GNSS Data Processing for High-Accuracy Positioning using Low-Cost Receiver Systems

GNSS Education Activities of CSIS

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The University of Tokyo
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Overview

- **GNSS Trainings, Workshops and Seminars**
  - Basically in Asian countries
    - Indonesia, India, Laos, Malaysia, Myanmar, Nepal, Thailand, The Philippines, Singapore, Vietnam
    - Bangladesh (planned in 2020), Egypt (FEB 2020)
  - Also, Some African Countries
    - Mozambique, Rwanda

- **Webinars**
  - Conduct webinars under MGA (Multi-GNSS Asia)
  - Global Access, Anybody can attend and free
    - Up to 100 participants online webinar at a time
    - Please register at [http://gnss.peatix.com](http://gnss.peatix.com)

- **Joint Research and Pilot Projects**
  - Low-Cost High-Accuracy GNSS Systems
  - Traffic Congestion Management
  - Traffic Monitoring
  - GNSS Signal Authentication
  - Supply-Chain Value Analysis
  - Illegal Fishing Monitoring
  - Any GNSS-based Application of your interest

- **Installation of GNSS CORS**
  - Install GNSS CORS in the Universities around the world for joint research, GNSS technology promotion and capacity building

- **RPD (Rapid Prototype Development) Challenge during MGA (Multi-GNSS Asia)**
  - Encourage students and researchers to bring solutions and business values by solving real-life problems
    - The 1st RPD Challenge was done during MGA 2018 in Melbourne, Australia on 24th OCT 2018
    - The 2nd RPD Challenge was done during MGA 2019 in Bangkok, Thailand on 27 – 29 AUG 2019
    - The 3rd RPD Challenge will be held during MGA 2020 in Bangkok, Thailand AUG 2020

- **Develop Low-Cost High-Accuracy Positioning Systems (L-CHAPS)**
  - Integrate low-cost receivers for RTK, PPK or PPP processing
    - Android or Raspberry Pi versions
    - Based on QZSS MADOCA Signals
  - RTKDROID: An android APP for RTK with external GNSS receiver
Global Navigation Satellite System (GNSS) Training, Course T-151
6 – 10 JAN 2020, AIT Conference Center, AIT, Thailand
GNSS Training, Course T-151 and GNSS for Policy and Decision Makers, Course T-131
14 – 18 January 2019
AIT Conference Center, AIT, Thailand
GNSS Training at GIC/AIT, Thailand, 23 – 26 JAN 2018

Afghanistan, Australia, Austria, Bangladesh, Bhutan, Cambodia, India, Indonesia, Japan, Maldives, Mongolia, Nepal, The Philippines, Sri Lanka, Tajikistan, Thailand, The United States of America, Vietnam

64 Participants from 15 Countries
<table>
<thead>
<tr>
<th>Number of Participants</th>
<th>JAN 2021</th>
<th>JAN 2021</th>
<th>JAN 2020</th>
<th>JAN 2019</th>
<th>JAN 2018</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>19 – 21 JAN</td>
<td>28 JAN</td>
<td>T-151</td>
<td>T-151/T-131</td>
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<td>(B) Other Funding (travel only)</td>
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<td>NA</td>
<td>X</td>
<td>4E</td>
<td>X</td>
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<tr>
<td>(C) Self Funded International</td>
<td>NA</td>
<td>NA</td>
<td>34</td>
<td>40</td>
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<tr>
<td>(D) Self-Funded Thailand</td>
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<td>18</td>
<td>27</td>
<td>42 (24 + 18)</td>
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<tr>
<td>Total (A + B + C + D)</td>
<td>270</td>
<td>160 tbc</td>
<td>71</td>
<td>94</td>
<td>67</td>
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<td>Applicants</td>
<td>360</td>
<td>Tbc</td>
<td>160+</td>
<td>180+</td>
<td>80+</td>
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<tr>
<td>Number of Resource Persons</td>
<td>15</td>
<td>6</td>
<td>16 7 (Int) + 9 (GIC)</td>
<td>20 11 (Int) + 9 (GIC)</td>
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<td>3</td>
<td>4</td>
<td>7</td>
<td>4</td>
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</tbody>
</table>
GNSS Training 2020: Participants Statistics

Countries of GNSS Training Participants
Red: Trainees / Yellow: Resource Persons
GNSS Training 2020: Participants Statistics

