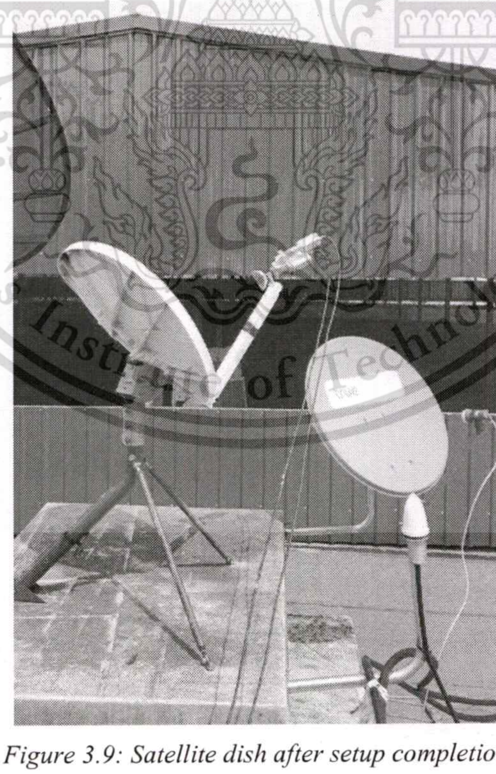


Figure 3.9: Satellite dish after setup completion.

3.6 IPSTAR modem setup

We Install the IPSTAR modem by connecting the BUC cable from the antenna to the SAT TX connector of the modem and connecting the LNB cable from the antenna to the SAT RX of the modem. Connect the network LAN RJ45 to the IP phone, as shown in Fig. 3.10. The status of the modem can be checked from the LEDs at the front panel.

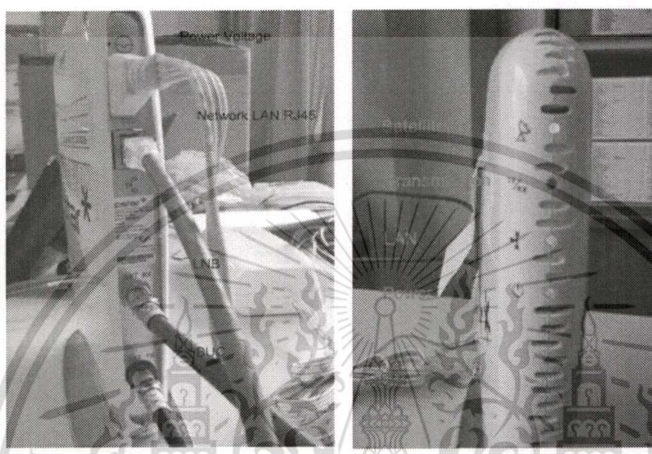


Figure 3.10: IPSTAR modem setup. Left: Cable connections to the IPSTAR modem. Right: Status LEDs of the IPSTAR modem.

Raspberry Pi is programmed to enter the IPSTAR configuration webpage at the URL http://192.168.5.100:8080/xwebgateway.cgi. We can configure many parameters through the Terminal Properties, such as networking details, satellite details. For satellite, we can adjust the antenna so that the signal strength is greater than 70 and the Es/No ratio is greater than 10. For the actual installation of the antenna at the rooftop of KMITL Telecommunications Engineering building, the signal strength level during testing is 60 and the Es/No ratio is 8.8 (see Fig. 3.11).

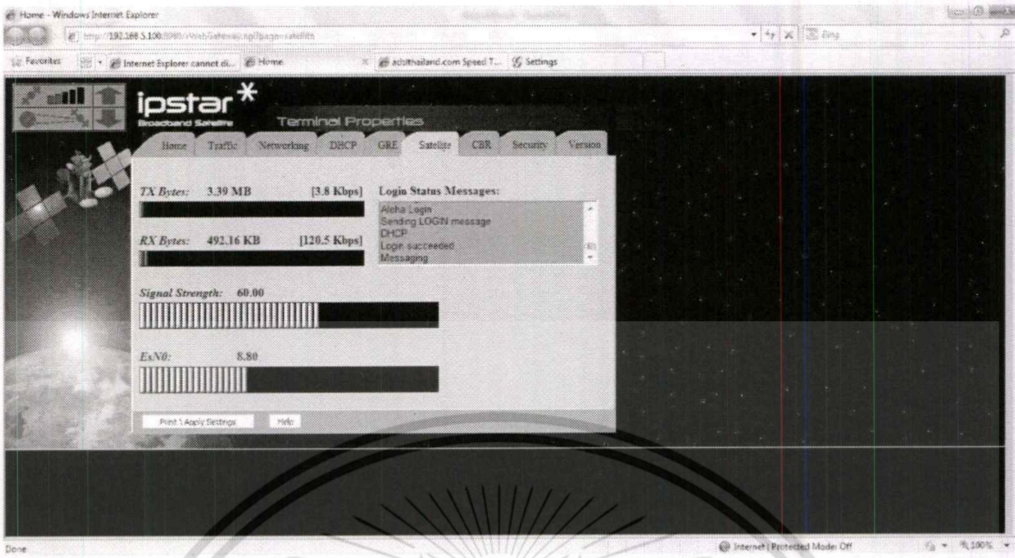


Figure 3.11: The iPSTAR configuration webpage.

3.7 IP Phone Installation

The phone model used in this project is Grandstream GXP-1405. We connect the network LAN from the IPSTAR modem to the LAN port of the IP phone. Then the network cable from the PC port on the IP phone is connected to LAN port of the Raspberry Pi. Supply 5V DC to the phone through PoE, and finally, connect the headset to the phone. The connections are depicted in Fig. 3.12.

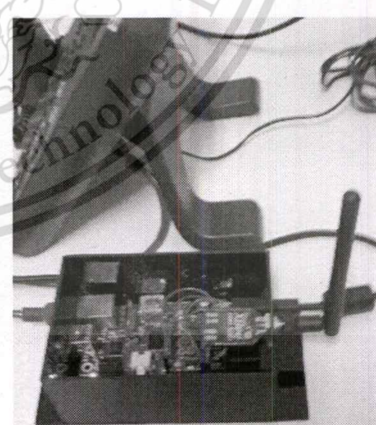


Figure 3.12: Left: Cable connections to the IP Phone. Right: Connection with Raspberry Pi.

The Raspberry Pi configures the IP phone via the Configuration webpage at http://192.168.5.3 (assigned from IPSTAR) with Login password "admin". The IP phone gets the IPv4 address from the iPSTAR modem, as seen in Fig. 3.13.

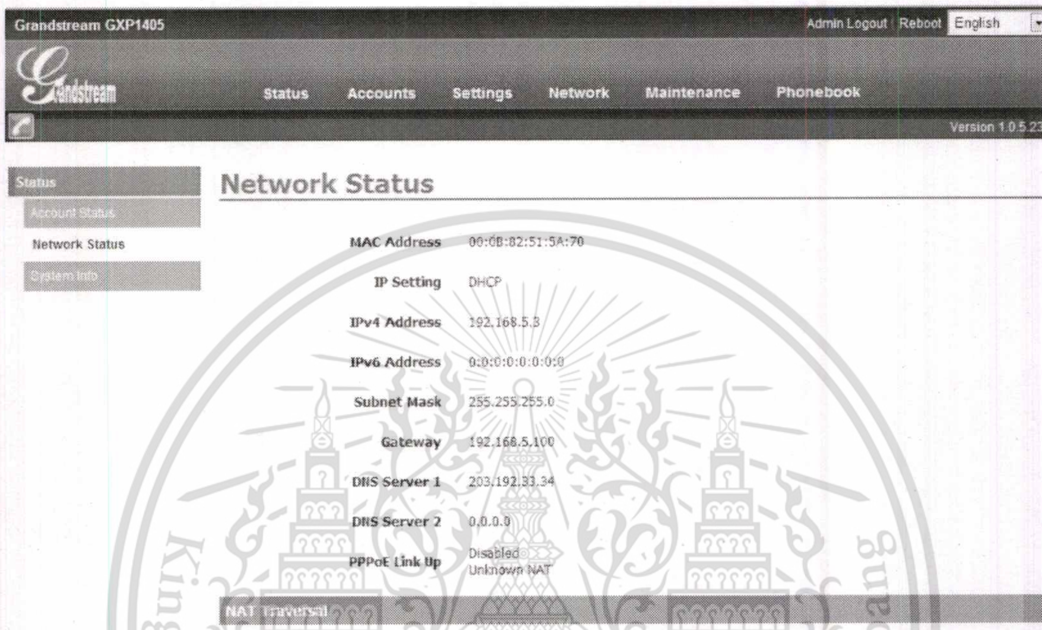


Figure 3.13: Network status window on the Configuration webpage.

Next, enter the SIP Account (from TOT), as shown in Fig. 33. Check the account registration. From Fig. 34, we can see that the phone number "0600045200" for this IP phone has been registered successfully. The phone model used can set up two SIP accounts, however we only use one account here.

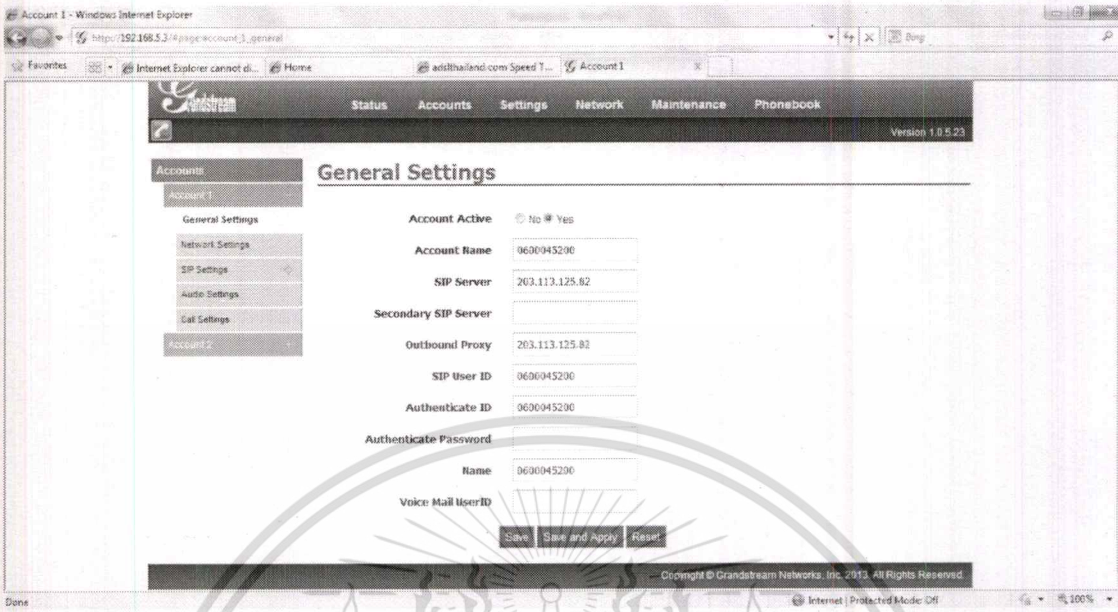


Figure 3.14: General settings window for entering the SIP account information.

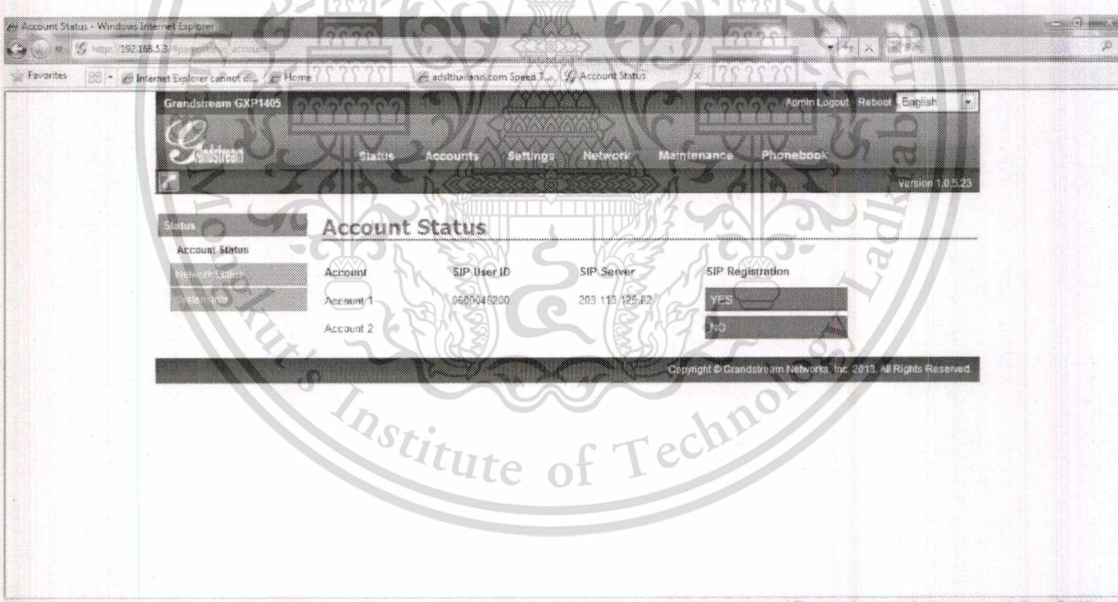


Figure 3.15: Account status window for checking the IP phone registration.

The phone operation is tested by checking the number configured to the IP phone. Fig. 3.16 displays the assigned number "0600045200" on the IP phone.

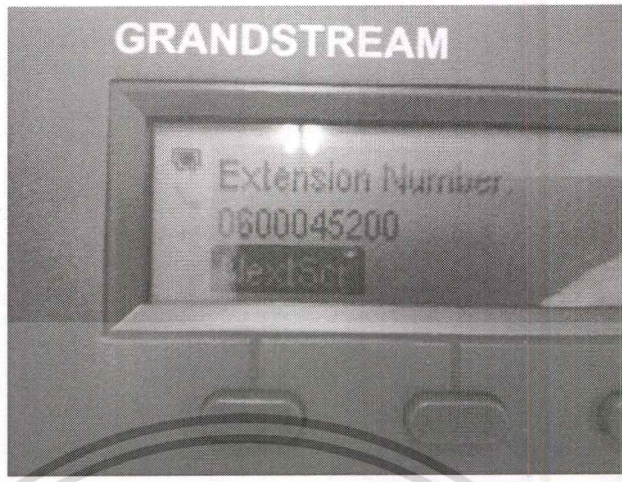


Figure 3.16: Display of the phone number assigned to the IP Phone via the configuration procedure.

After testing, the IP phone can now be used for two-way communications. The call can be placed from the IP Phone to any phone numbers (of any carriers). However, only phones on an AIS network can call the IP Phone because it is the only carrier that is supported by the iPSTAR service.

Chapter 4

The Central Data Management System

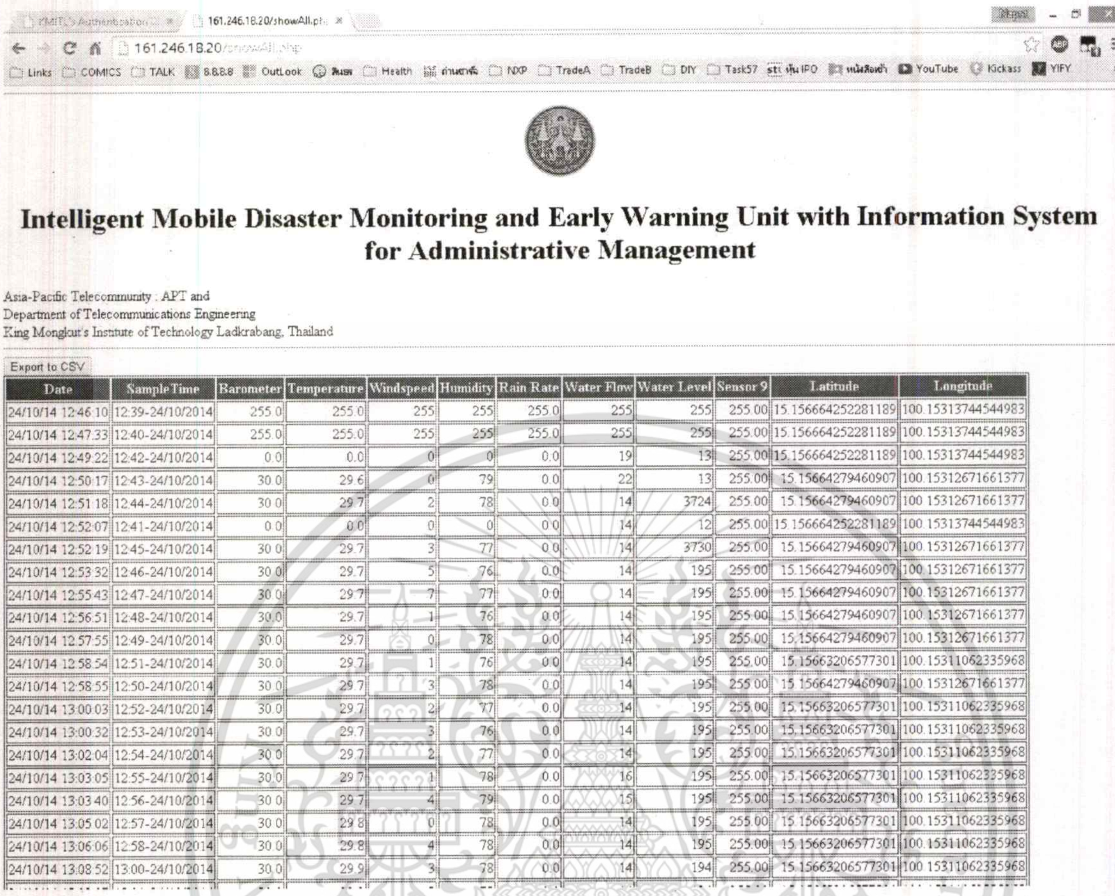
The central data management system has three main functionalities. First, it is the main server that combines data from the mobile monitoring station that is sent via GPRS module over cellular network and the data from satellite communications unit in case of cellular network damage or service disruption. Secondly, it houses the risk analysis algorithm using fuzzy expert system and sends warning alarm to corresponding official response units. Lastly, it serves as the web server that hosts information accessible to the public.

The hardware used in this project for setting up the central data center:

- IBM server (X3500 M4 model). The CPU is Intel Xeon E5-2620 6 cores 2.0 GHz, 15 MB internal cache, 16 GiB Ram, 300 GB Hard drive, Hot-Swap 2.5" SAS, 10,000 rpm. The operating system on the server is Debian 3.2.60 x64 (Linux Kernel 3.2.0).
- The Server URL is http://apt.telecom.kmitl.ac.th/
- APC SMART UPS Uninterrupted Power Supply 1000VA/670W
- DELL Inspiron 3537 W561011TH-3537-Black-Ubuntu laptop for on-site data processing
- 42" Philips 42PFL3008S/98 Display monitor

The software includes Apache 2.4.10 for the web server, MySQL 5.5.40 for database management, and PHP 5.6.0 interpreter.

The data center displays the location of the available mobile base stations. There is one mobile base stations currently sending data to the server. By clicking the "Show All" button all data from the mobile station can be monitored. Figure 4.1 displays the sensor data received from the mobile floods monitoring station operating on the test site in Chainat province. The data can also be exported in .csv format (Fig. 4.2) to other programs for subsequent processing.



