HypoLine

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General Scope

HypoLine is an interactive program for earthquake location at near, local, and regional distances. It is especially suited to process sparse information from 6 traces of a "*Seismic Navigating System*" (**SNS**) made up by 3 vertical geophones in a small aperture, equilateral triangle, and a three-component instrument in the center. **HypoLine** does so by displaying all parameters and location constraints in maps with "*hypolines*", i.e., circles for tS-tP, hyperbola for any P onset pairs (and a half-space layer model), or beams by array steering. The complete suite of displays is constantly updated after any parameter or onset change, thus presenting the location constraints as kind of virtual reality while the user is "walking" through parameter space. Of course, hypolines depend on depth and model, e.g., circles shrink with increasing depth, and hyperbola degrade to complex curves for multi-layer models showing discrete steps from the cross over of refracted waves. In addition to this data-driven mode which proceeds from observation to result, you can place and move solutions anywhere in parameter space, and always get the simulated observations updated.

The concept of **HypoLine** for earthquake location is very different from finding a hypocenter by the well established programs *Hypo71*, *HypoLayer*, and others. These programs are purely data-driven: Once the onsets are given (by other modules), they find the one solution with minimum residual error for this largely overdetermined problem. You don't get an information about the uniqueness of the solution, nor can you modify results except by running the whole loop again. **HypoLine** in its data-driven part will display the manifold of possible choices, with visual access to distinct solutions featuring similar qualities. However, **no** decision is done how to rate the overdetermend problem to find one solution. Instead, you must introduce uniqueness by explicitly selecting a solution in parameter space. Thus you locate an event by placing the **simulation**, usually at the most reasonable site characterized by its accumulation of hypolines which directly corresponds to the best agreement of simulated and picked phases. However, you can always overrule this criterion and rate, e.g., the agreement of simulated phases to the actual seismograms differently, ignore constraining information, or choose more probable solutions according to external knowledge of geology and source processes.

In the same philosophy of data handling, you adjust the magnitude interactively, once you have determined one or more pairs of amplitude/distance information from 3-C stations, and then compare predicted amplitudes to real seismograms. Likewise, you determine the most suited array beam by placing the simulation in the f-k plane once you see the variation of solutions achieved by permutating the maximum of 4 array traces per subnet to four three-station clusters.

HypoLine can switch between different layer models for the velocity profile, and features a halfspace and 1-layer model with full, interactive control of v_p and layer depth. All changes are displayed immediately allowing for optimum tuning of layer parameters to data fit in unknown regimes. Likewise, **HypoLine** can switch between different crustal models for amplitude decay in the magnitude determination with just one key stroke, and it features additional display tools to ease data processing and adjustment of simulations, like sonograms, f-k beam maps, and hypograms, i.e., maps of accumulation or cell hit count by hypolines.

Modes of Operation

Hypoline can process any set of seismograms as network or array traces. In **network** mode, the epicenter is in or close to the station aperture, causing incoherent waveforms of different lengths and amplitudes at any station; thus phases are picked individually. In **array** mode, the epicenter distance is at least 10 times the aperture. Then a plane wave front is propagating over the stations which gives coherent signals with same amplitude. Suited signal processing schemes exploit this feature by beam forming or f-k analysis, resulting in advanced phase picking with associated azimuth and slowness tests.

In **magnitude** mode, the traces of a 3-C station are converted to ground displacement to simulate seismograms from the Wood-Anderson seismograph. Once the maximum half wave (peak-peak) is picked, its related distance/amplitude entry is displayed together with different distance-.magnitude correction curves for Ml.

Future releases will incorporate additional modules for three-component analysis and comparison to results of standard location programs. Also we will extend the simultaneous handling of more stations, based on displays with pixel resolution beyond the current layout maximum of SXGA (1280 * 1024).

User Interface

The work with **HypoLine** basically reduces to three fundamental operations: (I) adjust the view to data and results, (II) set or modify parameters of evaluation, like phases, depth, or layer model, and (III) select and adjust simulation results which make up the final output of event processing. The first task is performed in **overview** windows by adjusting and resizing the subframes of zoom windows. These **zoom** windows are displayed at the bottom for both seismograms and epicenter map. Then tasks two and three are restricted to these zoom windows, the filter bars, the slowness maps, and the layer stack of the results window. For example, to set the epicenter of a simulation appropriately, you must first adjust the zoom map to the approximate area, afterwards you mark the epicenter of simulation by mouse click in the zoom window.