**Participants' Country**

- Japan: 20
- Austria: 1
- Nepal: 1
- USA: 1

**Gender Balance**

- Male: 54
- Female: 17

**Organization Type**

- Academy / Education: 39
- Government: 16
- Private Company: 13
- NPO/NGO: 4

**Resource Persons by Country**

- Japan: 4
- Austria: 1
- Nepal: 1
- USA: 1
## GNSS Training 2020: Participants Statistics

<table>
<thead>
<tr>
<th>Number of Participants</th>
<th>JAN 2020</th>
<th>JAN 2019</th>
<th>JAN 2018</th>
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<tbody>
<tr>
<td>T-151</td>
<td>T-151/T-131</td>
<td>T-141</td>
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<td>(A) ICG Funded International (travel only)</td>
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<td>(B) ESCAP Funded International (travel only)</td>
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<tr>
<td>(C) Self Funded International</td>
<td>40</td>
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<td>11</td>
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<tr>
<td>(D) Self-Funded Thailand</td>
<td>20</td>
<td>27</td>
<td>42 (24 + 18)</td>
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<tr>
<td>Total (A + B + C + D)</td>
<td>81</td>
<td>94</td>
<td>67</td>
</tr>
<tr>
<td>Applicants</td>
<td>160+</td>
<td>180+</td>
<td>80+</td>
</tr>
<tr>
<td>Number of Resource Persons</td>
<td>17 (16)</td>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>7 (Int) + 10 (GIC)</td>
<td>11 (Int) + 9 (GIC)</td>
<td>7 (Int) + 6 (GIC)</td>
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<tr>
<td>Number of Countries</td>
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<td>Resource Persons Countries</td>
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GNSS Training Lectures : 2020
Sponsor Lecture and Demo : 2020
GNSS Field Survey : 2020
GNSS Field Survey and Data Processing, 2019
GNSS Field Survey and Data Processing, 2019
Day 1: Online Presentation
GPS Introduction : David Turner, State Dept. of the USA
GPS Signal Structure : Tom Stansell, Stansell Consulting, USA

1. Sharafat Gadimova, UNOOSA/ICG, Austria
2. Dinesh Manandhar, Associate Professor, The University of Tokyo, Japan
3. Yuichi Hayakawa, Associate Professor, The University of Tokyo, Japan
4. Nobuaki Kubo, Associate Professor, TUMST, Japan
5. Suelynn Choy, Associate Professor, RMIT University, Australia
6. David Turner, State Department, USA (online lecture)
7. Thomas Stansell, Stansell Consulting, USA (online lecture)
8. GIC/AIT resource persons and staffs
MGA GNSS Webinar

Upcoming Webinars: (1) RTK from Android GNSS Raw Data (2) Early Warning System (3) GNSS Signal Authentication (4) PNT from Micro/Cube Satellites and many more.....

Webinar Registration: [http://gnss.peatix.com](http://gnss.peatix.com)
Past Webinar Reference: [https://home.csis.u-tokyo.ac.jp/~dinesh/WEBINAR.htm](https://home.csis.u-tokyo.ac.jp/~dinesh/WEBINAR.htm)

We need YOU as a Resource Person. Please contact us.....

Dinesh Manandhar, CSIS, The University of Tokyo, dinesh@csis.u-tokyo.ac.jp
MGA Webinars

<table>
<thead>
<tr>
<th>MGA Webinar #08</th>
<th>MGA Webinar #09</th>
<th>MGA WEBINAR #12</th>
<th>MGA WEBINAR #13</th>
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<tbody>
<tr>
<td>by GNSS</td>
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<td>by GNSS</td>
<td>by GNSS</td>
</tr>
<tr>
<td>Tokyo</td>
<td>Tokyo</td>
<td>Surat, Gujarat, India</td>
<td>Tokyo</td>
</tr>
<tr>
<td>Dec 6, 2018 (Thu)</td>
<td>Jul 16, 2019 (Tue)</td>
<td>Dec 6, 2019 (Fri)</td>
<td>May 14, 2020 (Thu)</td>
</tr>
<tr>
<td>Invitation Ticket (Free)</td>
<td>By Registration Only</td>
<td>Free Invitation</td>
<td>Invited Participants</td>
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<td>Tickets closed</td>
<td>Tickets closed</td>
<td>Tickets closed</td>
<td>Tickets closed</td>
</tr>
<tr>
<td>33 ATTENDING</td>
<td>37 ATTENDING</td>
<td>30 ATTENDING</td>
<td>122 ATTENDING</td>
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Please Refer the following sites for details (Past presentation files, video files and data are available):

https://gnss.peatix.com/
https://home.csis.u-tokyo.ac.jp/~dinesh WEBINAR.htm
Asian Base-Station Network
Installation of Base-Stations in Universities for Capacity Building
## Installation of Base- Stations in Universities for Capacity Building