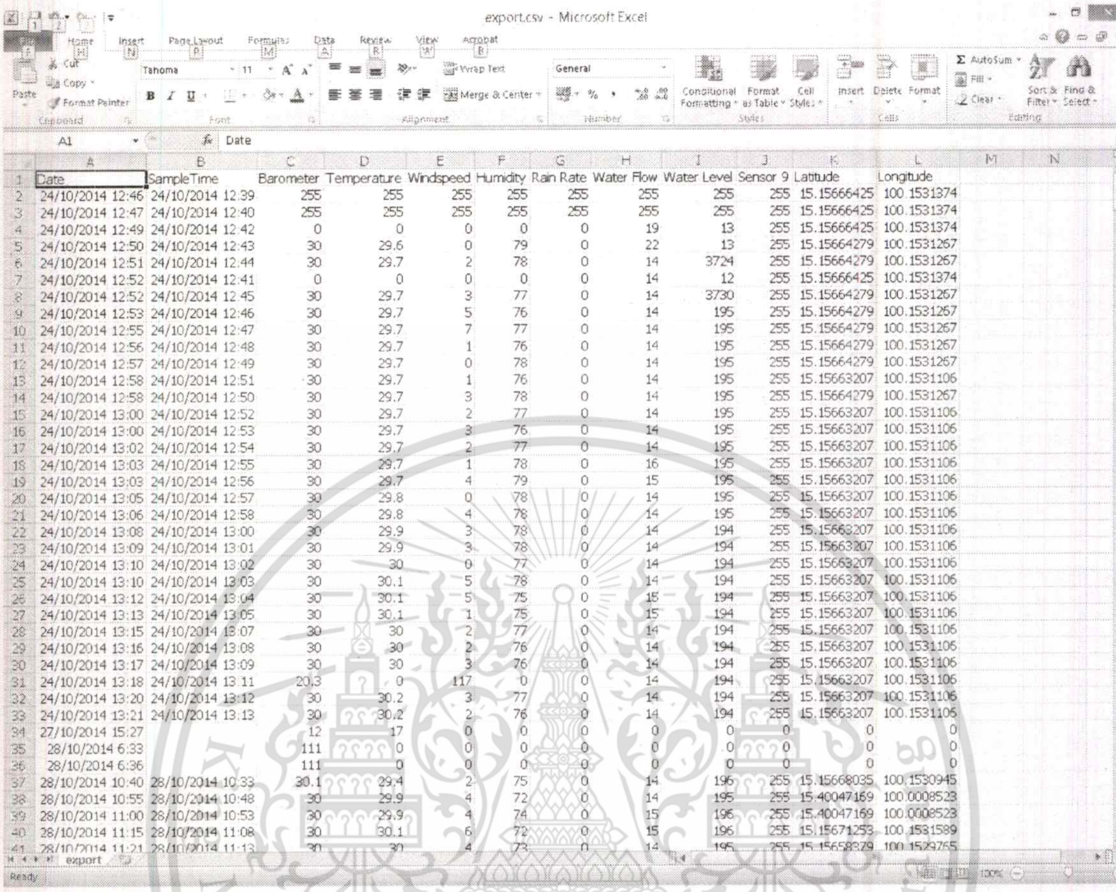
Intelligent Mobile Disaster Monitoring and Early Warning Unit with Information System for Administrative Management

Asia-Pacific Telecommunity : APT and
Department of Telecommunications Engineering
King Mongkut's Institute of Technology Ladkrabang, Thailand

Export to CSV

Date	SampleTime	Barometer	Temperature	Windspeed	Humidity	Rain Rate	Water Flow	Water Level	Sensor 9	Latitude	Longitude
24/10/14 12:46:10	12:39-24/10/2014	255.0	255.0	255	255	255.0	255	255	255.00	15.156664252281189	100.15313744544983
24/10/14 12:47:33	12:40-24/10/2014	255.0	255.0	255	255	255.0	255	255	255.00	15.156664252281189	100.15313744544983
24/10/14 12:49:22	12:42-24/10/2014	0.0	0.0	0	0	0.0	19	13	255.00	15.156664252281189	100.15313744544983
24/10/14 12:50:17	12:43-24/10/2014	30.0	29.6	0	79	0.0	22	13	255.00	15.15664279460907	100.15312671661377
24/10/14 12:51:18	12:44-24/10/2014	30.0	29.7	2	78	0.0	14	3724	255.00	15.15664279460907	100.15312671661377
24/10/14 12:52:07	12:41-24/10/2014	0.0	0.0	0	0	0.0	14	12	255.00	15.156664252281189	100.15313744544983
24/10/14 12:52:19	12:45-24/10/2014	30.0	29.7	3	77	0.0	14	3730	255.00	15.15664279460907	100.15312671661377
24/10/14 12:53:32	12:46-24/10/2014	30.0	29.7	5	76	0.0	14	195	255.00	15.15664279460907	100.15312671661377
24/10/14 12:55:43	12:47-24/10/2014	30.0	29.7	7	77	0.0	14	195	255.00	15.15664279460907	100.15312671661377
24/10/14 12:56:51	12:48-24/10/2014	30.0	29.7	1	76	0.0	14	195	255.00	15.15664279460907	100.15312671661377
24/10/14 12:57:55	12:49-24/10/2014	30.0	29.7	0	78	0.0	14	195	255.00	15.15664279460907	100.15312671661377
24/10/14 12:58:54	12:51-24/10/2014	30.0	29.7	1	76	0.0	14	195	255.00	15.15663206577301	100.15311062335968
24/10/14 12:58:55	12:50-24/10/2014	30.0	29.7	3	78	0.0	14	195	255.00	15.15664279460907	100.15312671661377
24/10/14 13:00:03	12:52-24/10/2014	30.0	29.7	2	77	0.0	14	195	255.00	15.15663206577301	100.15311062335968
24/10/14 13:00:32	12:53-24/10/2014	30.0	29.7	3	76	0.0	14	195	255.00	15.15663206577301	100.15311062335968
24/10/14 13:02:04	12:54-24/10/2014	30.0	29.7	2	77	0.0	14	195	255.00	15.15663206577301	100.15311062335968
24/10/14 13:03:05	12:55-24/10/2014	30.0	29.7	1	78	0.0	16	195	255.00	15.15663206577301	100.15311062335968
24/10/14 13:03:40	12:56-24/10/2014	30.0	29.7	4	79	0.0	15	195	255.00	15.15663206577301	100.15311062335968
24/10/14 13:05:02	12:57-24/10/2014	30.0	29.8	0	78	0.0	14	195	255.00	15.15663206577301	100.15311062335968
24/10/14 13:06:06	12:58-24/10/2014	30.0	29.8	4	78	0.0	14	195	255.00	15.15663206577301	100.15311062335968
24/10/14 13:08:52	13:00-24/10/2014	30.0	29.9	3	78	0.0	14	194	255.00	15.15663206577301	100.15311062335968

Figure 4.1: Data displayed after clicking the "Show All" button.



	Date	SampleTime	Barometer	Temperature	Windspeed	Humidity	Rain Rate	Water Flow	Water Level	Sensor 9	Latitude	Longitude
2	24/10/2014 12:46	24/10/2014 12:39	255	255	255	255	255	255	255	255	15.15666425	100.1531374
3	24/10/2014 12:47	24/10/2014 12:40	255	255	255	255	255	255	255	255	15.15666425	100.1531374
4	24/10/2014 12:49	24/10/2014 12:42	0	0	0	0	0	19	13	255	15.15666425	100.1531374
5	24/10/2014 12:50	24/10/2014 12:43	30	29.6	0	79	0	22	13	255	15.15664279	100.1531267
6	24/10/2014 12:51	24/10/2014 12:44	30	29.7	2	78	0	14	3724	255	15.15664279	100.1531267
7	24/10/2014 12:52	24/10/2014 12:41	0	0	0	0	0	14	12	255	15.15666425	100.1531374
8	24/10/2014 12:52	24/10/2014 12:45	30	29.7	3	77	0	14	3730	255	15.15664279	100.1531267
9	24/10/2014 12:53	24/10/2014 12:46	30	29.7	5	76	0	14	195	255	15.15664279	100.1531267
10	24/10/2014 12:55	24/10/2014 12:47	30	29.7	7	77	0	14	195	255	15.15664279	100.1531267
11	24/10/2014 12:56	24/10/2014 12:48	30	29.7	1	76	0	14	195	255	15.15664279	100.1531267
12	24/10/2014 12:57	24/10/2014 12:49	30	29.7	0	78	0	14	195	255	15.15664279	100.1531267
13	24/10/2014 12:58	24/10/2014 12:51	30	29.7	1	76	0	14	195	255	15.15663207	100.1531106
14	24/10/2014 12:58	24/10/2014 12:50	30	29.7	3	78	0	14	195	255	15.15664279	100.1531267
15	24/10/2014 13:00	24/10/2014 12:52	30	29.7	2	77	0	14	195	255	15.15663207	100.1531106
16	24/10/2014 13:00	24/10/2014 12:53	30	29.7	3	76	0	14	195	255	15.15663207	100.1531106
17	24/10/2014 13:02	24/10/2014 12:54	30	29.7	2	77	0	14	195	255	15.15663207	100.1531106
18	24/10/2014 13:03	24/10/2014 12:55	30	29.7	1	78	0	16	195	255	15.15663207	100.1531106
19	24/10/2014 13:03	24/10/2014 12:56	30	29.7	4	79	0	15	195	255	15.15663207	100.1531106
20	24/10/2014 13:05	24/10/2014 12:57	30	29.8	0	78	0	14	195	255	15.15663207	100.1531106
21	24/10/2014 13:06	24/10/2014 12:58	30	29.8	4	78	0	14	195	255	15.15663207	100.1531106
22	24/10/2014 13:08	24/10/2014 13:00	30	29.9	3	78	0	14	194	255	15.15663207	100.1531106
23	24/10/2014 13:09	24/10/2014 13:01	30	29.9	3	78	0	14	194	255	15.15663207	100.1531106
24	24/10/2014 13:10	24/10/2014 13:02	30	30	0	77	0	14	194	255	15.15663207	100.1531106
25	24/10/2014 13:10	24/10/2014 13:03	30	30.1	5	78	0	14	194	255	15.15663207	100.1531106
26	24/10/2014 13:12	24/10/2014 13:04	30	30.1	5	75	0	15	194	255	15.15663207	100.1531106
27	24/10/2014 13:13	24/10/2014 13:05	30	30.1	1	75	0	15	194	255	15.15663207	100.1531106
28	24/10/2014 13:15	24/10/2014 13:07	30	30	2	77	0	14	194	255	15.15663207	100.1531106
29	24/10/2014 13:16	24/10/2014 13:08	30	30	2	76	0	14	194	255	15.15663207	100.1531106
30	24/10/2014 13:17	24/10/2014 13:09	30	30	3	76	0	14	194	255	15.15663207	100.1531106
31	24/10/2014 13:18	24/10/2014 13:11	20.3	0	117	0	0	14	194	255	15.15663207	100.1531106
32	24/10/2014 13:20	24/10/2014 13:12	30	30.2	3	77	0	14	194	255	15.15663207	100.1531106
33	24/10/2014 13:21	24/10/2014 13:13	30	30.2	2	76	0	14	194	255	15.15663207	100.1531105
34	27/10/2014 15:27		12	17	0	0	0	0	0	0	0	0
35	28/10/2014 6:33		111	0	0	0	0	0	0	0	0	0
36	28/10/2014 6:36		111	0	0	0	0	0	0	0	0	0
37	28/10/2014 10:40	28/10/2014 10:33	30.1	29.4	2	75	0	14	196	255	15.15668035	100.1530945
38	28/10/2014 10:55	28/10/2014 10:48	30	29.9	4	72	0	14	195	255	15.40047169	100.0008523
39	28/10/2014 11:00	28/10/2014 10:53	30	29.9	4	74	0	15	196	255	15.40047169	100.0008523
40	28/10/2014 11:15	28/10/2014 11:08	30	30.1	6	72	0	15	196	255	15.15671253	100.1531589
41	28/10/2014 11:21	28/10/2014 11:13	30	30	4	73	0	14	195	255	15.15658379	100.1529765

Figure 4.2: Sample data from mobile base station in .csv format.

4.1 Early Floods Warning Software

Disaster risk analysis and early warning algorithm has been developed for floods warning up to 24 hours in advance. The measured data from different sensor modules is sent and collected at the central data server. Risk analysis is performed using Adaptive Neuro Fuzzy Inference Systems (ANFIS). The ANFIS combines artificial neural network with the fuzzy inference system, where reference from disaster experts is used to construct the rule (rule-based fuzzy logic) for disaster inference.

The algorithm is installed on both the mobile monitoring station and the central data management system. Once the algorithm detects possible incoming disaster, the preliminary warning is promptly sent out from the mobile station. At the same time, the central data management system will report the detected potential disaster to the official disaster response unit, who will consequently analyze the severity of the situation. Official alarm and appropriate protocol will be sent to all related governmental units as well as to appointed local contact person. It is also possible to adjust the inference rule/criteria when additional local information or prior information on past disasters becomes available.

4.1.1 Algorithm design

The disaster analysis and early warning algorithm has been designed for floods monitoring. The algorithm is designed to predict an event of floods 24 hours in advance. Floods prediction uses two ANFIS systems, as shown in Fig. 4.3. The Inputs of the system are today's water level and flow rate, and the differential flow rate between yesterday and today. The first ANFIS uses today's water level and the differential flow rate as inputs to predict tomorrow's water level. The second ANFIS predicts tomorrow's flow rate from today's flow rate and the differential flow rate. The outputs are compared with the flooding criteria to determine whether it is normal, critical, or at flooding level. Note that these criteria (Normal, Critical, and Flood) are location-dependent. Floods happens when either the water level or the water flow rate meet the flooding criteria.

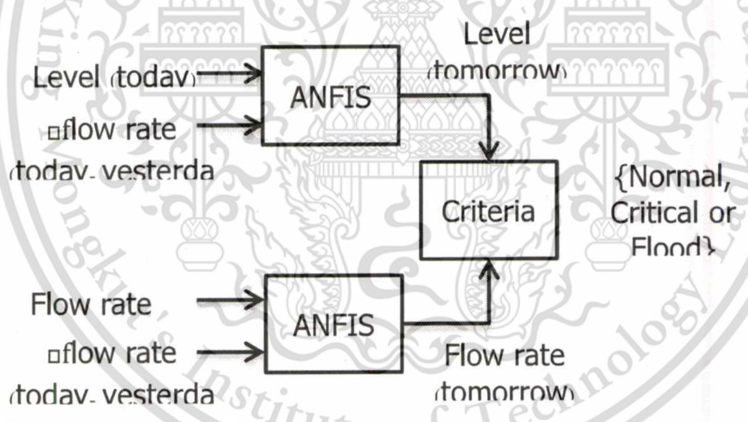


Figure 4.3: Block diagram of the early floods warning system.

The architecture of the proposed ANFIS for early flood warning is illustrated in Fig. 4.4.

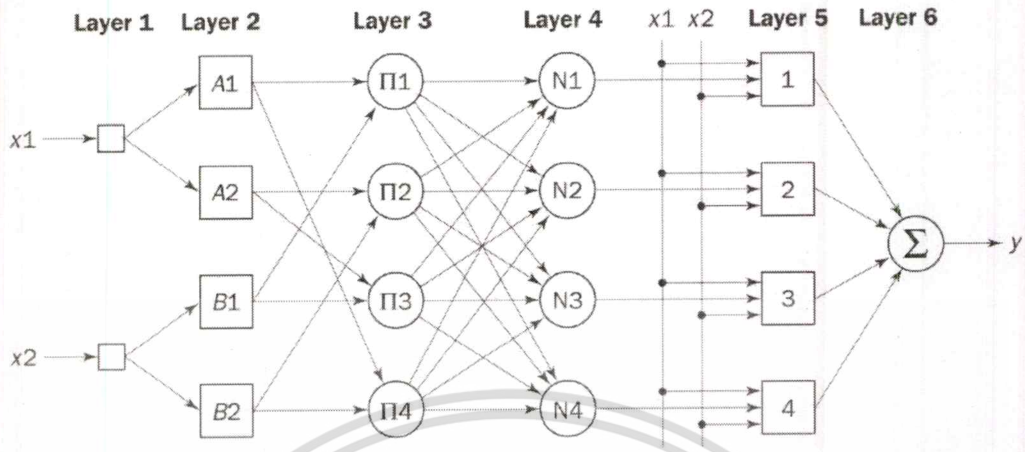


Figure 4.4: Architecture of the ANFIS.

The structure consists of *6* layers according to the feed-forward neural network. There are two system inputs x*1* and x*2*. Input x*1* corresponds to two fuzzy sets A*1* and A*2*, whereas fuzzy sets B*1* and B*2* are for input x*2*. There is one output, y. Following Sugeno fuzzy model, we construct four rules:

<u>Rule 1:</u>
If x_1 is A_1
And x_2 is B_1
Then $y = f_1 = k_{10} + k_{11}x_1 + k_{12}x_2$

<u>Rule 2:</u>
If x_1 is A_2
And x_2 is B_2
Then $y = f_2 = k_{20} + k_{21}x_1 + k_{22}x_2$

<u>Rule 3:</u>
If x_1 is A_2
And x_2 is B_1
Then $y = f_3 = k_{30} + k_{31}x_1 + k_{32}x_2$

<u>Rule 4:</u>
If x_1 is A_1
And x_2 is B_2
Then $y = f_4 = k_{40} + k_{41}x_1 + k_{42}x_2$

k_{i0}, k_{i1}, and k_{i2} are consequent parameters of rule i.

The operations in each layer can be summarized as follows.

1) <u>Layer 1: Input layer</u>

This layer processes the inputs before passing it to Layer 2, using

$$y_i^{(1)} = x_i \tag{2}$$

where i is the index for the i^{th} neuron.

2) <u>Layer 2: Fuzzification layer</u>

The fuzzification step takes the inputs from Layer 1 and determines the degree to which these inputs belong to each of the fuzzy sets via the membership functions $m_{A_i}(x)$

$$y_i^{(2)} = m_{A_i}(y_i^{(1)}) \tag{3}$$

when $y_i^{(2)}$ is the membership function of A_i. The membership function adopted from Jang's model is the Bell activation function, whose equation is

$$y_i^{(2)} = \frac{1}{1+\left(\dfrac{y_i^{(1)}-a_i}{c_i}\right)^{2b_i}} \tag{4}$$

where a_i, b_i, and c_i are the parameters for controlling the center, the width, and the slope of such function, respectively.

3) Layer 3: Rule layer

The rule layer computes the firing strength of the rules for each neurons. The result in this layer is from the product

$$y_i^{(3)} = \prod_{j=1}^{m} x_{ji}^{(3)} \tag{5}$$

For example, the output of rule layer for the rule in the first neuron (Π_1) is

$$y_1^{(3)} = y_1^{(2)} \times y_3^{(2)} = \mu_1 \tag{6}$$

μ_1 is the firing strength or truth value of Rule 1.

4) Layer 4: Normalization layer

The Normalization calculates the normalized firing strength

$$y_i^{(4)} = \frac{\mu_i}{\sum_{j=1}^{n} \mu_j} = \bar{\mu}_i \tag{7}$$

5) Layer 5: Defuzzification layer

This layer calculates the weighted consequent values of the rules using the inputs,

$$y_i^{(5)} = \bar{\mu}_i \left[k_{i0} + \sum_{j=1}^{m} k_{ij} x_j \right] \tag{8}$$

6) Layer 6: Summation neuron

The output y of the ANFIS is finally calculated using

$$y = \sum_{i=1}^{2m} y_i^{(5)} \tag{9}$$

The ANFIS training algorithm utilizes a hybrid learning algorithm, which combines a least-square estimator with a gradient descent method, to adjust parameters k's and the membership functions. The weights in the feedforward pass are determined using least-square estimations. The backward pass applies the back-propagation algorithm.

For the Sugeno-style ANFIS used in this algorithm, the output y is a linear function. Therefore, from the input-output pattern we can write P linear equations to represent the parameter outputs as,

$$f = y_i^{(5)} \tag{10}$$

Alternatively, in matrix form we have

$$\mathbf{y_d} = \mathbf{Ak} \tag{11}$$

where $\mathbf{y_d}$ is $P \times 1$ vector of the desired output.

$$\mathbf{y_d} = \begin{bmatrix} y_d(1) \\ y_d(2) \\ \vdots \\ y_d(p) \\ \vdots \\ y_d(P) \end{bmatrix} \tag{12}$$

$\mathbf{A}$ is a $P \times n(1+m)$ matrix,

$$\mathbf{A} = \begin{bmatrix} \bar{\mu}_1(1) & \bar{\mu}_1(1)x_1(1) & \cdots & \bar{\mu}_1(1)x_m(1) & \cdots & \bar{\mu}_n(1) & \bar{\mu}_n(1)x_n(1) & \cdots & \bar{\mu}_1(1)x_m(1) \\ \bar{\mu}_1(2) & \bar{\mu}_1(2)x_1(2) & \cdots & \bar{\mu}_1(2)x_m(2) & \cdots & \bar{\mu}_n(2) & \bar{\mu}_n(2)x_n(2) & \cdots & \bar{\mu}_1(1)x_m(1) \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots & \vdots & \cdots & \\ \bar{\mu}_1(p) & \bar{\mu}_1(p)x_1(p) & \cdots & \bar{\mu}_1(p)x_m(p) & \cdots & \bar{\mu}_n(p) & \bar{\mu}_n(p)x_n(p) & \cdots & \bar{\mu}_1(1)x_m(1) \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots & \vdots & \cdots & \\ \bar{\mu}_1(P) & \bar{\mu}_1(P)x_1(P) & \cdots & \bar{\mu}_1(P)x_m(P) & \cdots & \bar{\mu}_n(P) & \bar{\mu}_n(P)x_n(P) & \cdots & \bar{\mu}_1(1)x_m(1) \end{bmatrix} \tag{13}$$

and $\mathbf{k}$ is an $n(1+m)\times 1$ vector of the unknown parameters,

$$\mathbf{k}=[k_{10}\;k_{11}\;k_{12}\ldots k_{1m}\;k_{20}\;k_{21}\;k_{22}\ldots k_{2m}\ldots k_{n0}\;k_{n1}\;k_{n2}\ldots k_{nm}]^{T} \tag{14}$$

Typically, if the number of equations P in the learning process is larger than the number of parameters (*n(1+m)*), the system of linear equation is over-determined, and we can use the pseudo-inverse technique to solve for k,

$$\mathbf{k}^{*}=(\mathbf{A}^{T}\mathbf{A})^{-1}\mathbf{A}^{T}y_{d} \tag{15}$$

We can calculate the error vector,

$$e = y_d - y \tag{16}$$

The Back-propagation algorithm is utilized in the backward pass, and the parameters are updated using chain rule. When there is an update of the weight for parameter a of Bell activation function for neuron A_1, we obtain the following chain rule,

$$\Delta a=-\alpha\frac{\partial E}{\partial a}=-\alpha\frac{\partial E}{\partial a}\times\frac{\partial e}{\partial y}\times\frac{\partial y}{\partial(\bar{\mu}_i f_i)}\times\frac{\partial(\bar{\mu}_i f_i)}{\partial\bar{\mu}_i}\times\frac{\partial\bar{\mu}_i}{\partial\mu_i}\times\frac{\partial\mu_i}{\partial\mu_{A1}}\times\frac{\partial\mu_{A1}}{\partial a} \tag{17}$$

The variable α is the learning rate, and E is the error of the ANFIS output.

