Weighted RAndom sampling in Seismic Event Detection/Location (WRASED): Applications to Local, Regional and Global Seismic Networks

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April 19, 2017

Center for Energy & Geo Processing

Outline

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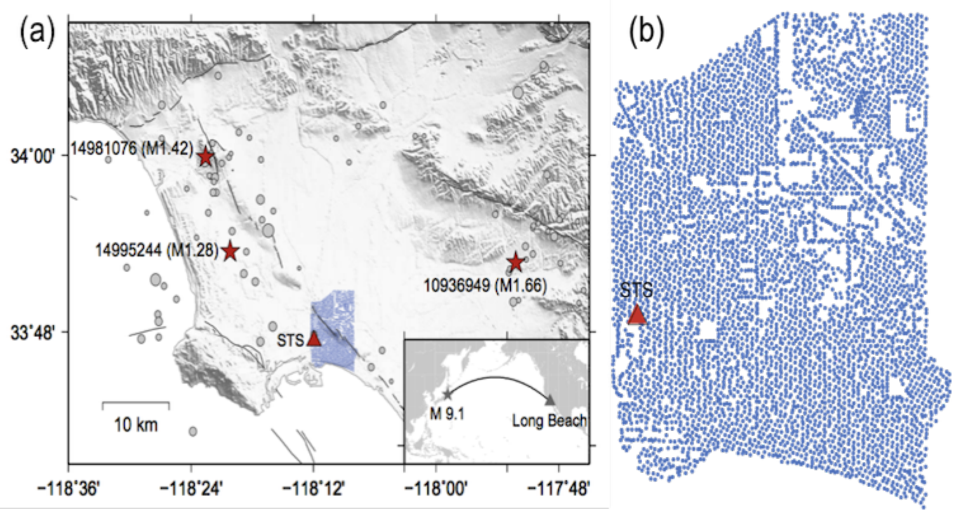
Continuous Seismic Recording on a 5200-element Long Beach Nodal Array [Inbal et al., 2016, Li et al., 2017]



- Stacking of *cross-correlation* between adjacent stations results in local coherence measure [Li et al., 2017]
- Event detection is significantly improved by local coherence
- Rearranging traces according to receiver locations results in *picks* forming a **moveout surface**