<table>
<thead>
<tr>
<th>Country</th>
<th>Place</th>
<th>University</th>
<th>Receiver Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indonesia</td>
<td>Jakarta</td>
<td>University of Indonesia</td>
<td>GNSS (1) / GNSS + MADOCA (1)</td>
</tr>
<tr>
<td>Japan</td>
<td>Tokyo-A</td>
<td>The University of Tokyo</td>
<td>GNSS (1) / GNSS + MADOCA (1)</td>
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<tr>
<td>Japan</td>
<td>Tokyo-B</td>
<td>Tokyo University of Marine Science &amp; Tech.</td>
<td>GNSS (1) / GNSS + MADOCA (1)</td>
</tr>
<tr>
<td>Japan</td>
<td>Tokyo-C</td>
<td>KEIO University</td>
<td>GNSS (1)</td>
</tr>
<tr>
<td>Laos*</td>
<td>Vientiane</td>
<td>National University of Laos</td>
<td>GNSS (1)*</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Kuala Lumpur</td>
<td>Malaysia Japan International Institute of Tech.</td>
<td>GNSS (1) / GNSS + MADOCA (1)</td>
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<tr>
<td>Myanmar*</td>
<td>Yangon</td>
<td>Yangon Technological University</td>
<td>GNSS (1)*</td>
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<tr>
<td>Thailand</td>
<td>Bangkok</td>
<td>Chulalongkorn University</td>
<td>GNSS (1) / GNSS + MADOCA (1)</td>
</tr>
<tr>
<td>Thailand</td>
<td>Pathumthani</td>
<td>Asian Institute of Technology</td>
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<td>Philippines</td>
<td>Manila</td>
<td>University of the Philippines</td>
<td>GNSS (1) / GNSS + MADOCA (1)</td>
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<tr>
<td>Vietnam</td>
<td>Ho Chi Minh City</td>
<td>International University Vietnam National University</td>
<td>GNSS (1) GNSS + MADOCA (Sep 2020)</td>
</tr>
<tr>
<td>Mozambique*</td>
<td>Maputo</td>
<td>Universidade Eduardo Mondlane</td>
<td>GNSS (1)*</td>
</tr>
<tr>
<td>Singapore</td>
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<td>Singapore Land Authority</td>
<td>GNSS + MADOCA (Sep 2020)</td>
</tr>
<tr>
<td>Australia</td>
<td>Perth</td>
<td>Curtin University</td>
<td>GNSS + MADOCA (1)</td>
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</tbody>
</table>
Low-Cost High-Accuracy Receiver System Development
Low-Cost High-Accuracy Receiver System Development

• Based on RTK/PPK
  • Requires Base-Station
  • Accuracy: few cm to 20cm

• Based on QZSS MADOCA PPP
  • Does not require Base-Station
  • Accuracy: 10 – 20cm

Note: QZSS CLAS service provides few cm accuracy
But, this service is only for Japan
Our Definition of Low-Cost Receiver

- **Price**: $100 or less
- **Accuracy**: Better than 100cm
- **Weight**: 100g or less (Without Battery)

$100 \times 100\text{cm} \times 100\text{g}$

Will it be possible?

**Current Status:**
- **Price**: $200 - $500
- **Accuracy**: 10 – 70cm
- **Weight**: 100 – 500gm

How to Reduce Cost? Improve Accuracy?
- Bulk Purchase / Manufacturing in Volume
- Find Good Quality Antenna
- System Design as per End-User Requirement:
  - Bsse-Design + Top-On Systems: Design System Required by End-User Applications
Low-Cost High-Accuracy Positioning System (L-CHAPS)

Our Definition of Low-Cost: $100 \times 100\text{cm} \times 100\text{gm}

L-CHAPS, Development Cycle

DEC, 2016

Raspberry Pi B

GNSS Antenna

WiFi + BT

GNSS Receiver

SD Memory Card

DEC, 2018

GNSS Antenna

GNSS Receiver

Tablet

RasPi

APP Ver. 1.0

BT

Internet

NTRIP Caster

MAY, 2017

Raspberry Pi 3B

GNSS Antenna

GNSS Receiver

Tablet

RTKDROID APP

Ver. 1.0

Tablet

NTRIP Caster

MAR, 2018
Low-Cost High-Accuracy Receiver System (RTK/PPK)