Because

$$E=\frac{1}{2}e^{2}=\frac{1}{2}(y_d - y)^{2} \tag{18}$$

Hence,

$$\Delta a=-\alpha(y_d-\mathbf{y})(-1)f_i\times\frac{\bar{\mu}_i(1-\bar{\mu}_i)}{\mu_i}\times\frac{\mu_i}{\mu_{A1}}\times\frac{\partial\mu_{A1}}{\partial a} \tag{19}$$

or

$$\Delta a=\alpha(y_d-y)f_i\bar{\mu}_i(1-\bar{\mu}_i)\times\frac{1}{\mu_{A1}}\times\frac{\partial\mu_{A1}}{\partial a} \tag{20}$$

where

$$\frac{\partial\mu_{A1}}{\partial a}=-\frac{1}{\left[1+\left(\frac{x1-a}{c}\right)^{2b}\right]^{2}}\times\frac{1}{c^{2b}}\times 2b\times(x1-a)^{2b-1}\times(-1) \tag{21}$$

$$= \mu^2_{A1} \times \frac{2b}{c} \times \left(\frac{x1 - a}{c}\right)^{2b-1} \tag{22}$$

Parameter b and c can be calculated in a similar manner.

4.1.2 Algorithm testing for early floods warning

We test the performance of our algorithm using the data at Bangbal station (C37) in Ayuttaya province, Thailand. This location experiences annual flooding during the rainy season. Hence, there are sufficient data to create flooding criteria based on actual events. During flooding, the water level and water flow rate exceed the river capacity. The flooding criteria at C37 station are displayed in Table 4.1.

Table 4.1: Flooding criteria at Bangbal station

Water level (m)			**Water flow rate (m^3/s)**		
Normal	Critical	Flood	Normal	Critical	Flood
< 3.35	3.35-3.80	> 3.80	< 110	110-134	> 134

The system learns from the water level and water flow rate data between 2008 and 2011. For the fuzzification layer (Layer 2), the fuzzy sets of the first input (A_1 and A_2) and those for the second input (B_1 and B_2) in terms of the membership functions are illustrated in Fig.4.5.

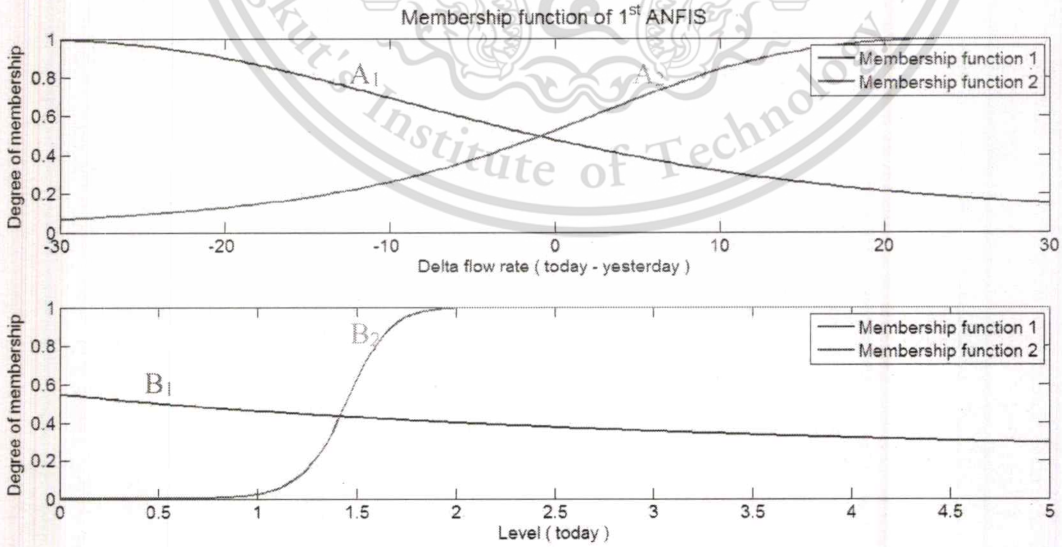


Figure 4.5: Membership functions of the 1st ANFIS.

Using the bell activation function,

$$y_i^{(2)} = \frac{1}{1+\left(\dfrac{y_i^{(1)}-a_i}{c_i}\right)^{2b_i}} \quad (23)$$

a_i , b_i and c_i are calculated to be

$$A_1 : a_1 = -34.83 \ b_1 = 1.345 \ c_1 = 33.71$$

$$A_2 : a_2 = 32.32 \ b_2 = 2.11 \ c_2 = 33.09$$

$$B_1 : a_3 = -1.752 \ b_3 = 0.3962 \ c_3 = 0.3962$$

$$B_2 : a_4 = 3.711 \ b_4 = 10.27 \ c_4 = 2.267.$$

For defuzzification layer (Layer 5), the coefficients k_{i0} , k_{i1} and k_{i2} for the first order equation

$$y_i^{(5)} = \bar{\mu}_i \left[k_{i0} + \sum_{j=1}^{m} k_{ij} x_j \right] \quad (24)$$

are

$$k_{10} = 2.573 \ k_{11} = 0.1058 \ k_{12} = 0.3198.$$

$$k_{20} = -1.767 \ k_{21} = -0.04154 \ k_{22} = 1.333$$

$$k_{30} = -2.322 \ k_{31} = 0.1372 \ k_{32} = 1.572$$

$$k_{40} = 1.54 \ k_{41} = -0.04321 \ k_{42} = 0.7214$$

Similarly, we obtain the membership functions for the 2nd ANFIS, as depicted in Fig. 4.6, along with the following coefficients,

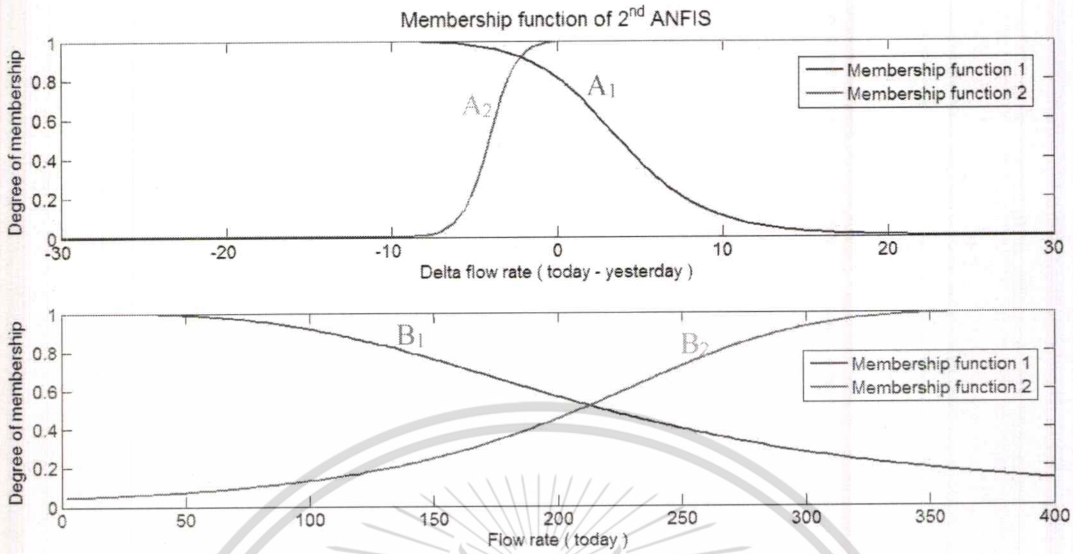


Figure 4.6: Membership functions of the 2nd ANFIS.

$$A_1 : a_1 = -31.12 \;\; b_1 = 6.494 \;\; c_1 = 34.83$$

$$A_2 : a_2 = 28.38 \;\; b_2 = 20.04 \;\; c_2 = 32.48$$

$$B_1 : a_3 = 5.509 \;\; b_3 = 1.488 \;\; c_3 = 212.4$$

$$B_2 : a_4 = 419.3 \;\; b_4 = 2.241 \;\; c_4 = 209.7$$

and

$$k_{10} = -5.135 \;\; k_{11} = -0.206 \;\; k_{12} = 0.9859$$

$$k_{20} = -30.66 \;\; k_{21} = 0.6983 \;\; k_{22} = 1.084$$

$$k_{30} = 4.163 \;\; k_{31} = 0.4111 \;\; k_{32} = 0.9912$$

$$k_{40} = 34.38 \;\; k_{41} = 0.7558 \;\; k_{42} = 0.9029.$$

After training, the algorithm predicts the daily water levels and water flow rates for 2012. The predicted water levels and flow rates, compared against the actual measurements, are depicted in Fig. 4.7 and 4.8, respectively.

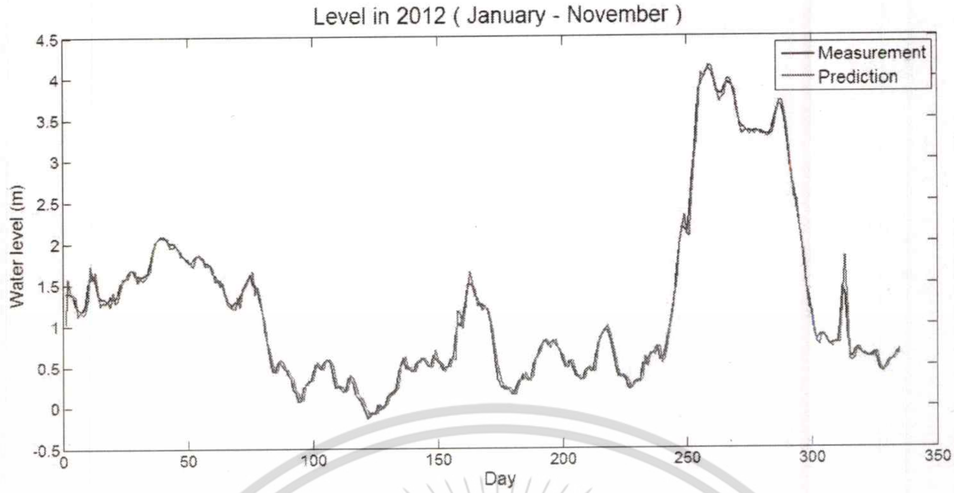


Figure 4.7: Predicted and measured daily water level in 2012.

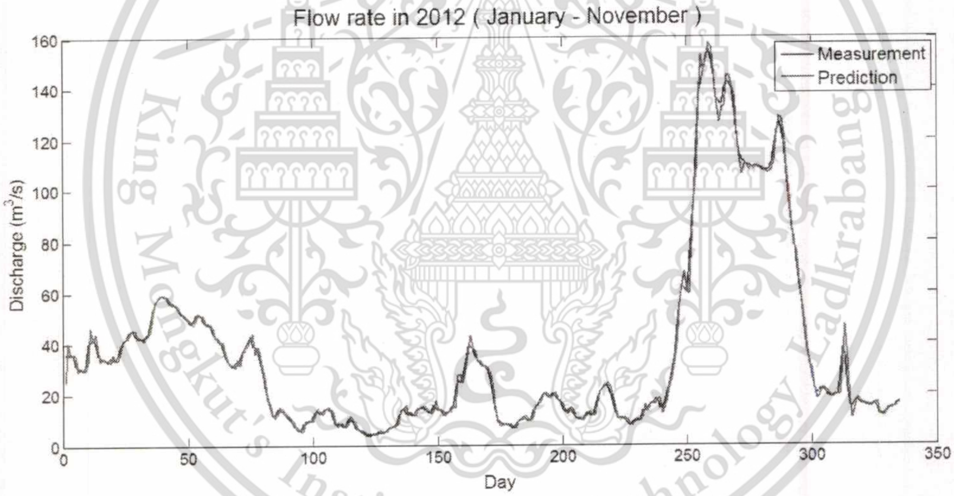


Figure 4.8: Predicted and measured daily water flow rate in 2012.

It is observed that the predicted results are in excellent agreement with the actual measurements with minimal errors. The maximum errors for the algorithm predictions are 0.3 m for water level, and 0.45 m^3/s for water flow rate. Fig. 4.9 illustrates the predicted results in January 2012.

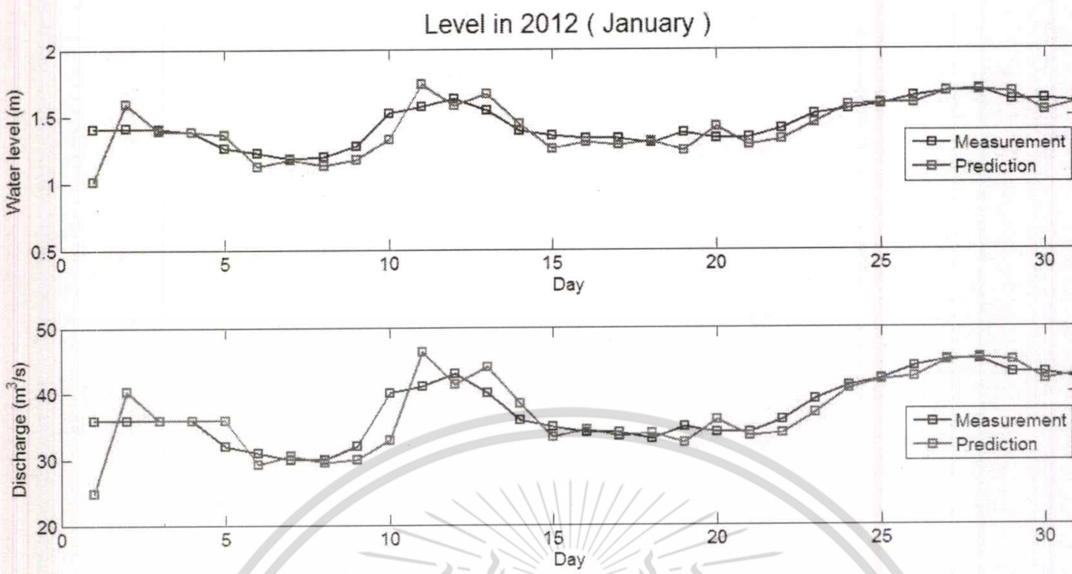


Figure 4.9: Predicted and measured daily water level and flow rate in January 2012.

We measure the efficiency of our algorithm using three indices, namely the mean absolute deviation (MAD), the mean square error (MSE), and the efficiency index (EI). These quantities are given by the following equations.

$$MAD = \frac{\sum_{i=1}^{N}|t_i - z_i|}{N} \quad (25)$$

$$MSE = \frac{\sum_{i=1}^{N}(t_i - z_i)^2}{N} \quad (26)$$

$$EI = \frac{(ST - SSE)}{ST} \quad (27)$$

with $ST = \sum_{i=1}^{N}(t_i - \overline{t_i})^2$ and $SSE = \sum_{i=1}^{N}(t_i - z_i)^2$. t_i and z_i are measured and predicted values, respectively. The performance of the algorithm in terms of these performance measures are given in Table 4.2. Note that the efficiency indices are above 99% for all cases, confirming the efficacy of our algorithm.

Table 4.2: Performance indices for the early floods warning algorithm using data at C37 station.

	Water level		Water flow rate	
	2008-2011 data	**2012 data**	**2008-2011 data**	**2012 data**
MAD	0.0691 m	0.0605 m	2.0260 m^3/s	1.6687 m^3/s
MSE	0.0102 m	0.0073 m	11.1248 m^3/s	6.5649 m^3/s
EI	0.9960	0.9932	0.9986	0.9949

For 2012, there were two floods happening in September (during September 11-18, 2012 and 21-24 September, 2012). Our algorithm is able to correctly predict both events, as shown in Fig. 4.10.

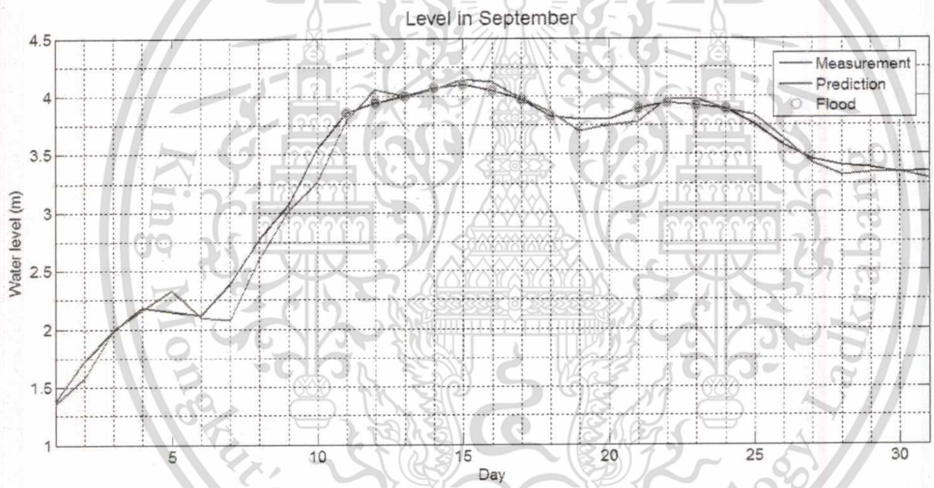


Figure 4.10: Floods predictions in September 2012.

The early flood warning algorithm is installed in the central data management system. It analyzes the data sent to the central server from the mobile monitoring stations. The display GUI is designed using LabVIEW. Fig. 4.11 is an example of the GUI which monitors Bangbal station (C37). The left panel shows the location of the monitoring station on a google map. The right panel displays the monitoring status. In Fig. 4.12, the system sends out a warning that that there would be floods occurring on September 11, 2012 based on the predicted water level (4 m, shown in red graph). The measured sensor data in Fig. 4.13 (blue graph) confirms that the prediction was correct and the water level was in the flooding zone (>3.8 m).

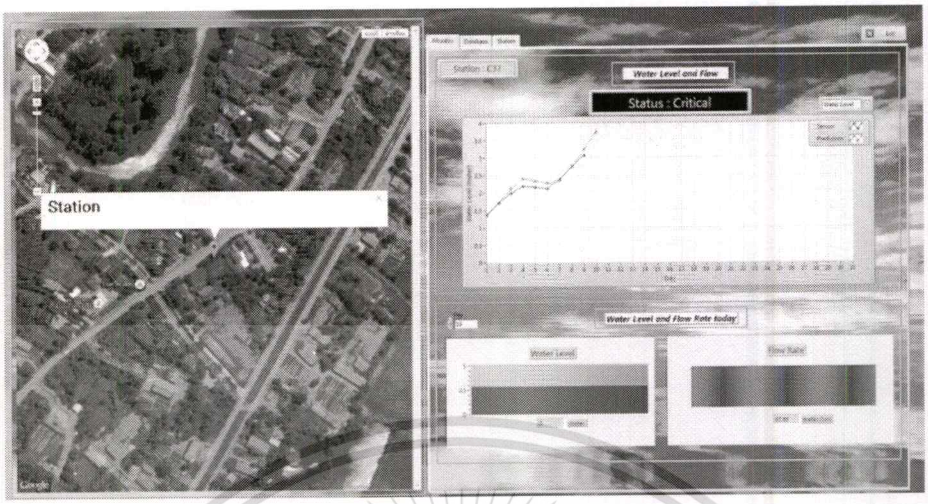


Figure 4.11: Display GUI of the floods monitoring system.