All operations are performed by mouse clicks, arrow keys, and single character input in the respective windows. There is no need for any menu / submenu selection, which makes **HypoLine** an extremely fast interactive program. The same input action causes different results dependent on the actual window of the cursor. All supported input options are listed in the **on-line help** which you evoke by <F1>. Of course, its contents also differs per window.

HypoLine makes equal use of left (LMB) and right (RMB) mouse buttons. The general rule is that **LMB** affects the left corner, P phase, left maximum, lower frequency, or upscale, while **RMB** means right corner, S onset, right maximum, higher frequency, or downscale. Sometimes double clicks are supported too, like for Pg and Lg, or for the lengths of P and S windows in beam forming. Special action is taken for mouse clicks on reserved regions of each window. Above scale bars, it will up/downscale, outside frames or seismograms it will erase, above the layer stack it adjusts depth, and on the frequency axis it will apply the same filter to all traces. Note that 3-C traces will always get common scaling and filter settings.

Once any zoom or parameter is set, it can be adjusted by new mouse clicks, or by incremental shifts via arrow keys. Sometimes <crtl> allows for a second option in shifting parameters or selecting the focus of attention. To explore all options and different meanings per frame, please try <F1> whose output also differs by frame and processing option, e.g., network or array mode.

HypoLine conforms to a simple color code where ever possible. **Blue** stands for P onsets and all parameters and hypolines that depend on this information. **Green** means S, and all its related information like tS-tP circles. **Light red** applies to all, or marks the auxiliary lines that anchor the zoom in its overview windows. **Yellow** is exclusively reserved for simulations, it determines your final selection of hypocenter and magnitude entries to the output files. **Red** marks the **focus of attention**, i.e., the actual phase that is modified by arrow keys and the affected hypolines. You update the focus of attention by any next phase pick via mouse click, shift it from trace to trace by arrow keys, or set it explicitly by clicking the station buttons, which will also take this choice as the new reference phase for any simulation. Finally, **purple** marks adjustment to special cases, like a common scaling factor for all seismograms, or the ground displacement output in magnitude mode.

The most relevant **results** are directly written into the appropriate frames. More extensive information is available by <F2> which is frame-dependent like the on-line hell of <F1>.

HypoLine has so many actions taken by any user input, that accidentally you may alter a phase reading or so, just by clicking its window to get it into foreground of the MS Windows system. Then you can **undo** this last operation by <u>. However, the undo feature is not available for all input actions.

Special Displays

HypoLine features some innovative displays that ease data interpretation by its new concept and inherent capabilities of self-adaptation. **Seismograms** can be largely increased by zoom and gain adjustment but their plotted resolution will never exceed the precision of LSB and time quantization. This will result in step wise seismograms instead of interpolation even when digital filtering wound pretend sub-quantum resolution.

Sonograms are non-linearly scaled and noise muted power spectral density plots of sliding Fourier transforms, as largely discussed for **SonoDet**, the pattern based detector approach of ***SparseNet***. Sonograms in **HypoLine** will overlay the zoom window but correspond in timing to the seismograms still visible in the above overview.

Slowness maps display the results of beam forming over the full range of interesting slowness and azimuths. They can equally well be understood like an f-k analysis within narrow bandpass limits. To gain useful results for the very restricted spatial sampling of 3-4 array stations, **HypoLine** applies a non-linear scaling and muting scheme very similar to the sonogram approach of PSD representation.

Hypograms are just another way to display the location constrains of hypolines. As the number of hyperbola raises with (n-1)! for n stations, they epicenter maps get cluttered for more than, say, 4 stations. Instead of plotting each hypoline, the hypogram sums up the cell hit count of all hypolines to a suitably chosen grid of cells. Then this number is scaled and displayed in color code, like for sonograms. In case of a single, distinct maximum it is marked by red circle.

The **Depth maps** are first of all a simple graphical compilation of the chosen layer model. Once you select a station as focus of attention, the travel path is marked in the epicenter maps, while the layer stack is complemented by displaying the fastest path. This may either be the (multi-layer) **direct path** from source to surface marked by straight line, or any **refracted path** with indication of its turning layer by an "_/" mark. Of course, this information may be different for hypolines and simulation if different source depths are chosen. In future, hypolines will be displayed in the two vertical cuts oriented NS and EW as outlined in the zoomed epicenter map.