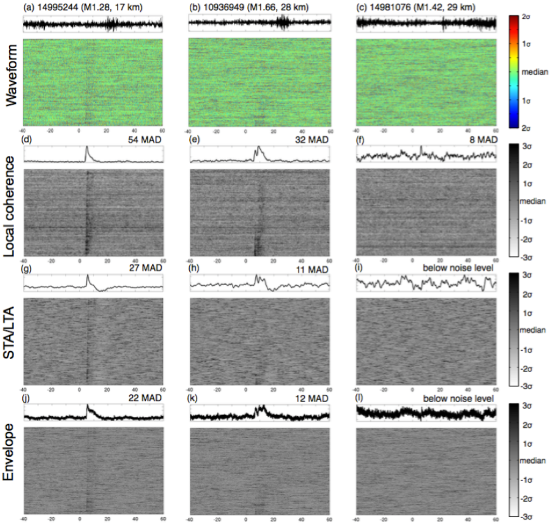


Figure 2: Results from the study in 2016

Challenges for Processing Dense Array Data

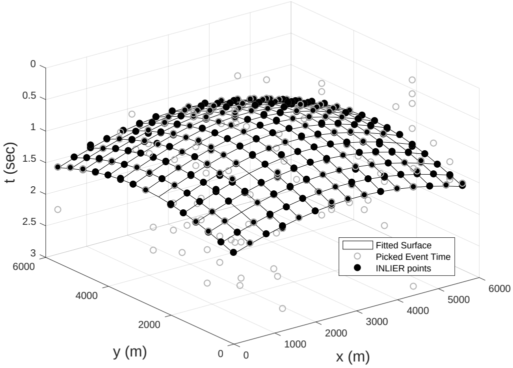
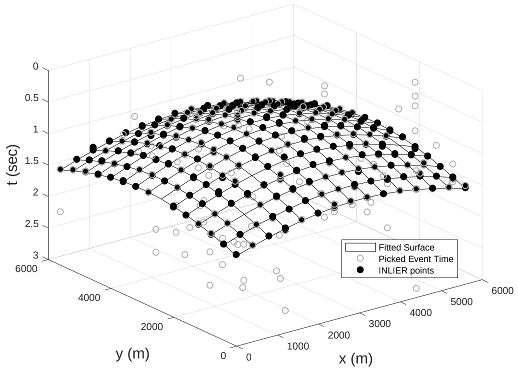


Figure 3: Picks from an event form a hyperbolic surface.

Challenges for Processing Dense Array Data



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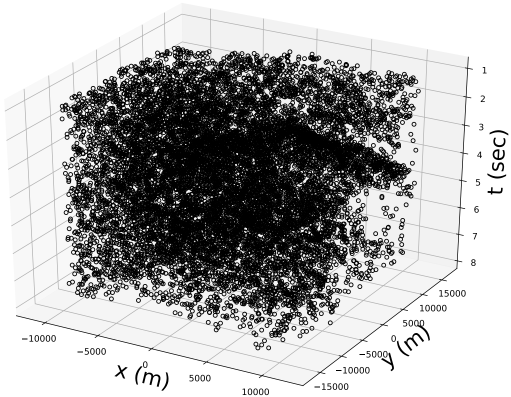


Figure 4: Picks from noisy field data.

Challenges for Processing Dense Array Data

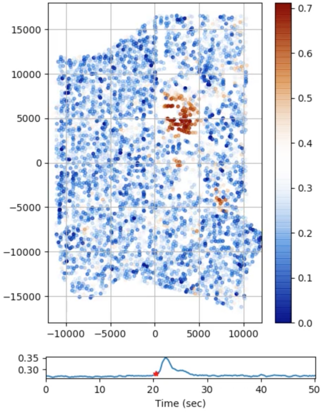
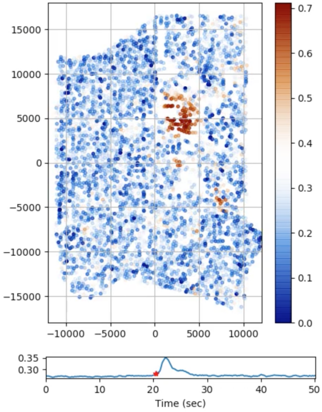


Figure 5: Wave propagation received on surface array.



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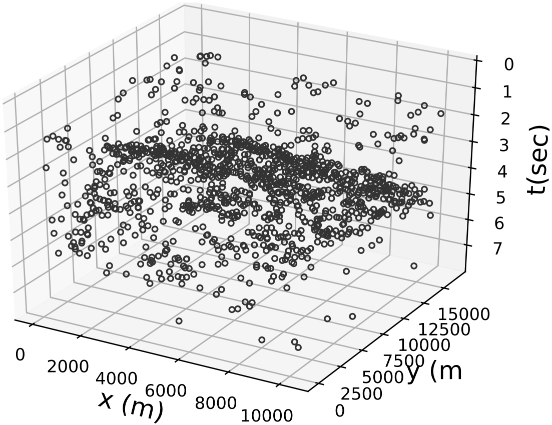


Figure 6: Picked arrival times on northeast quadrant of the surface array.