Figure 4.12: Flooding is predicted on September 11, 2012.

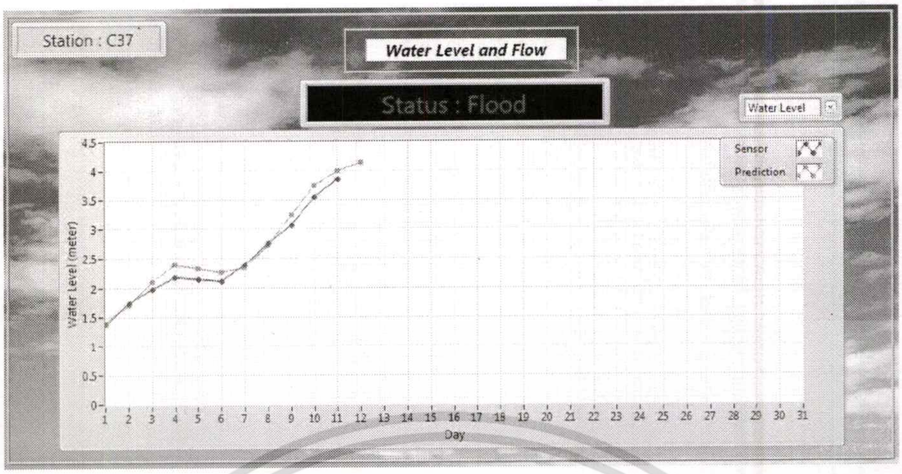


Figure 4.13: Flooding is observed on September 11, 2012.

In addition, the GUI displays other sensor data acquired from the weather station at C37, for example, temperature, atmospheric pressure, humidity, wind speed and direction, and rainfall rate, as shown in Fig 4.14.

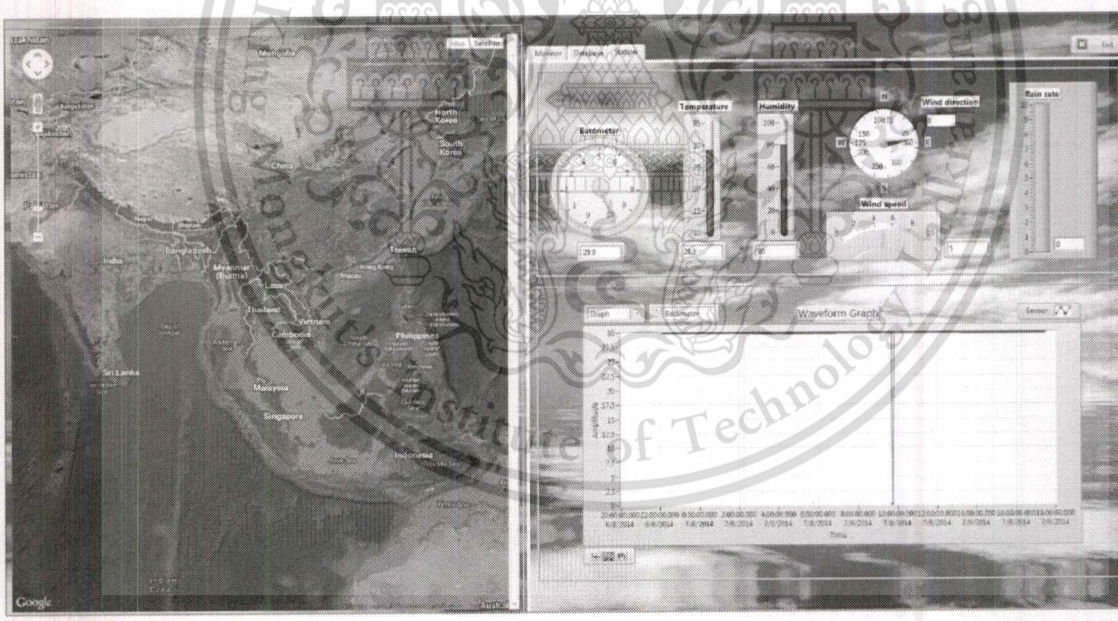


Figure 4.14: Weather parameters displayed on the GUI.

4.2 Landslide monitoring and detection system

4.2.1 Landslide monitoring using hazard map

In Thailand, statistics collected since 1970 suggest that a landslide caused by flash floods from heavy rainfall happen every five years or so, usually in the northern or southern provinces. Reoccurrences at previously affected areas are also rare. Different types of rocks have been recorded and classify according to the corresponding landslides. Rain-induced landslides, which can cause severe damage to human life and property, have been on the increase in the past decade. Examples of past landslides are illustrated in Fig. 4.15.

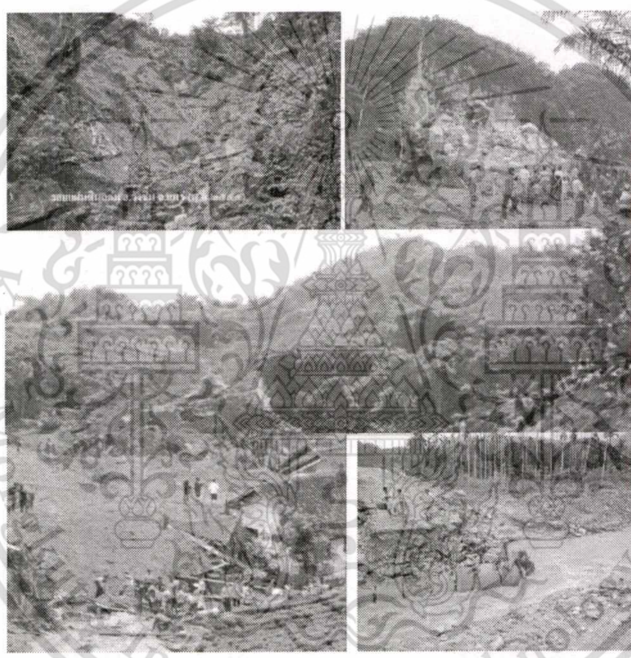


Figure 4.15: Past landslide events in Thailand.

A hazard map for landslide can be created using either a weighting factor or a geotechnical engineering analysis. A hazard map allows active monitoring of specific areas that are prone to landslide. Related government entities such as the Department of Mineral Resources and Land Development Department utilize geographical information to produce such maps using weighting factor method. Factors that are correlated to landslide occurrence such as surface slope, soil characteristics, land usage, local rainfall rate, or past incidences are weighted to assign risk level for each area. Figure 4.16 and 4.17 depicts a landslide hazard map for the entire country, and for a specific province, Phrae, respectively.

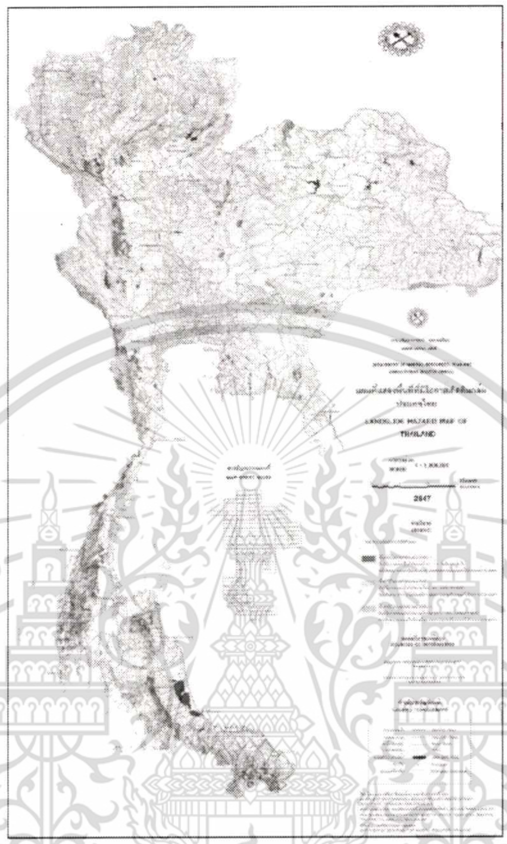


Figure 4.16: Landslide hazard map for Thailand.

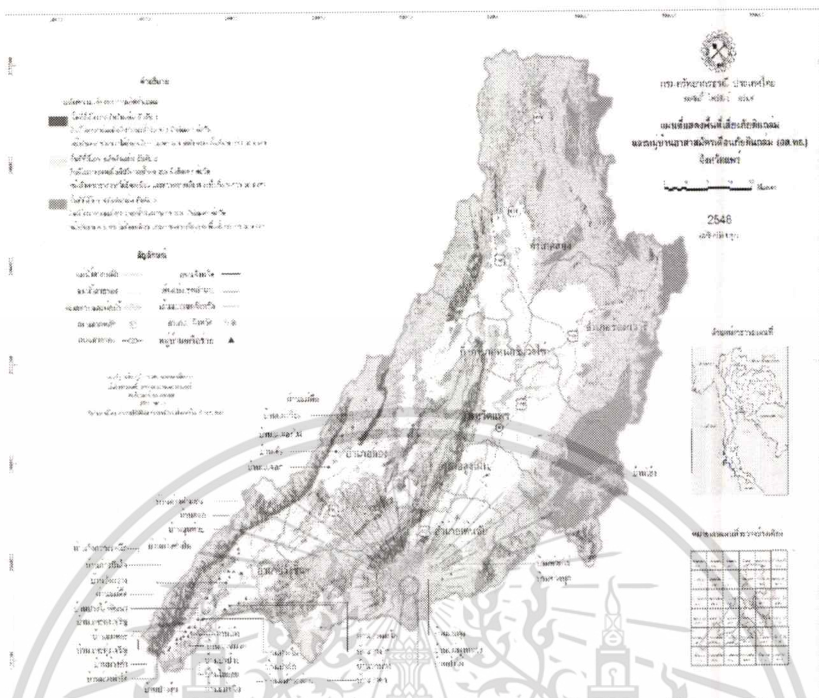


Figure 4.17: Landslide hazard map for Phrae province.

Although there are other indices that may be used to indicate a possibility of a landslide, for example, faults (from rock/soil movements), soil moisture level, water clarity (in rivers/lakes), or cloud density, a rainfall rate is currently the best index for landslide warning. Using a rainfall rate in the target area as an index is convenient because the measurement can be performed easily; Data sensing is inexpensive and can be done automatically as part of the sensor network.

S. Soralump of Kasetsart University have proposed using a Critical Antecedent Precipitation Index *(API_{cr})* for landslide warning criterion. A landslide hazard map has been generated based in this API_{cr} value, as illustrated in Fig. 4.18, with six different hazard zones. The range of average API_{cr} value is 885-1068 mm with 180-263 mm standard deviation (SD). The coefficients of variation (COV) are between 20.23-26.12%.

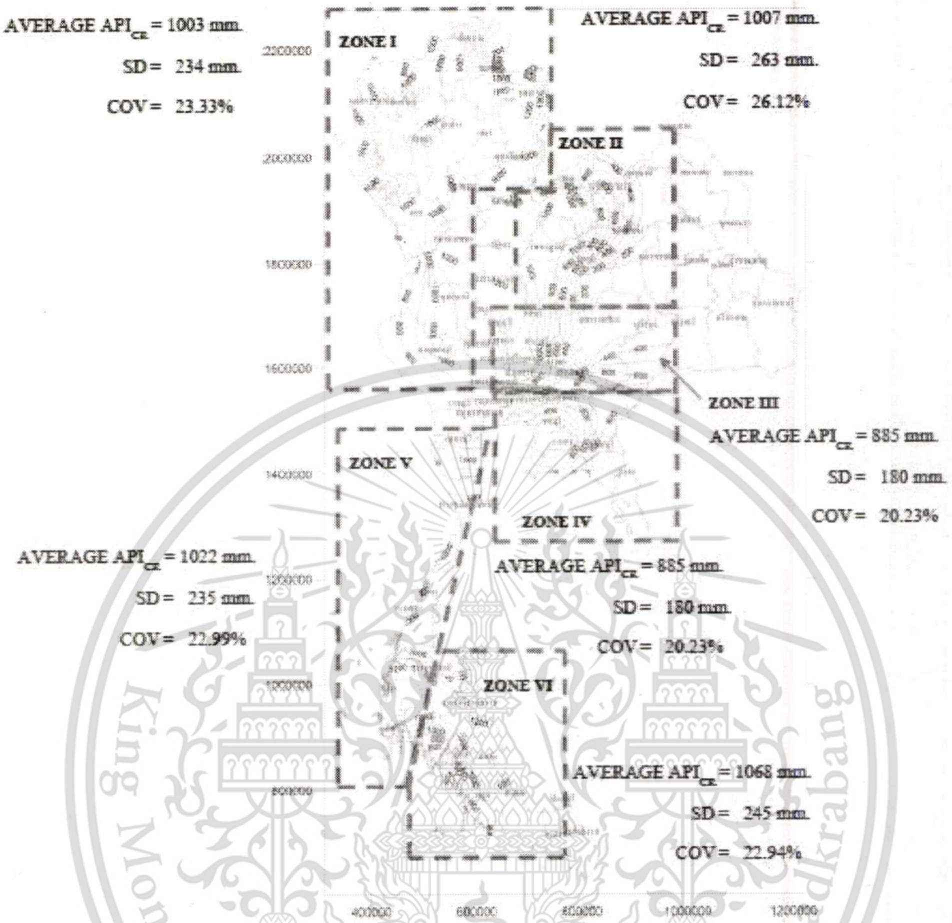


Figure 4.18: Landslide hazard map based on the API_{cr} index.

For landslide monitoring using the API_{cr}-based hazard map, rainfall rate collected at the mobile monitoring station is sent to the central data management system. The system calculates the actual API index from the rainfall data and compare it to the the critical API value at the monitoring site. If the current API exceeds the API_{cr} value, a landslide warning can be issued.

There are other landslide warning criteria which also utilize statistics of rainfall data. For example, for a landslide happening at soil surface (less than 2m depth) the rainfall intensity and rainfall duration are the proper criteria. On the other hand, for deep landslide (occurring more than 2m down) the daily rainfall amount and the cumulative rainfall are more suitable. Other statistics suggest that for the southern provinces, most landslide happens when the 3-day cumulative rainfall is greater than 100mm and the daily rainfall is greater than 50mm. For other regions, landslide is reported when the 3-day cumulative rainfall is more than 200 mm. Depending on the location and other prior information, the landslide early warning system can also adopt one of these criteria instead of the API_{cr} index.

4.2.2 Landslide detection demonstration kit

Because landslides usually happen in a very large scale, we design and built a small-scale landslide detection demonstration kit to demonstrate two alternative methods for warning. The system uses moisture level as measured using three moisture sensors to predict a possible landslide. The moisture level data is sent to the central data server via Zigbee module. Alternatively, a reed switch is used to detect a landslide when it occurs.

An arduino UNO R3 board is used as a processing unit for the demonstration system. The microcontroller receives data from the moisture sensor and send the data wirelessly to the data center via Zigbee module. In this project we use Xbee Pro 50mW RPSMA series 2, operating at 2.4 GHz with the 3 dBi duck antenna.

The reed switch and a magnet are placed inside a PVC tube, as shown in Fig. 4.19. When the landslide occurs, some soil would fall into the container at the top of the tube (Fig. 4.20(a)). The weight of the soil would bend the tube at a right angle (Fig. 4.20(b)), bringing a magnet closer to the reed switch and causing it to operate.

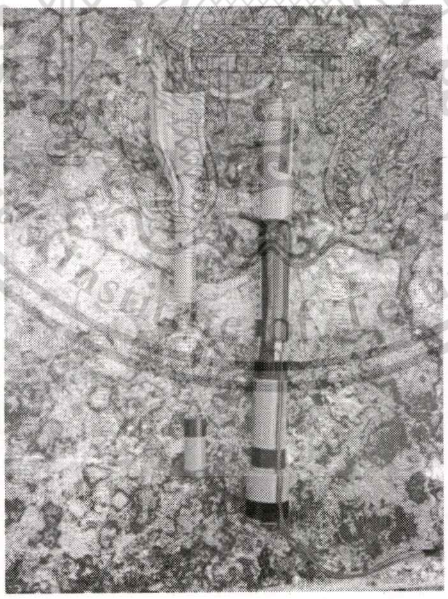


Figure 4.19: The equipments inside the PVC tube.

(a)

(b)

Figure 4.20: (a) The tube during normal event. (b) The tube during landslide.

The landslide demonstration system is depicted in Fig. 4.21. The system is built from MDF boards and metal bars. Its overall dimension is 1 m x 1 m x 0.5 m with a 0.5 m x 1 m ramp. The PVC tube containing reed switch is placed in the box at the bottom. A pulley system is used to lift the soil from the box at the back up and over the ramp. When the soil slides down the ramp to the box at the bottom it would trigger the reed switch inside the PVC tube and send out the alarm.

Note that this landslide demonstration kit serves a different purpose than the early-warning system. Here, the warning is what the landslide has already happened. It is to signal the emergency evacuation instead of predicting the potential landslide days in advance.

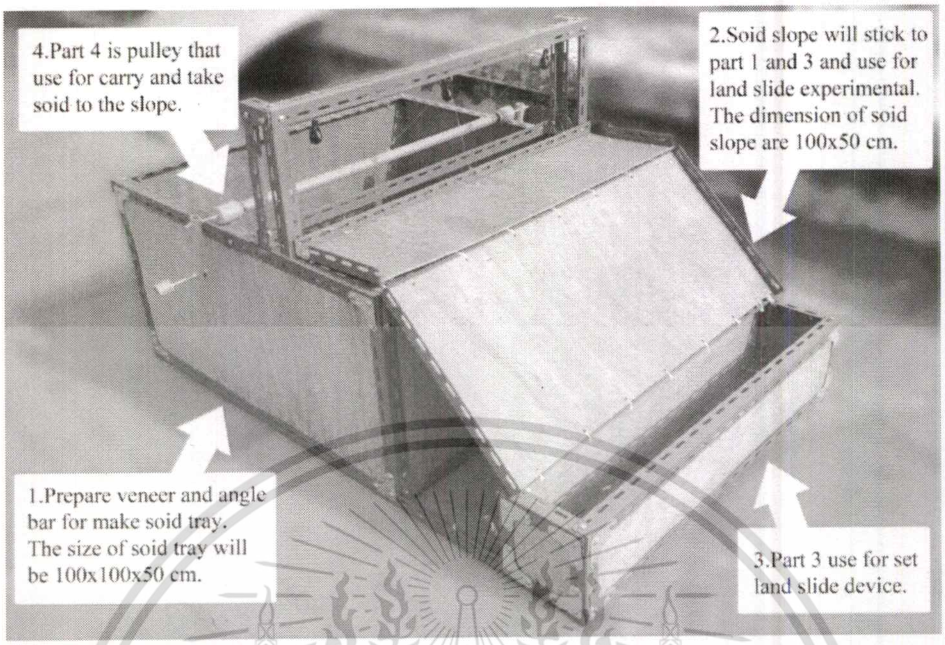


Figure 4.21: Landslide warning demonstration kit.

Appendix A

Researchers' Biography

Researchers' Biography

1. Name: Mr. Chuwong Phongcharoenpanich

Academic position: Assoc. Prof. Dr.

Institute / Address: Department of Telecommunications Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, 1 Chalongkrung Road, Ladkrabang, Bangkok 10520, **e-mail:** pchuwong@gmail.com

Academic field of specialty: Antenna design, Computational in electromagnetic, Wireless communication systems.