Configuration Files, Data Access, and Command Line Options

HypoLine is part of the ***SparseNet*** suite, and it conforms to the same principles of file access as **SonoDet**, especially the definition of several working directories in `snet.ini`, and the concept of a header file in `$WFPATH` for reference to raw data files in different formats. Details can be found in the extensive documentation about **SonoDet**.

HypoLine can not perform without the definition of the configuration file `hypoline.rbs` that contains all information about station coordinates, layer models, and grouping of stations into subnets. This file is expected either in `$KNOWPATH` or in `$WFPATH\knowbase`. HypoLine is restricted in its display mode to show just 6 traces simultaneously. Each set of up to 6 stations is referred to as a **subnet**, and there can only be one 3-C station with all three traces per subnet. You may have different subnets for your network, you may even include the same trace into different subnets. A common example is compiling all z into one subnet, and having each three component station make its own subnet. **HypoLine** will consider phases from all stations in any subnet for the location process, although these phases may actually not be displayed. Switching subnets is done by pushing the appropriate buttons in the station/subnet row just below the menu bar.

The proximity to **SonoDet** is stressed in selecting the length of the overview window by the `*.pre` and `*.sod` choices of **SonoDet** parameter files. However, this setting can be altered by single key stroke for new selections of resampling and sonogram scaling. Together, these two options cover a 1:32 range of sampling, e.g., with 100 Hz data you may choose between 40 sec and 20 min for the overview length.

Command line options are `-i<filename>` for overwriting the standard `snet.ini` file which is expected to reside in the directory of the executable, and `-xga` to force a 1024*768 pixel layout at larger screens. This last option is intended for simultaneous work with other modules as **HypoLine** runs in just a movable portion of MS Windows but compromizes for some display resolution. Other options are `-l<filename>` to change the default protocol file, and `-d<filename>` for another detection list.

Event Selection / Event Update

HypoLine has one way of manual event selection, and four different modes to automatedly adjust to the next event. Manual selection is done by choosing an entry from the header file by **`file->Select from Header File`** which displays all available data segments in a compressed view. This view summarizes for all stations, and appends segments which are separated by minor gaps. For comparison, the original view of all individual header entries is given by the same menu selection in **SonoDet**. Once selected, the adjustment within a segment is done by mouse click in the uppermost time bar.

The four automated modes of event selection are accessed by pushing any of the four head menu buttons `Automove`, `Syncmove`, `Protmove`, or `Bullmove`. With the exception of Syncmove, they all search for the next entry (in time) following the actual position of overview. Automove uses the results of automated processing with first choice of **MatchNet** in $SNETTMP\voting.btc, then **SonoDet** in $SNETTMP\detects.btc. Protmove scans the protocol file $SNETTMP\hypoprot.txt, and Bullmove relates to an externally compiled bulletin of IRIS type formatting in $WFPATH\hypobull.txt. Both latter choices will set **HypoLine** evaluation parameters accordingly, showing either the previously picked phases and/or the hypocenter location by simulation with related theoretical phase onsets. Finally, Syncmove will jump to exactly the same time window that has been found by an interactive run of **MatchNet** or **SonoDet** as another, currently active task of MS Windows.

Once you have selected an event window by any of these means, you may overwrite the current evaluation results by reloading the entries of the protocol or bulletin files via the menu options results->load from protocol or results->load from bulletin.

Output Choices

HypoLine writes an extensive, full text documentation of all evaluation results and adjustment of view parameters in its protocol file. This is either the preset choice $SNETTMP\hypoprot.txt or any selection by the -l<filename> command line option. The action is evoked by results->save to protocol, which will append the actual results to any existent file. Then an abbreviated entry of one line per event containing origin time, hypocenter, and magnitude (all "yellow" information) is appended to $SNETTMP\hypolist.txt too.

Discrimination ratios conforming to the IDC recommendations for regional seismic discrimination are written into $SNETTMP\{hypodscr.txt, hypo68_1.txt, hypo68_2.txt}. The first file features commented documentation of all parameters in up to five frequency bands, while both latter files contain, for the 6-8 Hz passband, columns of plain numbers without any comments, e.g., for further analysis by MATLAB. The determination of half-wave maxima is done automatedly in windows which either center around the manually picked phases (hypo68_1) or windows determined according to IDC rules for theoretical phases (hypo68_2). You perform this option by results-> save discriminants.

Hardcopy outputs the content of the full screen to the printer port. It's a very primitive solution, and to achieve uncluttered print out you must either use an HP DeskJet or LaserJet printer.