Two Challenges in Processing Dense Array

1. Associate picks from the same event and eliminate false picks

2. Isolate receivers that are event dominant (Good SNR)

Outline

Eliminate False Picks by RANSAC-based Curve Fitting

- Fit moveout curve to time picks
- **Robust** in the presence of many outliers [Fischler and Bolles, 1981]
- Hypothesize-and-test stretegy [Zhu et al., 2016]
- Computationally efficient
  - two parameters for line
  - five for hyperbola
  - nine for hyperbolic surface

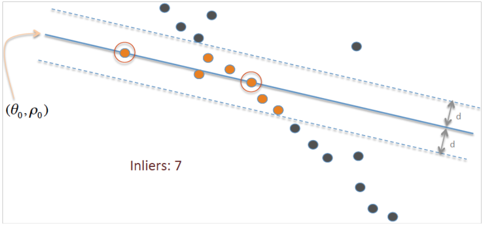


Figure 7: Illustration of RANSAC for line fitting (downloaded from Wikipedia).

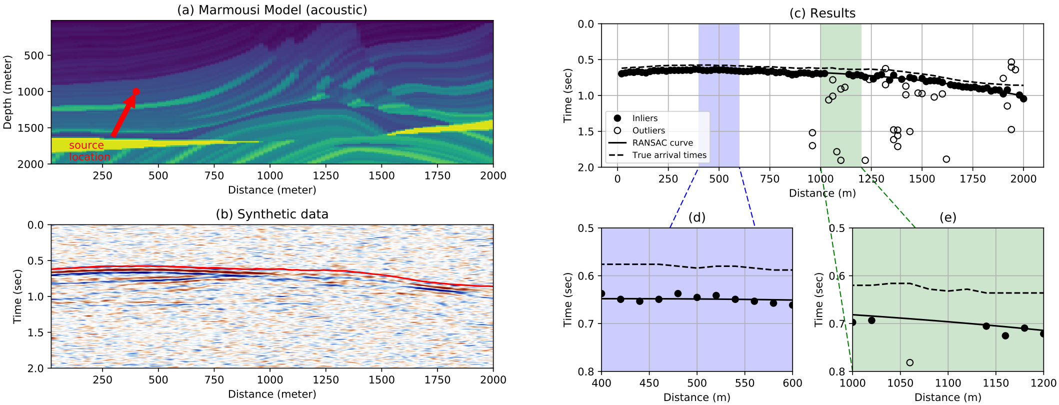


Figure 8: Synthetic example for non-layered medium.

RANSAC Fitting Results on Northeast Quadrant

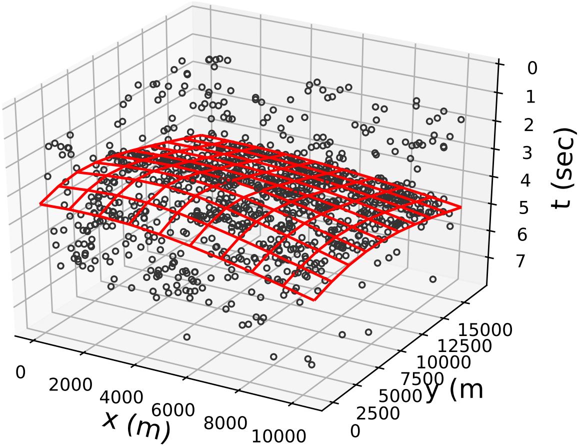


Figure 9: 3-D view of the picks (○) from the 2-D sensor array with fitted hyperboloid surface in red.

Outline

Map-views of Max Value on Traces

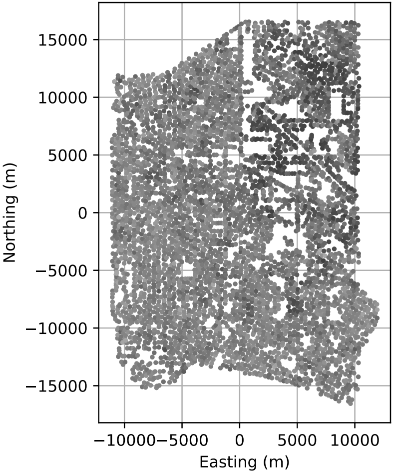
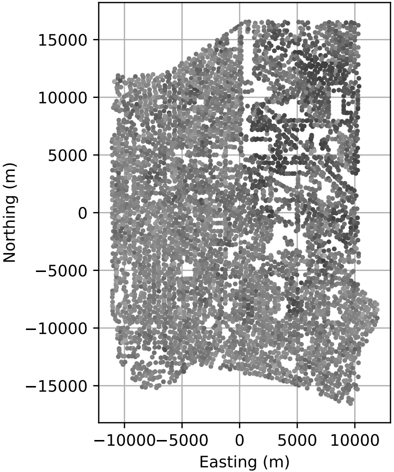


Figure 10: Max coherence value on traces.