Academic Background

Level	Institute	Year	Degree obtained	Field
Doctoral Degree	King Mongkut's Institute of Technology Ladkrabang	2001	D.Eng.	Electrical Engineering
Master Degree	King Mongkut's Institute of Technology Ladkrabang	1998	M.Eng.	Electrical Engineering
Bachelor Degree	King Mongkut's Institute of Technology Ladkrabang	1996	B.Eng. (Hons.)	Telecommunications Engineering

Research Project

Project Name	**Year**
Propagation Modeling in Durian Orchard for Wireless Sensor Network	2004-present
Performance Enhancement of RFID Antennas for Animal Identification	2004-present
Antenna for Wireless Sensor Network	2004-present

International Journal Publications

Title	Author	Published in	Year
A 2.4-GHz Dual Polarized Suspended Square Plate Rectenna with Inserted Annular Rectangular Ring Slot	**C. Phongcharoenpanich** K.Boonying	International Journal of RF and Microwave Computer-Aided Engineering	2016
The Multiple Loop Antenna with Unbalanced Feed Line for Enhanced Readability Performances of Near-Field UHF RFID Applications	R.Pansomboon **C.Phongcharoenpanich**	International Journal of RF and Microwave Computer-Aided Engineering	2016
A Horizontally Polarized Ominidirectional Antenna using Stacked Curve Dipoles for DTV Reception	**C.Phongcharoenpanich** W.Polkaew B.Luadang P.Akkaraekthalin	International Journal of Antennas and Propagation	2015
Circularly-Polarized Capacitively-Fed UHF-RFID Antenna with Truncated Reverse-Arc Shape	K.Boonying **C. Phongcharoenpanich**	Journal of Electromagnetic Waves and Applications	2015
A Low-Profile and Compact Split-Ring Antenna with Horizontally Polarized Omnidirectional Radiation	K.Lertsakwimarn **C.Phongcharoenpanich** T.Fukusako	International Journal of Antennas and Propagation	2015
Design of Wideband Tag Antenna for UHF RFID System Using Modified T-Match and Meander-Line Techniques	T.Pumpoung **C.Phongcharoenpanich**	Electromagnetics	2015

Modified Fruit Fly Optimization Algorithm with Adaptive Population Size for Analysis of Large Antenna Array	N.Mhudtongon **C.Phongcharoenpanich** S.Kawdungta	International Journal of Antennas and Propagation	2015
Design of Triple-band Antenna Using S-shaped Patch Fed by Cross Strip Line for WLAN and WiMAX Applications	Y.Chawanonphithak **C.Phongcharoenpanich**	IEEJ Transactions on Electrical and Electronic Engineering	2015
A Unidirectional Bow Tie Array Antenna with Incision Gap for Digital Video Broadcasting-T2 Base Station	B.Luadang **C.Phongcharoenpanich**	IET Microwaves, Antennas and Propagation	2015
Design of Circularly Polarized Electrical Small Antenna with Omnidirectional Radiation Pattern	K.Lertsakwimarn **C.Phongcharoenpanich** T.Fukusako	IEICE Trans.Comm.	2014
Rectangular Ring Antenna Excited by Circular Disc Monopole for WiMAX System	S. Vongsack **C.Phongcharoenpanich** S. Kosulvit K. Hamamoto T. Wakabayashi	International Journal of Antennas and Propagation	2014
Improvement of a Circular Microstrip Antenna Excited by Four Feeds and Suspended with Artificial Magnetic Conductors	S.Eardprab **C.Phongcharoenpanich** D.Torrungrueng	International Journal of Antennas and Propagation	2013
Circularly Polarized Low-Profile Antenna for Radiating	K.Lertsakwimarn **C.Phongcharoenpanich** T.Fukusako	International Journal of Antennas and Propagation	2013

Parallel to Ground Plane for RFID Reader Applications			
Extending Bandwidth of a CPW-Fed Monopole Antenna using Circular Arc Structure	M. Chongcheawchamnan K. Meelarpkit S. Julrat **C. Phongcharoenpanich** M. Krairiksh	Microwave and Optical Technology Letters	2012
A UWB Bidirectional Rectangular Ring Antenna Fed by CDM with a Rod and Ridges for Constant Beam Direction	S.Vongsack S.Lamultree P.Osklang, **C.Phongcharoenpanich** S.Kosulvit K.Hamamoto T.Wakabayashi	International Journal of Microwave Science and Technology	2012
Path-Loss Prediction of Radio Wave Propagation in an Orchard by using Modified UTD Method	K. Phaebua **C.Phongcharoenpanich** M.Krairiksh T. Lertwiriyaprapa	Progress in Electromagnetics Research	2012
Determination of Dielectric Property of Construction Material Products Using a Novel RFID Sensor	R.Suwalak **C.Phongcharoenpanich** D.Torrungrueng M.Krairiksh	Progress in Electromagnetics Research	2012
Unidirectional Antenna using Two-Probe Excited Circular Ring above Square Reflector for Polarization Diversity with High Isolation	S.Vongsack **C.Phongcharoenpanich** S.Kosulvit K.Hamamoto T. Wakabayashi	Progress in Electromagnetics Research	2012

A Novel Analysis of Planar Dipole Antenna Arrays in Free Space with the Multiple Sweep Method of Moments	S.Kawdungta **C.Phongcharoenpanich** D.Torrungrueng	Electromagnetics,	2011
An Analysis of Electrically Large Planar Dipole Antenna Arrays with an Efficient Hybrid MSMM/CG Method	S.Kawdungta **C.Phongcharoenpanich** D.Torrungrueng	Journal of Electromagnetic Waves and Applications,	2011
Adaptive Array Antenna using On-Off and CMA Algorithms for Microwave RFID Readers	T.Tantisopharak A.Boonpoonga, **C.Phongcharoenpanich** P.Sirisuk M.Krairiksh	IEICE Trans.Comm.	2011
A Switched-Beam Antenna using Circumferential-Slot on a Concentric Sectoral Cylindrical Cavity Excited by Coupling Slot	P.Wounchoum D.Worasawate **C.Phongcharoenpanich** M.Krairiksh	Progress in Electromagnetics Research	2011
Design of a Novel Dual-Loop Gate Antenna for Radio Frequency Identification (RFID) Systems at Low Frequency Band	S.Kawdungta **C.Phongcharoenpanich** D.Torrungrueng	Progress in Electromagnetics Research C	2010

Awards

Title	Awards/Institute	Year
Synthesis of the Antenna Array Pattern Accomplishing the Tapered Minor Lobe Distributions	Outstanding Contribution Paper in the 5th International Symposium on Antennas, Propagation and Electromagnetic Theory	2000

Title	Awards/Institute	Year
Theory and Experiment of a Circularly Polarized Conical Beam Spherical Slot Array Antenna	Honorable Mention in the Student Paper Competition in the 2001 IEEE International Symposium on Antennas and Propagation and USNC/URSI National Radio Science Meeting	2001

2. Name: Mr. Paramote Wardkein

Position: Associate Professor

Education

Degree	Major	Institution	Year
B.S.	Physics	Srinakharinwirot University	1985
M.Eng.	Electrical Engineering	KMITL	1989
วศ.ด.	Electrical Engineering	KMITL	1996

Contact: Department of Telecommunications Engineering, Faculty of Engineering

King Mongkut's Institute of Technology Ladkrabang

1 Soi Chalongkrung 1, Chalongkrung Rd., Ladkrabang, Bangkok, 10520

Tel : 02-3298324 FAX : 02-3298325

Expertise/Research interests: Analog and digital signal processing, Analog circuits in communication systems

Outputs:

Research/Innovation/Patent

Research

Project	Funding agency	Duration	Position
1.Research and develop short range radar system for initial velocity of bullet measurement	Directorate of Welfare	1 year (fiscal year of 2014)	Project consultant

Project	Funding agency	Duration	Position
2. Research and develop smart exercise program for personal division	Directorate of Welfare	1 year (fiscal year of 2014)	Project consultant

Publications

International journals

1. Thongchai Maneechukate, Kriangsak Prompak, Jeerasuda Koseeyaporn and **Paramote Wardkein**, "Accuracy behavior explanation of electrical second-order system based on multi-time technique", **Jour. Scientific Research and Essays**, vol. 8, no. 25, pp. 1180-1190, 4 July, 2013
2. R. Punchalard and **P. Wardkein**, "Linear prediction based adaptive algorithm for a complex sinusoidal frequency estimation", **Int. Jour. Electronics and Communications**, vol. 67, no. 6, pp. 521-527, June, 2013
3. W. Loetwassana, R. Punchalard, J. Koseeyaporn, **P. Wardkein**, "Unbiased plain gradient algorithm for a second-order adaptive IIR notch filter with constrained poles and zeros", **Signal Processing**, vol. 90, no. 8, pp. 2513-2520, August 2010
4. K. Watcharasitthiwat and **P. Wardkein**, "Reliability Optimization of Topology Communication Network Design using an Improved Ant Colony Optimization," **Int. J. Computers & Electrical Engineering**, vol.35, 5, pp.730 – 747, Sep. 2009
5. R. Punchalard, J. Koseeyaporn, **P. Wardkein**, "Indirect frequency estimation based on second-order adaptive FIR notch filter", **Signal Processing**, vol. 89, no. 7, pp. 1428-1435 July 2009
6. Panwit Tuwanut, Jeerasuda Koseeyaporn, **Paramote Wardkein**, "A novel versatile modulator circuit", **Int. Jour. Electronics and Communications**, vol. 63, no. 5, pp. 387-397, May 2009
7. R. Punchalard, J. Koseeyaporn, **P. Wardkein**, "Adaptive IIR notch filter using a modified sign algorithm", **Signal Processing**, vol. 89, no. 2, Feb. 2009, pp. 239-243

MS/PhD Thesis Advisee

-PhD (In progress)

1. Mr.Pakorn Sirichotdamrong (2014-Current)

Topic :

2. Mr. Tanun Kanachareon (2012-Current)

   Topic : PAM demodulation based on variable sinusoidal estimator

3. Mr. Kunanon Kittiputh (2012-Current)

   Topic : Harmonics injection lock and its applications

4. Ms. Anchalee Manoseob (2010-Current)

   Topic : Application of adapitive filter for digital demodulation

5. Mr. Arum Kittipongwattana (2010-Current)

   Topic : Analytical of oscillator based on multi-time variable principle and its applications

-Master (In progress)

1. Mr. Pattana Kainun (2014-Current)

   Topic: Motion artificial reduction in pulse oximeter using light sensor signal

2. Ms.Israporn Polinchotanun (2014-Current)

   Topic: Reference signal for adaptive filter biometric human identification system with eye blinking using artificial neural network

3. Name: Mrs.Jeerasuda Koseeyaporn

Position: Associate Professor

Education

Degree	Major	Institution	Year
B.Eng.	Telecommunication Engineering	KMITL	1994
M.S.	Electrical Engineering	Vanderbilt University, USA	1999
Ph.D.	Electrical Engineering	Vanderbilt University, USA	2003

Contact: Department of Telecommunications Engineering, Faculty of Engineering

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Tel : 02-3298324 FAX : 02-3298325

Expertise/Research interests: Analog and digital signal processing, Analog circuits in communication systems

Outputs:

Publications

International journals

1. Thongchai Maneechukate, Kriangsak Prompak, **Jeerasuda Koseeyaporn** and Paramote Wardkein, "Accuracy behavior explanation of electrical second-order system based on multi-time technique", **Jour. Scientific Research and Essays**, vol. 8, no. 25, pp. 1180-1190, 4 July, 2013
2. W. Loetwassana, R. Punchalard, J. Koseeyaporn, P. Wardkein, "Unbiased plain gradient algorithm for a second-order adaptive IIR notch filter with constrained poles and zeros", **Signal Processing**, vol. 90, no. 8, pp. 2513-2520, August 2010
3. R. Punchalard, J. Koseeyaporn, P. Wardkein, "Indirect frequency estimation based on second-order adaptive FIR notch filter", **Signal Processing**, vol. 89, no. 7, pp. 1428-1435 July 2009
4. Panwit Tuwanut, **Jeerasuda** Koseeyaporn, Paramote Wardkein, "A novel versatile modulator circuit", **Int. Jour. Electronics and Communications**, vol. 63, no. 5, pp. 387-397, May 2009
5. R. Punchalard, J. Koseeyaporn, P. Wardkein, "Adaptive IIR notch filter using a modified sign algorithm", **Signal Processing**, vol. 89, no. 2, Feb. 2009, pp. 239-243

MS/PhD Thesis Advisee

-PhD (In progress)

1. Mr.Lerson Kirasamuthranon (2014 -Current)

   Topic : The QPSK Modulator with Continuous Phase and Fast Response Based on Phase Locked Loop
2. Mr.Sakkarin Sinchai (2014-Current)

   Topic : Signal processing in automatic controlling system
3. Mr. Sukkarak Saechia (2010-Current)

   Topic : Applications of automatic gain control in communication systems

4. **Name:** Mr. Napat Sra-ium

Position: Assistant Professor

Education

Degree	Major	Institution	Year
B.Eng	Telecommunications Engineering	King Mongkut's Institute of Technology Ladkrabang	1994
M.Eng	Electrical Engineering	King Mongkut's Institute of Technology Ladkrabang	1997
D.Eng	Electrical Engineering	King Mongkut's Institute of Technology Ladkrabang	2012

Contact: Department of Telecommunications Engineering

Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang

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Tel: 02-3298000 ext. 3348 Fax: 02-3298325

Expertise/Research interests: Computer Network and Information Technology

Outputs:

Research

Project	Funding agency	Duration	Position
Development of Prescription Control for Carbapenems Antibiotic Agents	1	1 Year (Oct 2010-Sep 2011)	Head
Development of Remote Control Application via Android Platform	1	1 Year (Oct 2010-Sep 2011)	Researcher
VoIP Phone And CRM Ready Boxset	1	1 Year (Oct 2011-Sep 2012)	Head

Funding agency

1. King Mongkut's Institute of Technology Ladkrabang (KMITL)

Patent/Innovation/Award

- Development of Prescription Control for Carbapenems Antibiotic Agents 2011

5. **Name:** Mr. Sorawat Chivapreecha

Position: Assistant Professor

Education

Degree	Major	Institution	Year
B.Eng	Telecommunications Engineering	Suranaree University of Technology	1998
M.Eng	Electrical Engineering	King Mongkut's Institute of Technology Ladkrabang	2002
D.Eng	Electrical Engineering	King Mongkut's Institute of Technology Ladkrabang	2008

Contact: Department of Telecommunications Engineering
Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang
1 Soi Chalong Krung 1, Ladkrabang, Bangkok 10520
Tel: 02-3298000 ext. 3348 Fax: 02-3298325

Expertise/ Research interests: Digital Filter Design and Implementation, VLSI for Digital Signal Processing, Digital System Design and FPGA Applications, Informatics Software Defined Radio Technology and Remote Sensing Satellites System

Output

Research/Innovation/Patent

Research

Project	Funding agency	Duration
1. Development of NOAA Weather Satellites Ground Station in APT Mode Using Software-Defined Radio Technology and Application	National Research Council of Thailand	1 year (2013)

Project	Funding agency	Duration
2. Design and Implementation of A New Digital Filter for Low-Complexity High-Accuracy Digital Hearing Aids	National Research Council of Thailand 2012-2013	2 year (2012-2013)
3. Chaotic Crypto System for Communication Security Based on Nonlinear Phenomenon in Digital Filter : Design and Implementation	Faculty of Engineering	1 year (2011)
4. Development of Tracking and Positioning System for Public Vehicles via GPS/GPRS	Faculty of Engineering	1 year (2009)
5. Design of Real-Time Digital Image Processing System on FPGA	Faculty of Engineering	1 year (2007)

<u>Publications</u>

International Journals

1. P. Leekul, ***S. Chivapreecha***, C. Phongcharoenpanich, and M. Krairiksh, "Rician k-factors-based Sensor for Fruit Classification by Maturity Stage," ***IEEE Sensors Journal (In Press)***.
2. P. Leekul, ***S. Chivapreecha***, and M. Krairiksh, "Microwave Sensor for Tangerine Classification based on Coupled-Patch Antennas," ***International Journal of Electronics***, vol. 103, issue 8, pp. 1287-1300, 2016.
3. Parinya Sonntornwong and ***Sorawat Chivapreecha***, "Pascal-Interpolation-Based Noninteger Delay Filter and Low Complexity Realization," ***Radioengineering,*** vol. 24, no. 4, Dec. 2015.
4. Tian-Bo Deng, ***Sorawat Chivapreecha***, and Kobchai Dejhan, "Bi-Minimax Design of Even-Order Variable Fractional-Delay FIR Digital Filters," ***IEEE Trans. Circuits Syst. I : Regular Papers***, vol. 59, no. 8, pp. 1766-1774, August 2012.
5. Chusit Pradabpet, ***Sorawat Chivapreecha***, Douangsamone Phetsomphou, and Yoshikazu Miyanaga "An Improved GA in Hybrid of PTS-CAPPR Methods for PAPR Reduction in OFDM Systems" ***Journal of Communication and Computer***, vol. 7, no.12, pp. 63-68, December 2010.
6. Tian-Bo Deng, ***Sorawat Chivapreecha,*** and Kobchai Dejhan, "Unified Pascal Matrix for First-Order s-z Domain Transformations," ***IEEE Trans. Signal Processing***, vol. 57, no. 6, pp. 2130-2139, June 2009.

7. Tian-Bo Deng, ***Sorawat Chivapreecha***, and Kobchai Dejhan, "Generalized Pascal Matrices, Inverses, Computations and Properties Using One-to-One Rational Polynomial s-z Transformations," ***IEEE Trans. Circuits Syst. I : Regular Papers***, vol. 55, no. 9, pp. 2650-2663, Oct. 2008.
8. ***S. Chivapreecha*** and K. Dejhan, "Design of Logarithmic Encoder and Error Corrections," ***GESTS International Transactions on Computer Science and Engineering***, vol. 26, no. 1, pp. 222-240, Jan. 2006.

International Conferences

1. P. Leekul, ***S. Chivapreecha,*** and M. Krairiksh, "Microwave Sensor for Defected Fruit Classification" 2015 IEEE Conference on Antenna Measurement and Applications (CAMA), Nov. 30-Dec.2, 2015.
2. P. Leekul, T. Limpiti, T. Tantisopharak, P. Yoiyod, ***S. Chivapreecha***, C. Phongcharoenpanich, and M. Krairiksh, "Remote Sensing of the Physical Qualities of Fruits," Asia-Pacific Microwave Conference (APMC), Nov. 4-7, 2014.
3. P. Leekul, P. Yoiyod, ***S. Chivapreecha***, C. Phongchareonpanich, P. Youryon, K. Bunya-atichart, and M. Krairiksh, "Scattered Waves from Different Maturity Stages of Fruits," IEEE Asia-Pacific Conference on Antenna and Propagation (APCAP), pp. 153-154, Aug. 2013.
4. Jaraspat La-inchua, ***Sorawat Chivapreecha***, and Suttipong Thajchayapong, "An Improved Traffic Incident Detection System Using Fuzzy Logic," The 2013 IEEE Thailand Student Conference on Senior Capstone Project (IEEE Thailand SCAP 2013), Bangkok, Thailand, March 29, 2013.
5. Jaraspat La-inchua, ***Sorawat Chivapreecha***, and Suttipong Thajchayapong, "A New System for Traffic Incident Detection Using Fuzzy Logic and Majority Voting," The 10th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON 2013), Krabi, Thailand, May 15-17, 2013.
6. Wuttichai Putchana, ***Sorawat Chivapreecha***, and Tulaya Limpiti, "Wireless Intelligent Fall Detection and Movement Classification using Fuzzy Logic," Proc. The 2012 Biomedical Engineering International Conference (BMEiCON-2012), Ubon Ratchathani, Thailand, Dec. 5-7, 2012.
7. Piyamas Suapang, Chadaporn Naruephai, Methinee Thongyoun, and ***Sorawat Chivapreecha***, "Mammographic Masses Segmentation Based on Morphology," Proc. The 2012 Biomedical Engineering International Conference (BMEiCON-2012), Ubon Ratchathani, Thailand, Dec. 5-7, 2012.

8. Piyamas Suapang, Methinee Thongyoun, Rodjarin Boontawan, ***Sorawat Chivapreecha***, and Kobchai Dejhan, "A Mammography Database and Viewer System," Proc. The 2012 Biomedical Engineering International Conference (BMEiCON-2012), Ubon Ratchathani, Thailand, Dec. 5-7, 2012.

9. Anirut Trakultritrung and ***Sorawat Chivapreecha***, "Decomposed Distributed Arithmetic Structure for High Filter Length LMS Adaptive Filter," Proc. The 2nd International Symposium on Technology for Sustainability (ISTS 2012), pp. 485-488, Bangkok, Thailand, Nov. 21-24, 2012.

10. Chusit Pradabpet, Krung Luewattana, ***Sorawat Chivapreecha***, and Kobchai Dejhan, "The PTS Method with Iterated Local Search for PAPR Reduction in OFDM-WLAN Systems," Proc. The 2012 International Conference on Engineering, Applied Sciences, and Technology, pp. 142-146, Bangkok, Thailand, Nov. 21-24, 2012.

11. Dolchai Sookcharoenphol, ***Sorawat Chivapreecha***, and Pitak Thumwarin, "New Realization of Low Sensitivity Linear Phase Magnitude Complementary Filter Pair," Proc. The 2012 International Conference on Engineering, Applied Sciences, and Technology, pp. 460-464, Bangkok, Thailand, Nov. 21-24, 2012.

12. Narong Borijindakul, Chuwong Phongcharoenpanich, ***Sorawat Chivapreecha***, Monai Krairiksh, and Kittisak Phaebua, "Microwave Sensors for Sugar Concentration Measurement," Proc. The 2012 International Conference on Engineering, Applied Sciences, and Technology, pp. 479-482, Bangkok, Thailand, Nov. 21-24, 2012.

