Toward the Real-time Computational Seismology earthquake report in Taiwan

Shiann-Jong Lee

Institute of Earth Sciences, Academia Sinica
Outline

- **RMT**: Real-time Moment Tensor monitoring system
- **ROS**: Real-time Online earthquake Simulation
- **RCS**: Real-time Computational Seismology

earthquake report

- Routine earthquake report vs. RCS earthquake report
Introduction

Source
- M<6: Point source parameters
- M>6: Finite-fault source model
- Fault and seismogenic zone
- Kinetic and dynamic analyses

Path and site
- Large-scale velocity model
- Local velocity structure
- Surface topography
- Basin, sedimentary plain
- Moho, plate boundary... etc.

Earthquake simulation
- ShakeMovie: 3D wave propagation
- ShakeMap: PGA, PGV, Intensity map
- Synthetic waveforms
- Visualization

Real-time
- Moment Tensor
- Monitoring system

Real-time
- Online earthquake Simulation system

Real-time
- Computational Seismology
- Earthquake report
Real-Time Moment Tensor Monitoring System

Home  Report  |  RMT v3.2 (Latest update 2015/02/05)

RMT report list

2015
10/07 21:50:13 (UT), M 4.0
10/06 14:28:28 (UT), M 3.8
10/05 15:04:58 (UT), M 4.0
10/04 17:41:04 (UT), M 4.1
09/29 19:37:45 (UT), M 4.3
09/25 10:54:27 (UT), M 3.9
09/24 05:58:03 (UT), M 4.2
09/23 19:20:07 (UT), M 3.9
09/23 14:27:10 (UT), M 3.5
09/23 08:19:28 (UT), M 3.7
09/18 13:28:03 (UT), M 3.7
09/16 20:44:34 (UT), M 3.6
09/16 13:30:26 (UT), M 4.0
09/16 13:08:59 (UT), M 5.0
09/15 20:43:59 (UT), M 3.8
09/15 19:37:36 (UT), M 5.1
09/15 17:56:24 (UT), M 4.1
09/15 16:34:56 (UT), M 3.4
09/15 16:31:18 (UT), M 3.6
09/10 15:23:27 (UT), M 4.5
09/10 12:48:55 (UT), M 3.6
09/09 21:08:54 (UT), M 4.0
09/08 04:28:55 (UT), M 3.4
09/02 03:03:35 (UT), M 4.3
09/02 02:18:15 (UT), M 4.2

These events have been reviewed.
* M<sub>r</sub> lower than the threshold.

1. VWUC
2. SBCB
3. RLNB
4. TPUB
5. PHUB
6. YDQ7
7. YWNB
8. TDCB
9. S3LB
10. MASB
11. SXH
12. NACB
13. YULB
14. TWGB
15. TWKB
16. PCYB

Real-time Moment Tensor monitoring system (RMT):  http://rmt.earth.sinica.edu.tw

Real-time Moment Tensor monitoring system (RMT) takes advantage of a grid-based moment tensor inversion technique and long-period broadband seismic recordings (BATS) to automatically monitor earthquake activities in the vicinity of Taiwan. The centroid moment tensor (CMT) inversion technique and a grid search scheme are applied to obtain the information of earthquake source parameters, including the event origin time, hypocentral location, moment magnitude, and focal mechanism. All of these source parameters can be determined simultaneously within 117 seconds after the occurrence of an earthquake.

Real-time Moment Tensor monitoring system (RMT):  [http://rmt.earth.sinica.edu.tw](http://rmt.earth.sinica.edu.tw)
RMT Monitoring Results

- Online: 2012.01 - 2019 (present)
- Offline: 2010-2011
- Total detected events: 1341
- Total Mw > 4 events: 589

http://rmt.earth.sinica.edu.tw
Real-time Online earthquake Simulation system (ROS): http://ros.earth.sinica.edu.tw

Problem definition

- Rupture model (source)
- Simulation region (Path and Site)
- Physical properties (Max. freq., Min. Velocity, ... and so on)

Input

Community models

IES Green Cluster

Grid computing

Data Grid

Numerical output

Numerical visualization

Visualization, Analysis Machines (IES Green)

Numerical output

Result output

Storage
RCS flowchart

1. RMT
   Real-time Moment Tensor monitoring
   (<120 seconds)

2. ROS
   Real-time Online earthquake Simulation
   (<3 minutes)

3. RCS
   Real-time Computational Seismology earthquake report
   (~5 minutes)

BATS
continuous data
(Real-time)
RCS flowchart

1. RMT
   Real-time Moment Tensor monitoring (<120 seconds)

2. ROS
   Real-time Online earthquake Simulation (<3 minutes)

3. RCS
   Real-time Computational Seismology earthquake report (~5 minutes)
Real-time Computational Seismology (RCS)
earthquake report

Source parameters
- Centroid location
- Focal mechanism
- Waveform fittings

ShakeMovie

ShakeMap
- PGA
- PGV

Intensity Map
- CWB It scale
- MMI

Synthetic waveforms
- E component
- N component
- Z component

Surface deformation
- Vertical
- Horizontal

Download

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Real-time Computational Seismology earthquake report (RCS): http://rcs.earth.sinica.edu.tw
Real-time Computational Seismology (RCS) earthquake report

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Real-time Computational Seismology earthquake report (RCS): http://rcs.earth.sinica.edu.tw
RCS = RMT + ROS

Scientific results
Related links
Contact

2015/10/12
11:14:56
Mw 6.1
121.60°E 23.70°N
Depth 26.2 km

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Real-time Computational Seismology (RCS)
earthquake report