Map-views of Max Value on Traces



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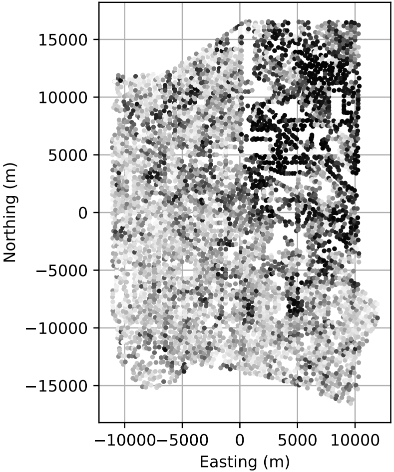

Figure 11: Scaled max coherence value on traces.

Scale Local Coherence as Weighting Function

- Flatten local coherence by histogram equalization
- Soft-thresholding by logistic function

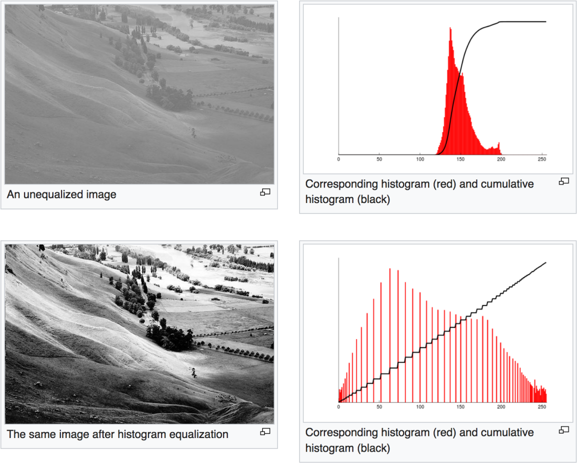

Figure 12: Example demonstrating histogram equalization for a natural image.

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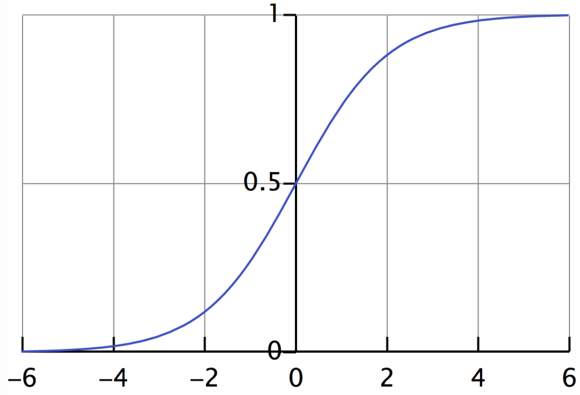

Figure 13: Logistic function centered at zero.