13. Nattawut Hochairat and ***Sorawat Chivapreecha***, "Design of Fractional Delay Allpass Filter Using Genetic Algorithm," Proc. The 2012 International Workshop on Smart Info-Media Systems in Asia (SISA 2012), pp.108-112, Bangkok, Thailand, Sept. 6-8, 2012.

14. Tiwakarn Saetang and ***Sorawat Chivapreecha***, "A New Design of Digital Filter for Digital Hearing Aids," Proc. The 2012 International Workshop on Smart Info-Media Systems in Asia (SISA 2012), pp.113-118, Bangkok, Thailand, Sept. 6-8, 2012.

15. Anirut Trakultritrung, Ekkawin Thanangchusin, and ***Sorawat Chivapreecha***, "Distributed Arithmetic LMS Adaptive Filter Implementation without Look-Up Table," Proc. The 9th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON 2012), Petchaburi, Thailand, May 16-18, 2012.

16. Supasin Kumsroy, ***Sorawat Chivapreecha***, and Akraphon Trirat, "On Hardware Realization of the Binomial Filter," Proc. 1st International Symposium on Technology for Sustainability (ISTS 2011), pp. 388-391, KMITL Bangkok, Thailand, Jan. 26-29, 2012.

17. Chusit Pradabpet, ***Sorawat Chivapreecha***, and Kobchai Dejhan, "An Improved GA by Using RCO for PAPR Reduction in OFDM Systems," Proc. 1st International Symposium on Technology for Sustainability (ISTS 2011), pp.194-197, KMITL Bangkok, Thailand, Jan. 26-29, 2012.

18. Parinya Soontornwong, ***Sorawat Chivapreecha***, and Chusit Pradabpet, "A Cubic Hermite Variable Fractional Delay Filter," Proc. The 2011 International Symposium on Intelligent Signal Processing and Communication Systems (ISPACS 2011), Chiang Mai, Thailand, Dec. 7-9, 2011.

19. ***Sorawat Chivapreecha***, "Universal Biquadratic Digital Filter with Tunable Capability," Proc. The 2011 IEEE Region 10 Conference (TENCON 2011), pp. 152-156, Bali, Indonesia, Nov. 21-24, 2011.

20. Pichet Srisangngam, ***Sorawat Chivapreecha***, and Kobchai Dejhan "A Design of IIR Based Digital Hearing Aids Using Genetic Algorithm", Proc. The 8th ECTI Conference (ECTI-CON 2011), Khon Kaen, Thailand, May 17-19, 2011.

21. Chusit Pradabpet, Yoshikazu Miyanaka, and ***Sorawat Chivapreecha*** "New Hybrid of PTS-CAPPR Methods with Non-Uniform Phase Factor and Coded SI Technique in OFDM Systems", Proc. The 8th ECTI Conference (ECTI-CON 2011), Khon Kaen, Thailand, May 17-19, 2011.

22. Ussanai Nithirochananont, ***Sorawat Chivapreecha***, Chanchai Peanvijarnpong, and Kobchai Dejhan "***GISTDA EOC Synthetic Aperture Radar Data Processing System***", *Proc. 6th International Colloquium on Signal Processing and Its Application (CSPA 2010)*, Malacca, Malaysia, May 21-23, 2010.

23. Chusit Pradabpet, Channarong Noybangyang, and ***Sorawat Chivapreecha*** "NEW HYBRID OF PTS-CAPPR METHODS FOR PAPR REDUCTION IN OFDM SYSTEMS", Proc. 25th International Technical Conference on Circuits/Systems, Computers and Communications (ITC-CSCC 2010), Pattaya, Thailand, July 4-7, 2010.

24. ***Sorawat Chivapreecha*** and Chusit Pradabpet "A NEW VARIABLE FRACTIONAL-DELAY FIR FILTER" Proc. 25th International Technical Conference on Circuits/Systems, Computers and Communications (ITC-CSCC 2010), Pattaya, Thailand, July 4-7, 2010.

25. Ussanai Nithirochananont, ***Sorawat Chivapreecha***, Chanchai Peanvijarnpong, and Kobchai Dejhan "***RADARSAT-1 DATA PRODUCTS VERIFICATION***", Proc. 25th International Technical Conference on Circuits/Systems, Computers and Communications (ITC-CSCC 2010), Pattaya, Thailand, July 4-7, 2010.

26. Chusit Pradabpet, Sutud U-thong, and ***Sorawat Chivapreecha*** "NEW PAPR REDUCTION IN OFDM SYSTEMS USING UNION ALGORITHM OF WL-SLM AND CAPPR TECHNIQUES" Proc. 25th

International Technical Conference on Circuits/Systems, Computers and Communications (ITC-CSCC 2010), Pattaya, Thailand, July 4-7, 2010.

27. ***Sorawat Chivapreecha*** and Tian-Bo Deng "Very Low-Complexity Structure for Lagrange-Type Variable Fractional-Delay Filter", Proc. International Conference on Green Circuits and Systems, Shanghai, P.R. China, June 21-23, 2010.

28. Chusit Pradabpet, Sutud U-thong, ***Sorawat Chivapreecha***, and Yoshikazu Miyanaga "Blind Detection of Hybrid PTS-CAPPR Methods in OFDM Systems", Proc. 2010 International Workshop on Information Communication Technology (ICT 2010), KMITL, Bangkok, Thailand, August 24-25, 2010.

29. Chusit Pradabpet, Narong Ravinu, ***Sorawat Chivapreecha***, Boonying Knobnob and Kobchai Dejhan, "An Efficient Filter Structure for Multiplierless Sobel Edge Detection," *Proc. 2009 Conference on Innovative Technologies in Intelligent Systems and Industrial Applications (CITISIA 2009)*, pp. 40-44, Malaysia, July 25-26, 2009.

30. Naohiko Shimizu, Masami Ikura, Warangrat Wiriya and ***Sorawat Chivapreecha***, "A New Logic Circuit Design Methodology with UML," *Proc. 24th International Technical Conference on Circuits/Systems, Computers and Communications (ITC-CSCC 2009)*, Jeju Island, Korea, July 5-8, 2009.

31. Chusit Pradabpet, ***Sorawat Chivapreecha***, Kobchai Dejhan and Surapan Yimman, "A New PTS Method Using GA for PAPR Reduction in OFDM-WLAN 802.11a Systems," *Proc. 6th International Joint Conference on Computer Science and Software Engineering (JCSSE2009)*, Phuket Thailand, May 13-15, 2009.

32. Ussanai Nithirochananont, ***Sorawat Chivapreecha*** and Kobchai Dejhan, "An FPGA-Based Implementation of Variable Fractional Delay Filter," *Proc. 5th International Colloquium on Signal Processing and Its Application (CSPA 2009)*, Kuala Lumpur, Malaysia, March 6-8, 2009.

33. ***Sorawat Chivapreecha***, Naohiko Shimizu and Kobchai Dejhan, "A New Multiplierless Sobel Edge Detection Filter Structure," *Proc. International Workshop on Nonlinear Circuits and Signal Processing (NCSP'09)*, Honolulu, Hawaii USA., March 1-3, 2009.

34. Ussanai Nithirochananont, Theetima Treepayak, ***Sorawat Chivapreecha***, Tian-Bo Deng and Kobchai Dejhan, "Discrete Pascal Filter and Its Hardware Realization," *Proc. 2008 International Symposium on Intelligent Signal Processing and Communication Systems (ISPACS 2008)*, pp. 461-464, Bangkok, Thailand, Feb. 8-10, 2009.

35. Pichet Srisangngam, ***Sorawat Chivapreecha*** and Kobchai Dejhan, **"Even Order Biquad Digital Filter Design Using Pascal Matrix,"** *Proc. 2008 International Symposium on Communications and Information Technology (ISCIT 2008)*, pp. 327-330, Vientien, Laos, October 21-23, 2008.

36. Chusit Pradabpet, Shingo Yoshizawa, Yoshikazu Miyanaga, ***Sorawat Chivapreecha*** and Kobchai Dejhan, **"New PTS Method with Coded Side Information Technique for PAPR Reduction in OFDM Systems,"** *Proc. 2008 International Symposium on Communications and Information Technology (ISCIT 2008)*, pp. 104-109, Vientien, Laos, October 21-23, 2008.

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61. ***S. Chivapreecha*** and K. Dejhan "Design of Symmetry IIR Notch Filter Using Quadratic Programming," *Proc. 7th International Conference and Exhibition on Digital Signal Processing and Its Applications (DSPA-2005)*, Moscow, Russia, March 16-18, 2005.

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63. A. Trirat, ***S. Chivapreecha***, T. Khunaworawet, T. Ruangrangsan and K. Dejhan, "Design of Multiplierless Elliptic Narrowband IIR Digital Filter based on Sensitivity Analysis," *Proc. 2004 International Symposium on Communications and Information Technology (ISCIT 2004)*, Sapporo, Japan, October 27-29, 2004.

64. ***S. Chivapreecha***, S. Piyamahachot, A. Namcharoenwattanakul, D. Chaimanee and K. Dejhan, "Distributed Arithmetic Adaptive Digital Filter using FPGA ," *Proc. 2004 International Conference on Control, Automation and Systems (ICCAS 2004)*, Bangkok, Thailand, August 25-27, 2004.

65. ***S. Chivapreecha***, N. Ronnarongrit, S. Yimman, C. Pradabpet and K. Dejhan, "Multiplierless Digital PID Controller using FPGA ," *Proc. 2004 International Conference on Control, Automation and Systems (ICCAS 2004)*, Bangkok, Thailand, August 25-27, 2004.

66. N. Whamook, S. Yimman, M. Puangpool, ***S. Chivapreecha*** and K. Dejhan, "Speed Sensorless DC Motor using Kalman Filter," *Proc. 2004 International Conference on Control, Automation and Systems (ICCAS 2004)*, Bangkok, Thailand, August 25-27, 2004.

67. ***S. Chivapreecha*** and K. Dejhan, "FPGA-Based Minimum Noise Distributed Arithmetic State-Space Digital Filter," *Proc. 2004 International Technical Conference on Circuits/Systems, Computers and Communications (ITC-CSCC 2004)*, Sendai/Matsushima, Japan, July 5-8, 2004.

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76. ***S. Chivapreecha*** and K. Dejhan, "Error Spectrum Shaping in State-Space Distributed Arithmetic Digital Filter for Self-roundoff Noise Cancellation," *Proc. 2003 International Technical Conference on Circuits/Systems, Computers and Communications (ITC-CSCC 2003)*, pp. 252-255, Korea, July 7-9, 2003.

77. ***S. Chivapreecha***, K. Dejhan and C. Pradapet, "Noise Reduction in State-Space Digital Filter using Error Spectrum Shaping," *Proc. Third Asian Conference on Industrial Automation and Robotic (ACIAR 2003)*, pp. 205-211, BITEC Bangkok, Thailand, May 8-9, 2003.

78. ***S. Chivapreecha***, S. Yimmun, C. Pradabpet and K. Dejhan, "Optimal Multiband Digital Filter Design based on Spline Transition Function Technique," *Proc. Third Asian Conference on Industrial Automation and Robotic (ACIAR 2003)*, pp. 212-217, BITEC Bangkok, Thailand, May 8-9, 2003.

6. **Name:** Miss Tulaya Limpiti

Position: Assistant Professor

Education

Degree	Major	Institution	Year
B.S.	Electrical Engineering	Northwestern University, Evanston, USA	2002
M.S.	Electrical Engineering	University of Wisconsin-Madison, USA	2004
Ph.D.	Electrical Engineering	University of Wisconsin-Madison, USA	2008

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Expertise/Research interests: Statistical signal processing, Array signal processing, Time series analysis, Multivariate signal model, Adaptive filter

Outputs:

Research/Innovation/Patent

Research

Project	**Funding agency**	**Duration**	**Position**
Iterative Neighbor-Joining Tree Clustering Framework for Population Structure Studies	1	Jun 2014- May 2016	Principal investigator
Space and Atmospheric Communication and Informatics Research Group	2	Jul 2013 - Jun 2014	Co-investigator

Project	Funding agency	Duration	Position
Dual-frequency GPS receiver network and analysis of Total Electron Content (TEC) variation over Chumphon, Thailand	2,3	Oct 2012 – Sep 2015	Co-investigator
Wireless Movement Detection and Classification System for Healthcare Monitoring of Elderly and Rehabilitative Patients	4	Oct 2011 – Sep 2012	Principal investigator
Improved iterative pruning principal component analysis for the study of large and highly structured population datasets	5	May 2011 – Apr 2012	Principal investigator

Funding agency

1. Thailand Research Fund (TRF)
2. King Mongkut's Institute of Technology Ladkrabang (KMITL)
3. National Research Council of Thailand
4. Faculty of Engineering, KMITL
5. Science & Technology Scholars Unit, National Science and Technology Development Agency (NSTDA)

Publications

International journals

1. **T. Limpiti**, et.al., "iNJclust: Iterative Neighbor-Joining Tree Clustering Framework for Inferring Population Structure," **IEEE/ACM Trans. Comp. Bio. and Bioinfo.**, vol . 11, no. 5, pp. 903-914, 2014. (impact factor = 1.44)

2. **T. Limpiti**, et.al., "Study of large and highly stratified population datasets by combining iterative pruning principal component analysis and STRUCTURE," **BMC Bioinformatics**, 12:255, 2011 (impact factor = 3.03)

3. **T. Limpiti**, B.D. Van Veen, and R.T. Wakai, "A Spatio-Temporal Framework for MEG/EEG Evoked Response Amplitude and Latency Variability Estimation," **IEEE Trans. Biomed. Eng.**, vol. 57, no. 3, pp. 616–625, 2010. (impact factor = 1.79)

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5. **T. Limpiti**, B.D. Van Veen, and R.T. Wakai, "Cortical patch basis model for spatially extended neural activity," IEEE Trans. Biomed. Eng., vol. 53, no. 9, pp. 1740–1754, 2006. (impact factor = 1.79)

Citations

All published international journals above

Patent/Innovation/Award

- Best 2010 Thesis Award (Engineering and Industrial research Category), Spatial-Temporal Framework for MEG/EEG Signal Estimation and Source Localization, from the National Research Council of Thailand

MS/PhD Thesis Advisee

-PhD (In progress and completed) None

-Master (In progress)

1. Mr. Aeggarut Pinkaew (2013-present)

Thesis title: Automated Classification of Malaria Parasite Species on Thick Blood Film Using Support Vector Machine

Advisor: Assistant Professor Dr. Tulaya Limpiti

Co-advisor: -

- Master (Completed)

1. Mr. Chainarong Amornbunchornvej (2011-2013)

Thesis title: Iterative clustering using hierarchical tree for high-dimensional genotypic data

Advisor: Assistant Professor Dr. Tulaya Limpiti

Co-advisor: -

2. Miss Jirutchaya Poolsawut (2012-2014)

Thesis title: Ka-band ground station site switching prediction due to rain-induced attenuation

Advisor: Assistant Professor Dr. Tulaya Limpiti

Co-advisor: -

7. Name: Mr. Akraphon Trirat

Position: Assistant Professor

Education

Degree	Major	Institution	Year
B.S.	Telecommunications Engineering	King Mongkut's Institute of Technology Ladkrabang	1994
M.S.EE	Electrical Engineering	University of Texas, Arlington	1997

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Expertise/Research interests: Digital Signal Processing, Audio Signal Processing, Image Processing, Digital Filter Design, Multimedia Technology, Data Compression

Output:

Research

Project Title	Status
High Efficiency Implementation of DCT using CORDIC Algorithm	Project leader
High Efficiency Implementation of WAVELET Transform using Multiplierless Structure	Project leader
Heart abnormalities classification using ECG signal	Project leader
Heart abnormalities classification using heart sound signal	Project leader
Automated Lighting control for energy saving l in Buildings	Project leader

Publications

1. Aeggarut Pinkaew, Tulaya Limpiti, Akraphon Trirat, "Automated classificationof malaria parasite species on thick blood film using support vector machine," The 8th Biomedical Engineering International Conference, Pattaya,Thailand, November 25 -27, 2015

2. Aeggarut Pinkaew, Tulaya Limpiti, Akraphon Trirat, "Chromatin detection in malaria thick blood film using automated image processing." The 2015 International Electrical Engineering Congress(iEECON2015), Phoket,Thailand, March 18-20, 2015

3. Supasin Kumsroy, Sorawat Chivapreecha, Akraphon Trirat ,"Discrete Wavelet Transform Implementation based on Binomial Filter and Coefficient- Distribution Distributed Arithmetic," Proc. International Electrical Engineering Congress,Chiang Mai,Thailand ,March13-15,2013

4. Supasin Kumsroy, Sorawat Chivapreecha, Akraphon Trirat,"On Hardware Realization of the Bionomial Filter", Proc. 1st Internattional Symposium on Technology for Sustainability, Bangkok ,Thailand, Jauary 26-29,2012

5. A. Trirat, S. Chivapreecha and K.Dejhan , "Design of multiplierless elliptic narrowband IIR digital filter based on sensitivity analysis," Proc. 2004 International Symposium on Communications and Information Technology (ISCIT 2004), Sapporo, Japan, October 27-29, 2004.

6. K. Dejhan, A, Trirat, F. Cheevasuvit," TMS 32010 Based Narrow Band Noise Rejection KALMAN Filter Implementation," IEEE International Conference on Industrial Technology Proceedings,Bangkok,Thailand, December 11-14,2002

7. Kobchai Dejhan, Akraphon Trirat, Napat Sraium," Low complexity Transform with Low Loss Compression", ," Ladkrabang Engineering Journal, March, 2545

8. Ket Nurat, Akraphon Trirat, Kobchai Dejhan,"Application Program Development for Radar Signal Detection on TCP/IP Protocol," Joumal of The National Research Council ofThailad, Vol.33,No.2 July-December 2001

9. K. Dejhan, A. Chattimala, A.Trirat, F. Cheevasuvit," Performance Analysis of Coherent DS-CDMA system comparing with single tone Jamming and Pulse Noise Jamming,"Proc. International Symposium on Communications and Information Technology, Chingmai,Thailand,.November 14-16,2001

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11. Kobchai Dejhan, Akraphon Trirat, "ATM switch Bandwidth Management Based on Queuing Theory," Ladkrabang Engineering Journal, December, 2543
12. Kobchai Dejhan, Aungkana Jaruvarakl, Akraphon, Fusak Cheevasuvit ,"A BiCMOS Current Mode Lossy Integrator Low-Pass Filter," Proc. 8th International Symposium on Integrated Circuits, Devices and Systems,Singapore, September 8-10, 1999

8. Name: Miss Nattakan Puttarak

Position: Assistant Professor

Education

Degree	Major	Institution	Year
B.Eng.	Electronics and Telecommunications Engineering	King Mongkut's University of Technology Thonburi (KMUTT), Thailand	2003
M.S.	Electrical Engineering	Lehigh University, USA	2007
Ph.D.	Electrical Engineering	Lehigh University, USA	2011

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Expertise/Research interests: Error-correcting codes for disk arrays and flash memory, network coding for multicast wireless communication and Information theory

Outputs:

Research/Innovation/Patent

Research

Project	Funding agency	Duration	Position
Maximum Distance Separable (MDS) Array codes for Disk Arrays	1	Jul 2012 – Jun 2014	Principal investigator
Space and Atmospheric Communication and Informatics Research Group	1	Jul 2013 - Jun 2014	Co-investigator
Graph-Based Network Coding for Wireless Transmission	2	September 2014 – August 2015	Principal investigator

Funding agency

1. King Mongkut's Institute of Technology Ladkrabang (KMITL)

2. Science & Technology Scholars Unit, National Science and Technology Development Agency (NSTDA)

Publications

International journals

1. P. Supnithi, W. Wiriya, W. Phakphisut, and **N. Puttarak**, "LDPC Decoder Using Pattern-Dependent Modified LLR for the Bit Patterned Media Storage with Written-In Errors," IEEE Transactions on Magnetics, Vol. 48, No. 11, Nov. 2012.
2. P. Kaewprapha, **N. Puttarak**, Jing Li (Tiffany), and Z. Shi, "Cooperative Data Dissemination Exploiting Offset Random Network Coding", SPIE 2010.

International proceedings

1. **N. Puttarak**, and P. Kaewprapha, "Low-Density MDS Array Codes Based on Rigid Graph Structure," iEECON 2014.
2. A. Sirirungsakulwong, **N. Puttarak**, and P. Supnithi, "Performance of Magnetic Recording Channels with Nonlinearity," SISA 2013.
3. P. Kaewprapha, and **N. Puttarak**, "Energy-Efficient Fault-Tolerance Storage System," the 3rd iSEEE 2013.
4. P. Kaewprapha, Jing Li (Tiffany), and **N. Puttarak**, "Cognitive Radio Sensing through Belief Propagation and Distributed Consensus", Allerton 2012.

