DigitSeis 1.5: Advances in Conversion of Paper Seismograms to Digital Time Series

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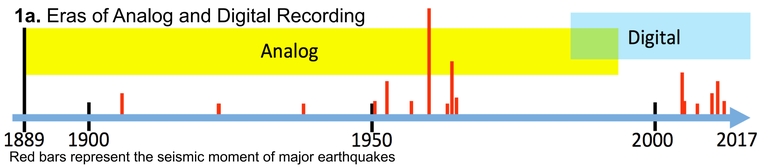
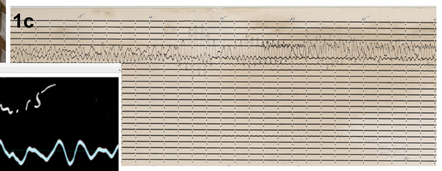
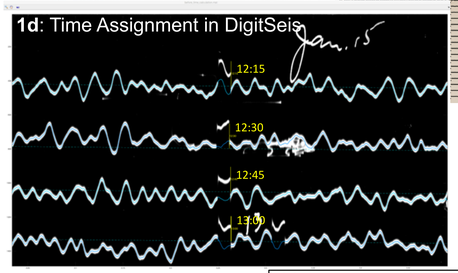
Introduction

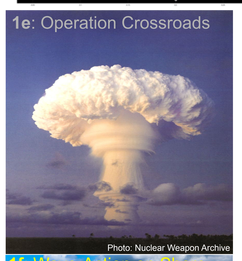


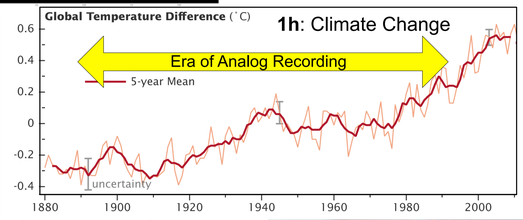
A large amount of seismic data was recorded during the analog era (**1a**) and is still stored around the world in the form of paper records (**1b**,**c**). However as a result of their analog format, these records are often inaccessible to modern analyses. To address this issue, there have been several softwares developed to convert scanned images of paper seismograms into digital traces. DigitSeis[1], a software developed by the Harvard Seismology Group, is one of the most flexible and versatile of these, and one of the few allowing assignment of timing.





Converting scanned images into digital time series via DigitSeis is partially automated but **still requires human inputs** for complications such as crossed traces (**1c**) and assigning reference times (**1d**).



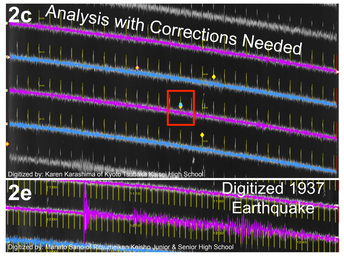


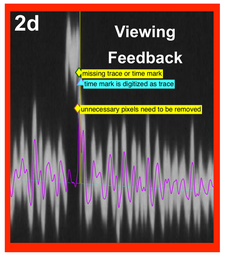
Applications for digitized analog seismograms are widespread and far-reaching. The greatest merit of analog records are the long time span they cover, allowing for quantitative analysis of long time scale or rare phenomenon. Examples of possible analyses include yields and behavior of nuclear tests (**1e**), behavior of past volcanic eruptions (**1i**), storm strength from wave-generated seismic noise (**1f**,**g**), and generally long time-scale problems not typically associated with seismology such as climate change (**1h**).

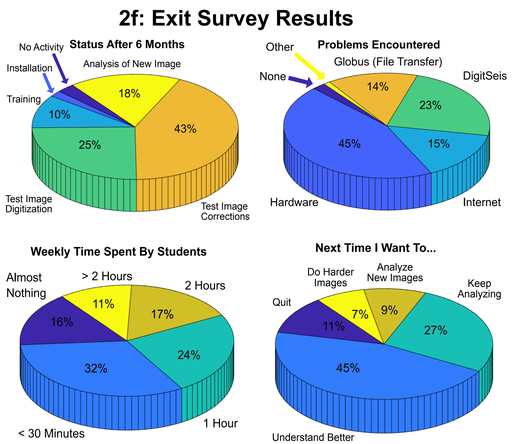
Deployment of 1.4β

Over the past six months, DigitSeis was deployed in Japanese high schools as a research experience where students provided the human oversight needed for digitization. This is the first large deployment of DigitSeis**,** and in total, 142 students from 13 high schools participated in the program as an extracurricular activity (**2a**,**b**). Of the 13 participating schools, 9 are interested in continuing for another year, and there are three schools joining for the 2019-2020 academic year.