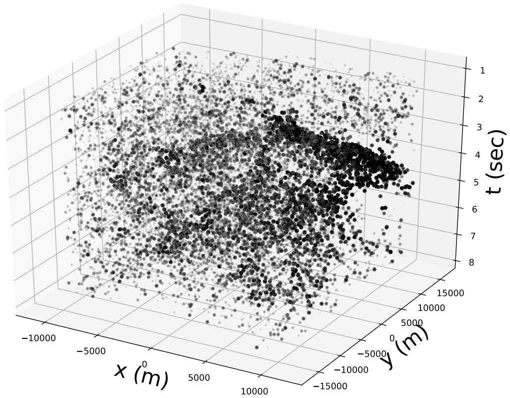

Figure 14: Weighted time picks

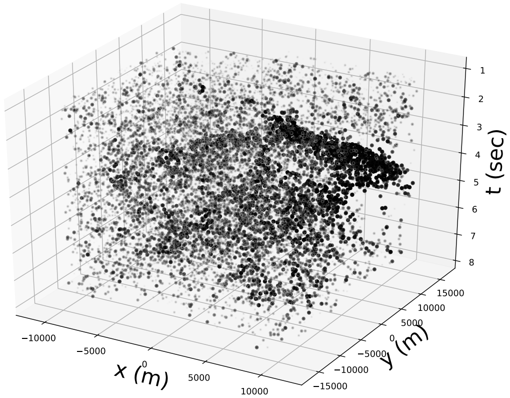

Figure 14: Weighted time picks

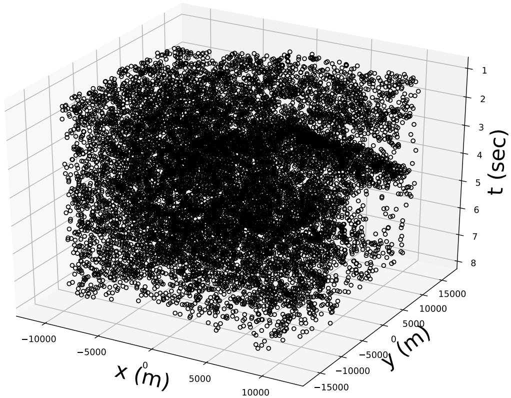

Figure 15: Original time picks

Event Location Results

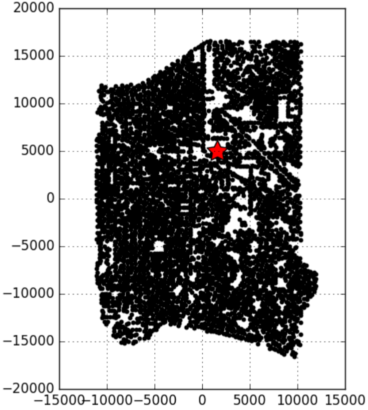

Figure 16: Event location estimated from weighted time picks.

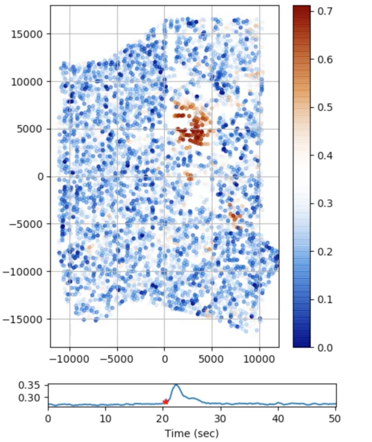

Figure 17: Wave propagation received.

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Future Work

- Fit P- and S-wave travel time difference using parabola to improve event depth estimation
    - Useful strategy for borehole arrays
    - Fewer parameters (three) for faster computation

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  - Useful strategy for borehole arrays
  - Fewer parameters (three) for faster computation

- Extend the current scheme to regional network using the Earth-flattening transformation

References

Fischler, M. A., and R. C. Bolles, 1981, Random sample consensus: a paradigm for model fitting with applications to image analysis and automated cartography: Communications of the ACM, **24**, 381–395.

Inbal, A., J. P. Ampuero, and R. W. Clayton, 2016, Localized seismic deformation in the upper mantle revealed by dense seismic arrays: Science, **354**, 88–92.

Li, Z., Z. Peng, and D. Hollis, 2017, High-resolution seismic event detection using 1ocal coherence for large-n arrays: Scientific Report., in revision.

Zhu, L., E. Liu, and J. H. McClellan, 2016, *in* An Automatic Arrival Time Picking Method Based on RANSAC Curve Fitting: EAGE Annual meeting 2016.