5. P. Kaewprapha, Jing Li (Tiffany), and **N. Puttarak**, "Ad Hoc Network Localization in Unit Multi-Radius Disk Graph Model", WCSP'12.
6. L. Myint, P. Supnithi, and, **N. Puttarak**, "Track Mis-registration Detection using Correlation Functions in Magnetic Recording," APMRC, 2012.
7. P. Supnithi, W. Wiriya, W. Phakphisut, and **N. Puttarak**, "LDPC Decoder using Pattern-Dependent Modified LLR for the Bit Patterned Media Storage with Written-in Errors," In Proc. Of Intermag, 2012.
8. L. Myint, P. Supnithi, C. Warisarn, and **N. Puttarak**, "Off-Track Detection in Magnetic Recording Based on the Readback Signals," In Proc. Of Intermag, 2012.
9. **N. Puttarak**, P. Kaewprapha, and Jing Li (Tiffany), "A New Class of MDS Erasure Codes based on Graphs", in CoRR, 2011.
10. P. Kaewprapha, Jing Li (Tiffany), and **N. Puttarak**, "Network Localization on Unit Disk Graphs", IEEE GLOBECOM, 2011.
11. **N. Puttarak**, P. Kaewprapha, and Jing Li (Tiffany), "A New Class of MDS Erasure Codes based on Graphs", Global Telecommunications Conference, IEEE GLOBECOM, 2009.
12. P. Kaewprapha, **N. Puttarak**, and Jing Li (Tiffany), "Nested Erasure Code to Achieve Singleton Bounds", Conference on Information Sciences and Systems, CISS 2009.
13. P. Kaewprapha, **N. Puttarak**, Haidong Wang, and Jing Li (Tiffany), "Receiver-Cooperation: Network Coding and Distributed Scheduling", Global Telecommunications Conference, IEEE GLOBECOM, 2008.

MS/PhD Thesis Advisee

-PhD (In progress and completed) None

-Master (In progress)

1. Mr. Nakhon Muangboonma (2013-present)

Thesis title: Designed Network Coding based on Graphs for Multicast Wireless Communications

Advisor: Assistant Professor Dr. Nattakan Puttarak

Co-advisor: -

- Master (Completed)

1. Miss Atitaya Sirirungsakulwong (2012-2015)

Thesis title: Target-Shaping Equalizer Design and Low-Density Parity-Check Codes for Nonlinear Magnetic Recording Channels

Advisor: Assistant Professor Dr. Nattakan Puttarak

Co-advisor: Associate Professor Dr. Pornchai Supnithi

Appendix B

Publication

FLOOD MONITORING AND EARLY WARNING USING INTELLIGENT INFORMATION SYSTEM

N. Puttarak, T. Limpiti, S. Chivapreecha, A. Trirat, J. Koseeyaporn, P. Wardkien, N. Sra-ium, and C. Phongcharoenpanich

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ABSTRACT

In Thailand, the annual recurrence of flood in northern and central-region provinces during rainy season may turn out to be a major disaster with the lack of good management. This project aims to apply ICT in disaster management, particularly flooding. Flood preparedness includes flood monitoring and warning efforts. This is achieved by developing an intelligent flood monitoring system. A mobile system prototype for a disaster monitoring station with integrated sensors for water level, water flow rate and direction, rainfall rate, as well as other weather parameters, has been constructed. The mobile monitoring unit includes the control unit, power supply unit, sensing components and two-mode communication module. The communications is via cellular network in normal operation mode and via satellite link when all other communications channels are down from disaster. The mobile station periodically sends data to the central data management system. Besides collecting and storing the data, the central management system houses a risk analysis algorithm based on adaptive neuro fuzzy inference. It sends warning alarm to corresponding official response units in case of a predicted disaster. It also serves as the web server that hosts information accessible to the public.

Our system had been tested on site at the Hydrology Irrigation Center for Central Region in Chainat province. The data was successfully transferred to the central data management system. In addition, the water data from Thailand' s Royal Irrigation Department Bangbal station in Ayuttaya province was used to test the risk analysis algorithm. We demonstrated that it is able to predict events of floods 24 hours in advance.

Keywords: Flood monitoring, early flood warning, disaster management, fuzzy inference, mobile sensor station

I. INTRODUCTION

The 2011 mega flood had a devastating effect on more than ten provinces of Thailand, especially in the central region along the Chao Phraya River including Bangkok. The disaster badly crippled the country both economically and socially. During that time, seven major industry estates were inundated, forcing many plants to shut down. People lost their jobs, as well as their home. Overall, this flood affected more than 13 million people and resulted in more than 680 deaths [2]. Unfortunately, this mega flood was not the only disaster we had to face. Each year many people suffer from heavy rains combined with tropical storms and landslides during a rainy season, while during crop season in the summer they face the droughts [3-5].

When it is not easy to access alert information about disaster occurrences, announcements from responsible officers may not reach appropriate people on time. Additionally, a thorough analysis on the causes of problems is crucial to prevent or alleviate possible damages in future disasters. At present, we do not have a real-time disaster monitoring and warning system that can effectively estimate and also record statistical disaster-related data for analysis.

In flood detection and monitoring, efficiently monitor, control, and manage water level, water flow, and rainfall during each year's rainy season is valuable. This project aims to design a mobile system for flood information networking. We use sensors to detect water level, water flow rate and direction. In addition, rain fall rate and other meteorological data are measured by a weather station. All sensors, the weather station and processing unit are integrated in the mobile stations that can be moved easily and located closed to disaster–prone areas. For the communication part, all measured data is wirelessly sent to a central data center via a GPRS (General Packet Radio Service). However, when mobile operators are out of service due to severe disasters, the sensor data is sent via satellite. To test the system, the mobile station has been installed at the Royal Irrigation department in Chainat province, Thailand. The measured sensor data has been successfully transferred to the central data management system. Besides collecting and storing the data, the central management system houses the risk analysis algorithm and sends warning alarm to corresponding official response units in case of a predicted disaster. It also serves as the web server that hosts information accessible to the public.

The specific contributions of this project are 1) develop a prototype mobile monitoring station and communications system with integrated sensors for flood monitoring, 2) design and implement an intelligent early-warning algorithm which analyzes the sensing data and broadcasts warning of potential disasters to local communities, as well as alerts authorities, and 3) build a central information server for administrative management.

This paper is organized as follow. Section II shows the overall system design of this project. Section III introduces the mobile monitoring station, which consists of plug-in sensors, a weather station, a processing unit, and a power supply. Then, the communication components including GPRS and satellite are be described in Section IV. A flood prediction model using Fuzzy inference system is discussed in Section V. Lastly, the conclusion is given in Section VI.

II. THE SYSTEM DESIGN

The overview of our system design is given in Fig. 1. Different mobile monitoring stations containing various types of sensors suitable for disaster monitoring of choice are placed at disaster-prone locations across the country. During normal situation, the mobile stations communicate via mobile networks, sending sensor data and other relevant information to the central data management system. During or after disaster, stations within the vicinity of the affected areas where mobile network is down sent the data alternatively using satellite link. The central data management system contains the information server, monitoring data during normal operations and during disaster. It also houses the risk analysis algorithm using fuzzy expert system and sends warning alarm to corresponding official response units. Lastly, it serves as the web server that hosts information accessible to the public.

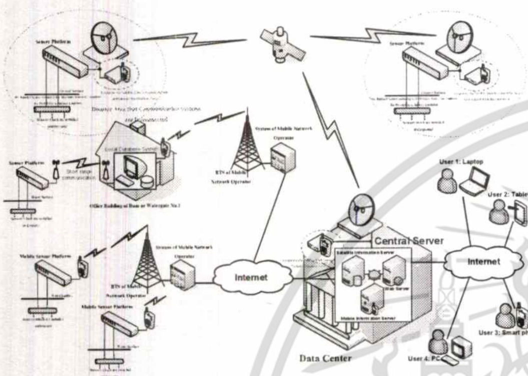


Figure 1: The system design.

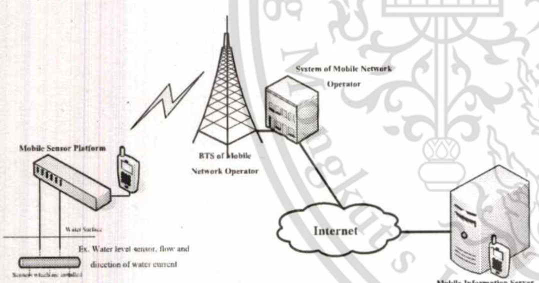


Figure 2: The communications during normal situation.

Figure 2 depicts the communications during normal situation. The sensor data and the location of the mobile station is routed to the mobile information server through the country's existing mobile network. In the cases that the mobile station is installed in the area where mobile network is not available, e.g . inside the jungle, in the valley, or in the disaster area where the terrestrial communication is disconnected, all measured data is sent to the server using the satellite communication link, as shown in Fig.3.

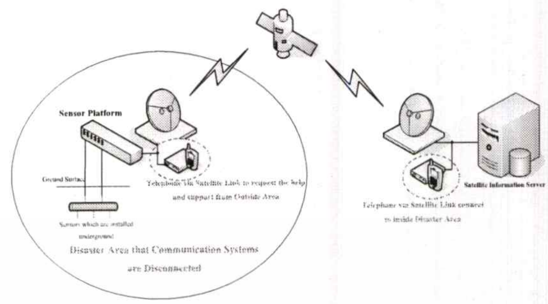


Figure 3: The satellite communications.

III. MOBILE MONITORING STATION

The mobile disaster monitoring station consists of two main parts—the control unit and the power supply unit. Sensor data received at the control unit are subsequently sent out to the central data management system to be analyzed for possible disasters either via a mobile network (normal situation) or a satellite link (during disasters). Components of the mobile monitoring station are displayed in Fig.4.

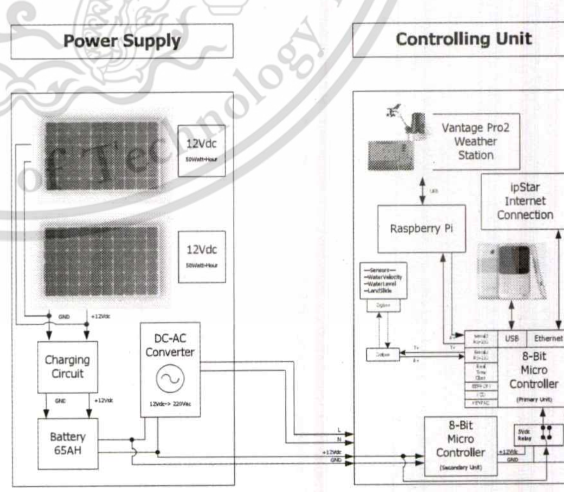


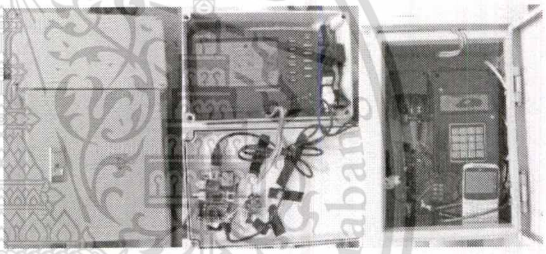
Figure 4: Block diagram of the mobile disaster monitoring station.

The mobile monitoring station can be powered two ways—using regular power outlets or using solar cells. For the units located in the city area, for example, units installed for additional measurements away from fixed-point monitoring stations, the units can use regular power outlets. Solar cells power is used for mobile units that are installed in the rural areas or difficult terrains without electricity, or used in the case that the electrical system is down due to disasters. For both power systems, inverter for charging reserve battery is provided. For usage, the user can choose the power supply manually.

Figure 6: Actual hardware of the power supply unit.

Figure 5: Hardware of mobile monitoring station.

Figure 5 depicts the hardware of mobile monitoring station located on top of the building of department of Telecommunications Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang for initial testing. Figure 6 and 7 show the actual hardwares of the supply unit and control unit including sensors installed at the mobile station.



(a) (b) (c)

Figure 7: The control unit and sensors installed at the mobile station. (a) External of the control unit. (b) Internal of the top control unit. (c) Internal of the bottom control unit.

The mobile monitoring station for flood warning has been tested on site at the Hydrology Irrigation Center for Central Region in Chainat province during a visit from the Japanese experts. The data (water level, water flow rate, and weather parameters) are successfully transferred to the central data management system.

IV. SATELLITE COMMUNICATION UNIT

In case of natural disasters such as floods, landslides, tsunami, or earthquakes, infrastructures of terrestrial and cellular telephone networks are often damaged or out of order. Relief efforts to restore the original networks could take weeks, so communications between stranded disaster victims and other areas are cutoff. To quickly restore communications during or immediately after such disasters, Raspberry Pi, a credit-card sized computer, is used as a server to control and manage sensor data from the weather station. The data is sent to the database on the central server via an Internet network of IPSTAR satellite. This real-time sensor data can be monitored and utilized by people in the disaster areas, as well as other people outside the affected areas. An IP phone is used to send and receive calls between disaster area and safe areas. This satellite communications system is depicted in Fig. 8.

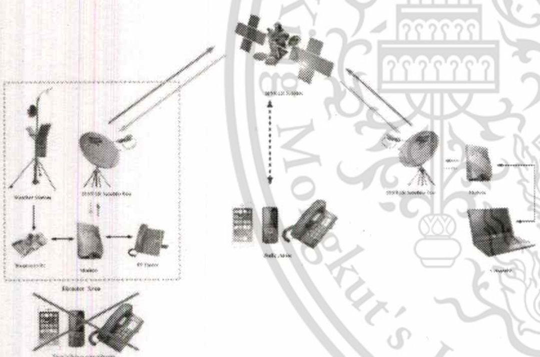


Figure 8: Communications system via IPSTAR satellite during disaster.

Figure 9 illustrates the IP Phone system via the IPSTAR satellite, which is composed of the antenna, the modem, the IP phone, and the computer.

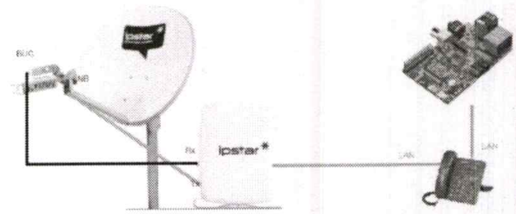


Figure 9: Block diagram of the IP phone system via IPSTAR satellite.

V. THE CENTRAL DATA MANAGEMENT SYSTEM

The central data management system has three main functionalities. First, it is the main server that combines data from the mobile monitoring station that is sent via GPRS module over cellular network and the data from satellite communications unit in case of cellular network damage or service disruption. Secondly, it houses the risk analysis algorithm using fuzzy expert system and sends warning alarm to corresponding official response units. Lastly, it serves as the web server that hosts information accessible to the public.

The data center displays the location of the available mobile base stations. There is one mobile base stations currently sending data to the server. By clicking the "Show All" button all data from the mobile station can be monitored. Fig. 10 displays the sensor data received from the mobile floods monitoring station operating on the test site in Chainat province. The data can also be exported in .csv format (Fig. 11) to other programs for subsequent processing.

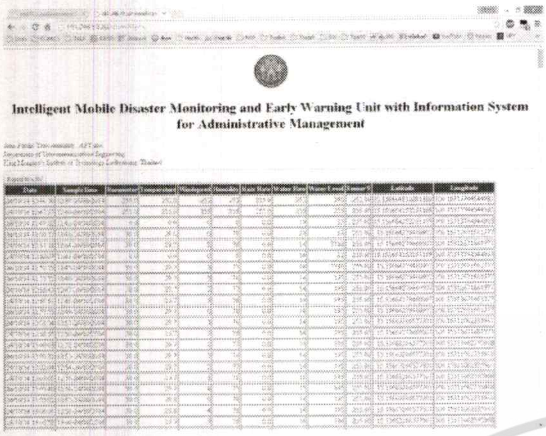


Figure 10: Data displayed after clicking the "Show All" button.

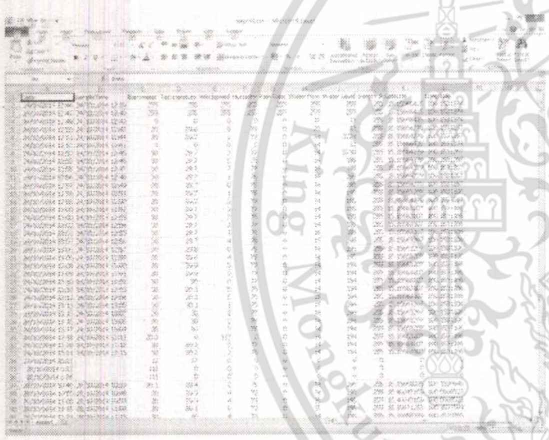


Figure 11: Sample data from mobile base station in .csv format.

VI. FLOODING ESTIMATION MODEL

Disaster risk analysis and early warning algorithm has been developed for floods warning up to 24 hours in advance. The measured data from different sensor modules is sent and collected at the central data server. Risk analysis is performed using Adaptive Neuro Fuzzy Inference Systems (ANFIS). The ANFIS combines artificial neural network with the fuzzy inference system, where reference from disaster experts is used to construct the rule (rule-based fuzzy logic) for disaster inference.

The algorithm is installed on both the mobile monitoring station and the central data management system. Once the algorithm detects possible incoming disaster, the preliminary warning is promptly sent out from the mobile station. At the same time, the central data management system will report the detected potential disaster to the official disaster response unit, who will consequently analyze the severity of the situation. Official alarm and appropriate protocol will be sent to all related governmental units as well as to appointed local contact person. It is also possible to adjust the inference rule/ criteria when additional local information or prior information on past disasters becomes available.

A. Algorithm design

The disaster analysis and early warning algorithm has been designed for floods monitoring. The algorithm is designed to predict an event of floods 24 hours in advance. Floods prediction uses two ANFIS systems, as shown in Fig. 12. The Inputs of the system are today's water level and flow rate, and the differential flow rate between yesterday and today. The first ANFIS uses today's water level and the differential flow rate as inputs to predict tomorrow's water level. The second ANFIS predicts tomorrow's flow rate from today's flow rate and the differential flow rate. The outputs are compared with the flooding criteria to determine whether it is normal, critical, or at flooding level. Note that these criteria (Normal, Critical, and Flood) are location-dependent. Floods happens when either the water level or the water flow rate meet the flooding criteria.

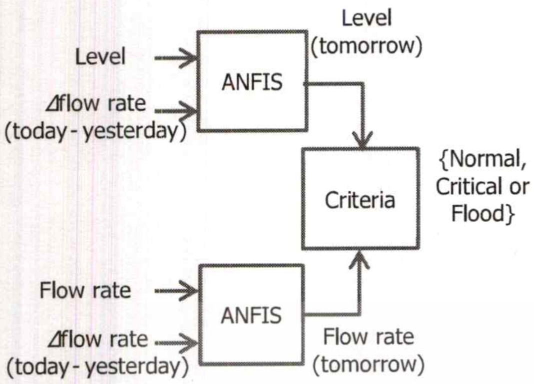


Figure 12: Block diagram of the early floods warning system.

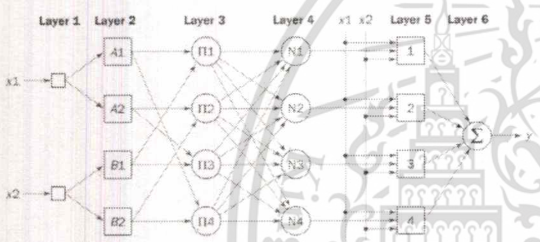


Figure 13: Architecture of the ANFIS.

The architecture of the proposed ANFIS for early flood warning is illustrated in Fig. 13. The structure consists of 6 layers according to the feed-forward neural network. There are two system inputs x_1 and x_2. Input x_1 corresponds to two fuzzy sets A_1 and A_2, whereas fuzzy sets B_1 and B_2 are for input x_2. There is one output, y. Following Sugeno fuzzy model, we construct four rules:

Rule 1:
If x_1 is A_1
And x_2 is B_1
Then $y = f_1 = k_{10} + k_{11}x_1 + k_{12}x_2$

Rule 2:
If x_1 is A_2
And x_2 is B_2
Then $y = f_2 = k_{20} + k_{21}x_1 + k_{22}x_2$

Rule 3:
If x_1 is A_2
And x_2 is B_1
Then $y = f_3 = k_{30} + k_{31}x_1 + k_{32}x_2$

Rule 4:
If x_1 is A_1
And x_2 is B_2
Then $y = f_4 = k_{40} + k_{41}x_1 + k_{42}x_2$

k_{i0}, k_{i1}, and k_{i2} are consequent parameters of rule i.