Participating schools were given materials about seismology and earthquakes. Special focus was put upon the ways in which the analog seismograms could be used in the future to solve big problems in science (e.g., finding new events, environmental monitoring, etc.). Students were also given and enjoyed multiple opportunities to interact with seismologists in the form of Q & A's, along with in writing and by video call.







Deployment

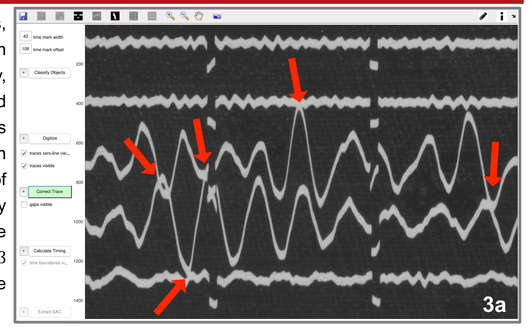
Students were given video-walkthroughs and a previously digitized test analysis to learn to use the DigitSeis software. Feedback was given on this analysis (**2c**,**d**) until it was completed satisfactorily, at which point students were asked to progress to other previously undigitized images (**2e**).

Results

Most students moving beyond the test image provided high-quality time series. The results of an exit survey (**2f**) conducted at the end of March 2019 show an interest in continuing from many students, with a significant fraction wanting to understand where things did not work out ("Understand Better", **2f**).

Advances in 1.5

Over the last two years, improvements have been made for better usability, efficacy, accuracy, and efficiency of the DigitSeis software, culminating in version 1.5 (**3a**). Some of these updates, especially those related to ease of use were rolled out in the 1.4β version used in the Japanese high school deployment.

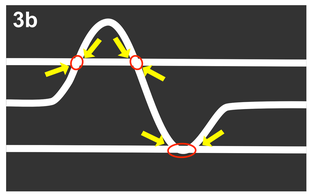


DigitSeis main window with red arrows indicating crossing traces

Changes for 1.5 include:

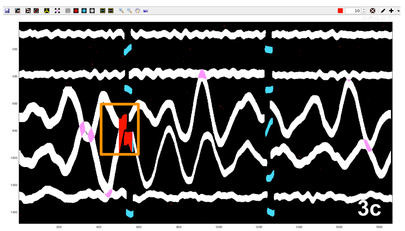
- Cleaner UI - Less complicated menus and main-screen layout (**3a**)
- Feedback and Note Tools - Tags can be added in areas with issues (**2c**,**d**)
- Language Options - Japanese & English (others can be easily added)
- More efficient memory and space usage (32-bit Windows compatible)
- Parallelization - Intense calculations are sped up
- Flexibility - Ability for users to control more options

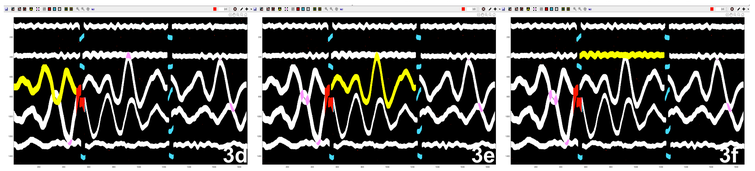
For version 1.5, more focus was given to under-the-hood changes that would improve efficiency and serve as **a step in the direction of automation**. One of the most work-intensive parts of the digitization process is the treatment of crossed traces. In previous releases of DigitSeis, this was a process done in a completely manual sense. **One of the most exciting aspects of 1.5 is the ability to address most crossing-trace scenarios automatically.**



This is achieved by first improving generation of the binary image (where the only two things defined are "background" and "not background"), from which the object classification is computed. With objects defined better, trace crossings (red circles) can be detected as areas in-between points where "background" areas are pinched out by crossings (yellow arrows) (**3b**).

By applying this technique, areas of crossing are detected, and the single region of crossing can be attributed to two separate traces along with their uncrossed portions in the classification step (i.e., overlapping is allowed). This is also done in an automated sense, and is highlighted below overlapping object pixels shown in pink (**3c**), and individual traces including overlapping region shown in yellow (**3d-3f**). Currently, if an overlapping region cannot be automatically separated, it is classified as noise (orange box) (**3c**).





Anticipated Release Date for DigitSeis.v.1.5: Summer 2019

References: 1) Bogiatzis, P., and M. Ishii (2016). DigitSeis: A New Digitization Software for Analog Seismograms. *Seismological Research Letters*, 87(3), 726-736. **Links:** DigitSeis Main Page: http://www.seismology.harvard.edu/research/DigitSeis.html, DigitSeis Citizen Science (English): http://www.seismology.harvard.edu/research/DigitSeisJapan/index_en.html, DigitSeis Citizen Science (Japanese): http://www.seismology.harvard.edu/research/DigitSeisJapan/index.html
Acknowledgements: We thank Moeko Kobayashi of Kyoto University for assistance with translation.