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Real-time Computational Seismology (RCS) earthquake report

Source parameters
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- Focal mechanism
- Data fitting

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Real-time Computational Seismology earthquake report (RCS): http://rcs.earth.sinica.edu.tw
CWB earthquake report

- Earthquake Final Report (Regional Network)
- Central Weather Bureau (CWB), Taiwan, R.O.C.
- This is Informal Information for Rapid Dissemination, the Official Report will be Broadcasted by CWB, Taiwan, R.O.C., at http://www.cwb.gov.tw/
- Magnitude, ML=4.8
- Origin Time: 8/18/19 04:05:14.6 (UT)
- Get Result Time ===> 04:09:58
- Location: 23.75N 121.54E, Depth: 5.0 KM

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Intensity Scale:

1: 0.8 - 2.5 gal
2: 2.5 - 8 gal
3: 8 - 25 gal
4: 25 - 80 gal
5: 80 - 250 gal
6: 250 - 400 gal
7: > 400 gal
Earthquake Final Report (Regional Network)
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<td>121.21E</td>
<td>1.0</td>
<td>2.4</td>
<td>75.0</td>
<td>27.7</td>
<td></td>
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</tr>
<tr>
<td>ENA</td>
<td>24.43N</td>
<td>121.75E</td>
<td>1.4</td>
<td>2.2</td>
<td>77.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALS</td>
<td>23.51N</td>
<td>120.81E</td>
<td>1.7</td>
<td>2.2</td>
<td>79.2</td>
<td>29.4</td>
<td>39.5</td>
<td></td>
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<tr>
<td>ECS</td>
<td>23.10N</td>
<td>121.22E</td>
<td>1.0</td>
<td>2.1</td>
<td>79.7</td>
<td>30.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Intensity Scale
1: 0.8 - 2.5 gal
2: 2.5 - 8 gal
3: 8 - 25 gal
4: 25 - 80 gal
5: 80 - 250 gal
6: 250 - 400 gal
7: > 400 gal
CWB earthquake report

CWB Early Automatic Report (EAR):
Origin Time: 2019 8 18 4:5:14.00 (UT)
Hypocenter: 23.75 N 121.54 E 5.00 km
ML: 4.81

CWB SN_BB moment-tensor solution:
-0.4233703 0.3309798 0.4323435
0.3309798 -0.4449112 -1.1358339 x 1E+16 Nt-m
0.4323435 -1.1358339 0.8682815
Centroid depth: 4 km
Mw: 4.71
Azgap: 195.44
Average MISFIT: 0.396 (The fit is excellent)

Best double couple solutions:
nodal plane(1) strike/dip/slip: 233.74/18.58/116.92
nodal plane(2) strike/dip/slip: 25.56/73.49/81.34
RCS earthquake report

1. RMT
Real-time Moment Tensor monitoring (<120 seconds)

2. ROS
Real-time Online earthquake Simulation (< 3 minutes)

3. RCS
Real-time Computational Seismology earthquake report (~ 5 minutes)
RCS earthquake report

1. RMT
   Real-time Moment Tensor monitoring
   (<120 seconds)

2. ROS
   Real-time Online earthquake Simulation
   (<3 minutes)

3. RCS
   Real-time Computational Seismology earthquake report
   (~5 minutes)

BATS
continuous data
(Real-time)

PGA
MMI
Intensity
(it)
PGV
Deformation
Synthetic E-W
Synthetic N-S
Synthetic Z
RCS earthquake report

1. RMT
Real-time Moment Tensor monitoring (<120 seconds)

2. ROS
Real-time Online earthquake Simulation (< 3 minutes)

3. RCS
Real-time Computational Seismology earthquake report (~ 5 minutes)

T0: earthquake occurs
T1: Rapid report
T2: Focal mechanism
Tr: Final report
The Next: Global RMT
Global Real-time Moment Tensor monitoring system

Global earthquakes (1990–present, M≥5):
Total 46,382 earthquakes

Global grids (average distance at surface ~0.9 degree):
Total about 800,000 grid points

Global RMT grid points: 846,382
~ 1024+ CPU cores

RMT grid points: 399,840
512 CPU cores
Thank you for your attention

RMT: http://rmt.earth.sinica.edu.tw
ROS: http://ros.earth.sinica.edu.tw
RCS: http://rcs.earth.sinica.edu.tw

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Taiwan Velocity Model

SEM mesh model
- Large scale velocity model (Huang et al., 2014)
- Local structure model
- Surface topography (40m DEM)
- Basin model (Wang, et al., 2004)
- Vs30 (Kuo et al, 2012)

Resolution of the mesh at the surface:

- spectral elements along X = 512
- spectral elements along Y = 512
- GLL points along X = 2049
- GLL points along Y = 2049
- average distance between points along X in m = 287.747711
- average distance between points along Y in m = 321.030127
2019/04/18 M6.1 Hualien earthquake

(a) Comparison between BATS, CWB 24-bit data and island-wide forward synthetic waveforms. The black lines are observations and red lines are synthetics. All the waveforms are in the type of displacement and a bandpass filter with the period between 3 and 20 seconds was applied. The maximum amplitude of the observed data and misfit between observation and synthetic are shown at each station.

(b) Comparison between Palert data and island-wide forward synthetic peak ground acceleration for the frequency below 0.33 Hz. Color circles indicate the Palert observations and color background shows the synthetic. The blue star and open rectangular are the epicenter and the fault plane projected to the surface. Black lines are the active faults in Taiwan reported by the Central Geological Survey.