The operations in each layer can be summarized as follows.

1) Layer 1: Input layer

This layer processes the inputs before passing it to Layer 2, using

$$y_i^{(1)} = x_i$$

where i is the index for the i^{th} neuron.

2) Layer 2: Fuzzification layer

The fuzzification step takes the inputs from Layer 1 and determines the degree to which these inputs belong to each of the fuzzy sets via the membership functions $m_{A_i}(x)$

$$y_i^{(2)} = m_{A_i}(y_i^{(1)})$$

when $y_i^{(2)}$ is the membership function of A_i. The membership function adopted from Jang's model is the Bell activation function, whose equation is

$$y_i^{(2)} = \frac{1}{1+\left(\frac{y_i^{(1)} - a_i}{c_i}\right)^{2b_i}}$$

where a_i, b_i, and c_i are the parameters for controlling the center, the width, and the slope of such function, respectively.

3) Layer 3: Rule layer

The rule layer computes the firing strength of the rules for each neurons. The result in this layer is from the product

$$y_i^{(3)} = \prod_{j=1}^{m} x_{ji}^{(3)}$$

For example, the output of rule layer for the rule in the first neuron (Π_1) is

$$y_1^{(3)} = y_1^{(2)} \times y_3^{(2)} = \mu_1$$

μ_1 is the firing strength or truth value of Rule 1 .

4) Layer 4: Normalization layer

The Normalization calculates the normalized firing strength

$$y_i^{(4)} = \frac{\mu_i}{\sum_{j=1}^{n} \mu_j} = \bar{\mu}_i$$

5) Layer 5: Defuzzification layer

This layer calculates the weighted consequent values of the rules using the inputs,

$$y_i^{(5)} = \bar{\mu}_i \left[k_{i0} + \sum_{j=1}^{m} k_{ij} x_j \right]$$

6) Layer 6 : Summation neuron

The output y of the ANFIS is finally calculated using

$$y = \sum_{i=1}^{2m} y_i^{(5)}$$

The ANFIS training algorithm utilizes a hybrid learning algorithm, which combines a least-square estimator with a gradient descent method, to adjust parameters k's and the membership functions. The weights in the feedforward pass are determined using least-square estimations. The backward pass applies the back-propagation algorithm.

For the Sugeno- style ANFIS used in this algorithm, the output y is a linear function. Therefore, from the input- output pattern we can write P linear equations to represent the parameter outputs as,

$$f = y_i^{(5)}$$

Alternatively, in matrix form we have

$$\mathbf{y_d} = \mathbf{Ak}$$

where $\mathbf{y_d}$ is $P \times 1$ vector of the desired output.

$$\mathbf{y_d} = \begin{bmatrix} y_d(1) \\ y_d(2) \\ \vdots \\ y_d(p) \\ \vdots \\ y_d(P) \end{bmatrix}$$

$\mathbf{A}$ is a $P \times n(1+m)$ matrix,

$$\mathbf{A} = \begin{bmatrix} \bar{\mu}_1(1) & \bar{\mu}_1(1)x_1(1) & \cdots & \bar{\mu}_1(1)x_m(1) & \cdots & \bar{\mu}_n(1) & \bar{\mu}_n(1)x_n(1) & \cdots & \bar{\mu}_1(1)x_m(1) \\ \bar{\mu}_1(2) & \bar{\mu}_1(2)x_1(2) & \cdots & \bar{\mu}_1(2)x_m(2) & \cdots & \bar{\mu}_n(2) & \bar{\mu}_n(2)x_n(2) & \cdots & \bar{\mu}_1(1)x_m(1) \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots & \vdots & \cdots & \\ \bar{\mu}_1(p) & \bar{\mu}_1(p)x_1(p) & \cdots & \bar{\mu}_1(p)x_m(p) & \cdots & \bar{\mu}_n(p) & \bar{\mu}_n(p)x_n(p) & \cdots & \bar{\mu}_1(1)x_m(1) \\ \vdots & \vdots & \cdots & \vdots & \cdots & \vdots & \vdots & \cdots & \\ \bar{\mu}_1(P) & \bar{\mu}_1(P)x_1(P) & \cdots & \bar{\mu}_1(P)x_m(P) & \cdots & \bar{\mu}_n(P) & \bar{\mu}_n(P)x_n(P) & \cdots & \bar{\mu}_1(1)x_m(1) \end{bmatrix}$$

and $\mathbf{k}$ is an $n(1+m) \times 1$ vector of the unknown parameters,

$$\mathbf{k} = [k_{10}\ k_{11}\ k_{12} \ldots k_{1m}\ k_{20}\ k_{21}\ k_{22} \ldots k_{2m} \ldots k_{n0}\ k_{n1}\ k_{n2} \ldots k_{nm}]^T$$

Typically, if the number of equations P in the learning process is larger than the number of parameters ($n(1+m)$), the system of linear equation is over-determined, and we can use the pseudo-inverse technique to solve for k,

$$\mathbf{k}^* = (\mathbf{A}^T\mathbf{A})^{-1}\mathbf{A}^T y_d$$

We can calculate the error vector,

$$e = y_d - y$$

The Back-propagation algorithm is utilized in the backward pass, and the parameters are updated using chain rule. When there is an update of the weight for parameter a of Bell activation function for neuron A_1, we obtain the following chain rule,

$$\Delta a = -\alpha \frac{\partial E}{\partial a} = -\alpha \frac{\partial E}{\partial a} \times \frac{\partial e}{\partial y} \times \frac{\partial y}{\partial (\bar{\mu}_i f_i)} \times \frac{\partial (\bar{\mu}_i f_i)}{\partial \bar{\mu}_i} \times \frac{\partial \bar{\mu}_i}{\partial \mu_i} \times \frac{\partial \mu_i}{\partial \mu_{A1}} \times \frac{\partial \mu_{A1}}{\partial a}$$

The variable α is the learning rate, and E is the error of the ANFIS output.

Because

$$E = \frac{1}{2} e^2 = \frac{1}{2} (y_d - y)^2$$

Hence,

$$\Delta a = -\alpha (y_d - y)(-1) f_i \times \frac{\bar{\mu}_i (1 - \bar{\mu}_i)}{\mu_i} \times \frac{\mu_i}{\mu_{A1}} \times \frac{\partial \mu_{A1}}{\partial a}$$

or

$$\Delta a = \alpha (y_d - y) f_i \bar{\mu}_i (1 - \bar{\mu}_i) \times \frac{1}{\mu_{A1}} \times \frac{\partial \mu_{A1}}{\partial a}$$

where

$$\frac{\partial \mu_{A1}}{\partial a} = -\frac{1}{\left[1 + \left(\frac{x1 - a}{c}\right)^{2b}\right]^2} \times \frac{1}{c^{2b}} \times 2b \times (x1 - a)^{2b-1} \times (-1)$$

$$= \mu^2{}_{A1} \times \frac{2b}{c} \times \left(\frac{x1 - a}{c}\right)^{2b-1}$$

Parameters b and c can be calculated in a similar manner.

B. Algorithm testing for early floods warning

We test the performance of our algorithm using the data at Bangbal station (C37) in Ayuttaya province, Thailand. This location experiences annual flooding during the rainy season. Hence, there are sufficient data to create flooding criteria based on actual events. During flooding, the water level and water flow rate exceed the river capacity. The flooding criteria at C37 station are displayed in Table 1.

Table 1: Flooding criteria at Bangbal station

Water level (m)			Water flow rate (m^3/s)		
Normal	Critical	Flood	Normal	Critical	Flood
< 3.35	3.35-3.80	>3.80	< 110	110-134	> 134

The system learns from the water level and water flow rate data between 2008 and 2011. For the fuzzification layer (layer 2), the fuzzy sets of the first input (A_1 and A_2) and those for the second input (B_1 and B_2) in terms of the membership functions are illustrated in Fig. 14.

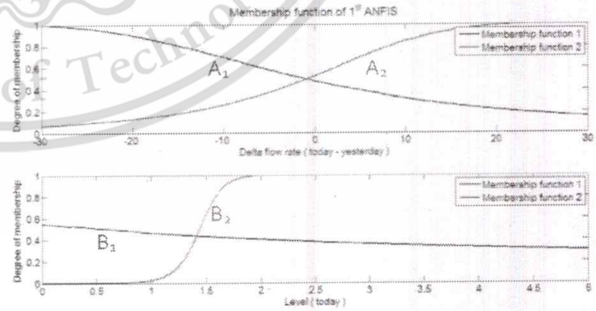


Figure 14: Membership functions of the 1st ANFIS.

Using the bell activation function,

$$y_i^{(2)} = \frac{1}{1+\left(\frac{y_i^{(1)}-a_i}{c_i}\right)^{2b_i}}$$

a_i, b_i and c_i are calculated to be

$A_1 : a_1 = -34.83$ $b_1 = 1.345$ $c_1 = 33.71$

$A_2 : a_2 = 32.32$ $b_2 = 2.11$ $c_2 = 33.09$

$B_1 : a_3 = -1.752$ $b_3 = 0.3962$ $c_3 = 0.3962$

$B_2 : a_4 = 3.711$ $b_4 = 10.27$ $c_4 = 2.267$

For defuzzification layer (Layer 5) the coefficients k_{i0}, k_{i1} and k_{i2} for the first order equation,

$$y_i^{(5)} = \bar{\mu}_i \left[k_{i0} + \sum_{j=1}^{m} k_{ij} x_j \right]$$, are

$k_{10} = 2.573$ $k_{11} = 0.1058$ $k_{12} = 0.3198$

$k_{20} = -1.767$ $k_{21} = -0.04154$ $k_{22} = 1.333$

$k_{30} = -2.322$ $k_{31} = 0.1372$ $k_{32} = 1.572$

$k_{40} = 1.54$ $k_{41} = 0.0432$ $k_{42} = 0.7214$

Similarly, we obtain the membership functions for the 2nd ANFIS, as depicted in Fig.15 along with the following coefficients,

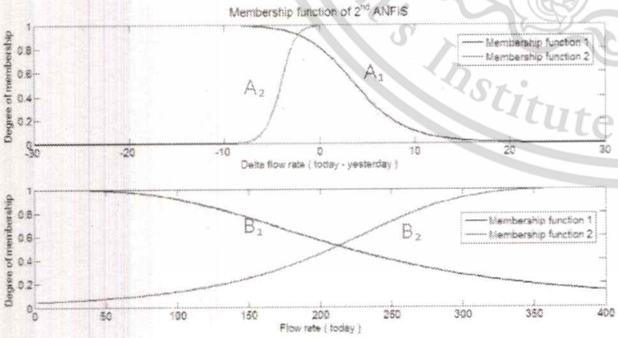


Figure 15: Membership functions of the 2nd ANFIS.

$A_1 : a_1 = -31.12$ $b_1 = 6.494$ $c_1 = 34.83$

$A_2 : a_2 = 28.38$ $b_2 = 20.04$ $c_2 = 32.48$

$B_1 : a_3 = 5.509$ $b_3 = 1.488$ $c_3 = 212.4$

$B_2 : a_4 = 419.3$ $b_4 = 2.241$ $c_4 = 209.7$

And

$k_{10} = -5.135$ $k_{11} = -0.206$ $k_{12} = 0.9859$

$k_{20} = -30.66$ $k_{21} = 0.6983$ $k_{22} = 1.084$

$k_{30} = 4.163$ $k_{31} = 0.4111$ $k_{32} = 0.9912$

$k_{40} = 34.38$ $k_{41} = 0.7558$ $k_{42} = 0.9029$

After training, the algorithm predicts the daily water levels and water flow rates for 2012. The predicted water levels and flow rates, compared against the actual measurements, are depicted in Fig.15 and Fig.16, respectively.

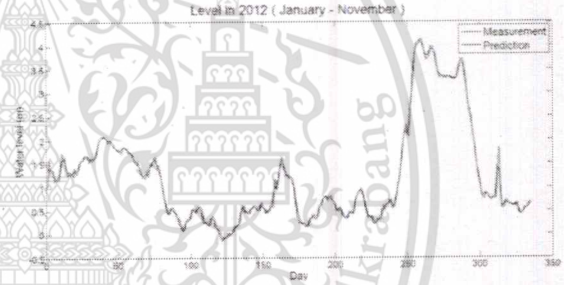


Figure 15: Predicted and measured daily water level in 2012.

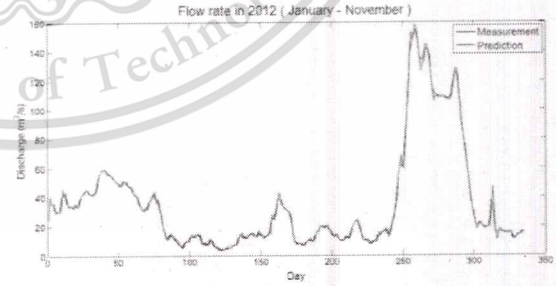


Figure 16: Predicted and measured daily water flow rate in 2012.

It is observed that the predicted results are in excellent agreement with the actual measurements with minimal errors. The maximum errors for the algorithm predictions are 0.3 m for water level, and 0.45 m^3/s for water flow rate. Fig. 17 illustrates the predicted results in January 2012.

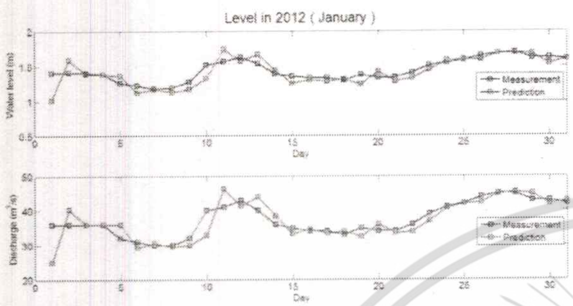


Figure 17: Predicted and measured daily water level and flow rate in January 2012.

We measure the efficiency of our algorithm using three indices, namely the mean absolute deviation (MAD), the mean square error (MSE), and the efficiency index (EI). These quantities are given by the following equations.

$$MAD = \frac{\sum_{i=1}^{N}|t_i - z_i|}{N}$$

$$MSE = \frac{\sum_{i=1}^{N}(t_i - z_i)^2}{N}$$

$$EI = \frac{(ST - SSE)}{ST}$$

With $ST = \sum_{i=1}^{N}(t_i - \overline{t_i})^2$ and $SSE = \sum_{i=1}^{N}(t_i - z_i)^2$. t_i and z_i are measured and predicted values, respectively.

The performance of the algorithm in terms of these performance measures are given in Table 2. Note that the efficiency indices are above 99 % for all cases, confirming the efficacy of our algorithm.

Table 2: Performance indices for the early floods warning algorithm using data at C37 station.

	Water level		**Water flow rate**	
	2008-2011 data	**2012 data**	**2008-2011 data**	**2012 data**
MAD	0.0691 m	0.0605 m	2.0260 m^3/s	1.6687 m^3/s
MSE	0.0102 m	0.0073 m	11.1248 m^3/s	6.5649 m^3/s
EI	0.9960	0.9932	0.9986	0.9949

For 2012, there were two floods happening in September (during September 11-18, 2012 and 21- 24 September, 2012). Our algorithm is able to correctly predict both events, as shown in Fig.18.

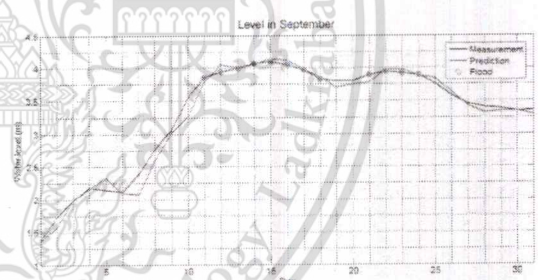


Figure 18: Floods predictions in September 2012.

The early flood warning algorithm is installed in the central data management system. It analyzes the data sent to the central server from the mobile monitoring stations. The display GUI is designed using LabVIEW. Fig.19 is an example of the GUI which monitors Bangbal station (C37). The left panel shows the location of the monitoring station on a Google map. The right panel displays the monitoring status. In Fig. 20 the system sends out a warning that there would be floods occurring on September 11, 2012 based on the predicted water level (4 m, shown in red graph). The measured sensor data in Fig.21 (blue graph) confirms that the prediction was correct and the water level was in the flooding zone (3.8 m).

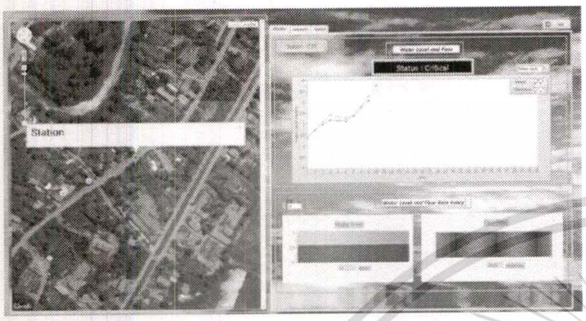


Figure 19: Display GUI of the floods monitoring system.

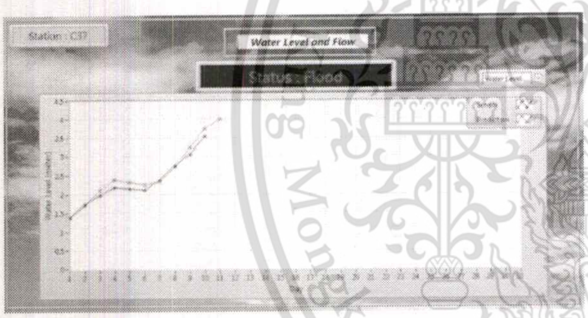


Figure 20: Flooding is predicted on September 11, 2012.

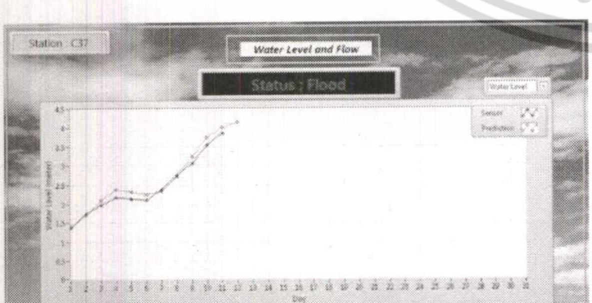


Figure 21: Flooding is observed on September 11, 2012.

In addition, the GUI displays other sensor data acquired from the weather station at C37, for example, temperature, atmospheric pressure, humidity, wind speed and direction, and rainfall rate, as shown in Fig.22.

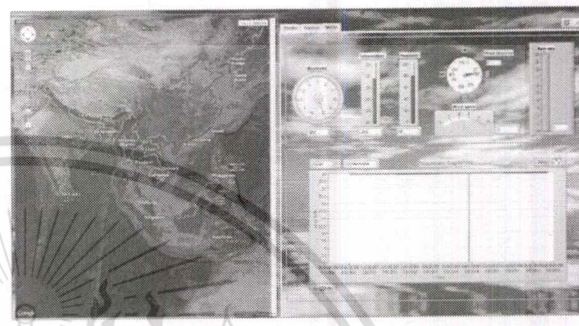


Figure 22: Weather parameters displayed on the GUI.

CONCLUTION

We has developed an early-warning system integration for flood disaster management in the form of a unified platform. The platform is flexible. It is customizable based on local needs and budget because all modules are plug-in. In addition, the mobile unit itself is portable and is easy to install. It can also be a stand-alone unit because it can send out early flood warning even without any communications with the central data management system. With the integration of the central data server, however, the system provides a complete nation-wide flood warning and response system that can be monitored wirelessly and can exchange information among corresponding governmental units promptly and seamlessly.

We also develop a new algorithm for analyzing potential floods from measured sensor data using the adaptive neuro fuzzy inference system. The disaster inference rules are designed using local information about the disasters. The algorithm is fully automated; the preliminary early warning alarm is sent from the mobile unit promptly while waiting for the official confirmation at the central data management system about proper protocol that the public should follow. This two-step warning (preliminary-official) allows the public to be informed and prepared for the potential disaster in a timely manner. The algorithm has been tested that it is able to predict events of floods 24 hours in advance.

Acknowledgement

This project was partially supported by King Mongkut' s Institute of Technology Ladkrabang grant #KREF085701 and the HRD programme for exchange of ICT researchers and engineers from the Asia-Pacific Telecommunity (APT). We would like to thanks the Hydrology Irrigation Center for Central Region for supporting us to demonstrate our system prototype on site in Chainat province.

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