TYPE R1  Type A: Low-Cost, High-Accuracy Receiver System
Real-Time and Post-Processing, Base and Rover Mode

TYPE R2  Type B: Low-Cost, High-Accuracy Receiver System
For Post-Processing & Rover Mode Only

TYPE A1  Type C: Low-Cost, High-Accuracy Receiver System
Real-Time and Post-Processing, Rover Mode Only

TYPE MA  Type D: Low-Cost, High-Accuracy Receiver System
Real-Time and Post-Processing, Rover Mode Only

Dinesh Manandhar, CSIS, The University of Tokyo, dinesh@csis.u-tokyo.ac.jp
## Low-Cost High-Accuracy Receiver System (MADOCA-PPP)

<table>
<thead>
<tr>
<th>Platform / OS</th>
<th>MAD-WIN</th>
<th>MAD-π</th>
<th>MADROID</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNSS Receiver</td>
<td>Windows</td>
<td>Raspberry Pi 3B or 4B</td>
<td>Android Device</td>
</tr>
<tr>
<td>MADOCRA Receiver</td>
<td>U-blox D9 only</td>
<td>U-blox D9 only</td>
<td>NA (MADOCA Online Correction Data only)</td>
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<tr>
<td>GNSS Receiver Data Format</td>
<td>UBX, SBF, RTCM3</td>
<td>UBX</td>
<td>UBX</td>
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<tr>
<td>MADOCRA Correction Data Format (Satellite)</td>
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<td>MADOCRA Correction Data Format (Online)</td>
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<td>Online Services from GPAS, UTokyo (Test Level)</td>
<td>GPAS Services, RTCM3</td>
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<td>UBX or RTCM3</td>
<td>UBX or RTCM3</td>
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<tr>
<td></td>
<td>RTCM3</td>
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</tbody>
</table>

### System Architecture

- **Antenna**
  - L1/L2 GNSS + MADOCRA Decoder
  - Computer (Windows)
- **Antenna**
  - L1/L2 GNSS + MADOCRA Decoder
  - Raspberry Pi 3B or 4B
- **Antenna**
  - L1/L2 GNSS + MADOCRA Decoder
  - Android Device
Low-Cost High-Accuracy Receiver System Development

• 低コストのMADOCA受信機システム
MAD-WIN and MAD-π Screen Shots

Receiver and MADOCA Correction Data Setup Menu

MADOCA PPP Output Display

Log of MADOCA PPP Solution, Receiver Raw Data and MADOCA Correction Data
MADROID Screenshots

MADOCA PPP based on Android Dual Frequency Receiver + Online MADOCA Data
GNSS Reference Station and Data at UT, Kashiwa

- A reference station is set at UT, Kashiwa, General Research Building rooftop
- CSIS can provide GNSS data and GNSS services for high-accuracy positioning for research purpose
  - Based on RTK
    - Real-Time and Post-Processing
  - Based on MADOCA
    - Real-Time and Post-Processing
    - Even Global Service is possible where QZSS is not visible
  - NTRIP Server is set at Kashiwa campus
- Different types of receivers, antenna, signal generating devices and test equipment are available
  - Receivers
    - Trimble NetR9
    - Septentrio PolaRx5, M2a, MOSAIC
    - u-blox M8T, M8U, M9N, F9P, D9
    - ASTRA Receiver for Scintillation and Space Weather Monitoring
  - Signal generators
    - Blade-RF SDR device
  - Spectrum Analyzer
    - Tektronix RSA306
  - Oscilloscope
    - Tektronix TBS1064
  - Please feel free to use

Dinesh Manandhar, CSIS, The University of Tokyo, dinesh@csis.u-tokyo.ac.jp
Link for Reference Materials

- Lab Home Page
  - [https://home.csis.u-tokyo.ac.jp/~dinesh/](https://home.csis.u-tokyo.ac.jp/~dinesh/)

- Facebook: [https://www.facebook.com/gnss.lab](https://www.facebook.com/gnss.lab) (GNSS Related)

- Contact: [dinesh@csis.u-tokyo.ac.jp](mailto:dinesh@csis.u-tokyo.ac.jp)