JRA4 Task B D3:
Software on array processing and user manual (version 1)

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Summary

This report briefly presents the current state of software package *sesarray* mainly developed during JRA4 Task B project. The list of available modules are given with short comments on their functionalities. Substantial efforts were also made on the diffusion of these tools through web services, international courses and publications. Finally, the contents of the attached CD-ROM is detailled.

1 Introduction

The objective of JRA 4 project is to investigate, develop and document reliable and low cost tools to measure shear wave profiles. The development of these tools partly relies on the results from the SESAME project dedicated to the use of ambient vibrations for site effect assessment (a FP5 project, n° EVG1-CT-2000-00026). *geopsy* project emerged as a side product of SESAME effervescence especially between LGIT and University of Potsdam. The objective of this joint effort has been to centralize in one unique framework all state-of-the-art techniques for processing ambient vibrations and to provide the tools for their necessary integration. Though built around ambient vibrations it was designed to cover most of the non-desctructive methods used in site characherization: for instance, refraction and active surface wave experiments. At the end of SESAME project, *geopsy* was made of several pieces of code not really suitable for a wide distribution and a usage by a large community. Furthermore, retrieving reliable information from complex ambient vibrations is poorly addressed by black-box softwares already available on the market.

With NERIES project, *geopsy* has evolved a lot, including a number of new modules developed with a graphical user interface (horizontal component processing, active surface wave experiments,...) and also accepting real-time feeding with data streams for on site checks. Definitively, we adopted an open source model for the distribution of these codes, which lets all doors open for further developments and improvements. Open source and free accessibility offer a quick diffusion to a wide community world wide which in turn accelerates the debug and stabilization processes (variety of environments and user opinions). In parallel, we developed course materials and provided extended seminars to teach ambient vibration fundamentals and explain how to use *geopsy* in this context. Thanks to NERIES project, *geopsy* project took the chance to evolve from a small software distributed at the research level only to a reference software distributed all around the globe in a wide range of communities. Substantial efforts were made to include more processing techniques and to integrate them in a comprehensive package.

geopsy is both the name of the software project itself and the name of the main application developed in this project. *geopsy* project currently distributes all developed softwares under a package called *sesarray*. It contains several tools dealing with all the aspects of the processing of ambient vibrations for soil characterization. The main applications shipped inside *sesarray* are *geopsy* and *dinver*, for signal processing and inversion, respectively.

2 Software products

This section briefly lists all the components developed and maintained during JRA4 project. We distinguish between general purpose libraries/applications and specialized ones (ambient vibrations and inversion of surface wave properties).

2.1 General purpose

2.1.1 Applications

geopsy: graphical user interface that accepts various input signal formats, visualisation of signals and basic signal processing.

dinver: inversion with Neighbourhood Algorithm modified after Wathelet (2008): surfave wave inversion,...

figue: edition of figures extracted from all other *sesarray* tools. Figures produced by figue are ready for publications (export to ps, pdf, jpeg, png, printer).

2.1.2 Libraries

geopsycore: core routines of geopsy database (no reference to graphical user interface).

geopsygui: graphical components for geopsy and geopsy plug-ins.

scifigs: implementation of 2D plots and related widgets used in all tools, compatible with figue.

Dinver plugins:

dinvercpp: basic skeleton that can serve as a base for the development of new inversion problems

dinverext: for inversion problems where direct computation is performed by an external application.

dinverfor: for inversion problems where direct computation is performed with Fortran.

2.2 Ambient vibration processing

2.2.1 Applications

build_array: design of array geometry and computation of theoretical array responses.

spac2disp: tool for estimating the reliability of experimental auto-correlation curves.

max2curve: tool for estimating the average and the uncertainties of a dispersion curve from FK or HRFK raw results.

gpsignal: compute synthetic signals

gpdc: computation of dispersion curves.

gpell: computation of ellipticity curves.

gpec8: determine site class from Vs profiles (Eurocode 8).

gpgroup2phase: scan possible phase dispersion curves from a group dispersion curve.

gpmodel2param: transform a model file into a parameterized ground structure

gpparam2model: produce model files from parameter sets and a given parameterized ground structure.

gppoisson: simple converter between Poisson's ratio, Vs, and Vp.

gpprofile: extract Poisson's ratio, Vs, or Vp profiles from a model file.

gpsh: computation of sh transfer curves (available but empty).

gpspac: computation of autocorrelation ratio curves.

gpsort: re-arrange curve order in a file (handy for gppac output).

gprefra: computation of hodochrones (available but empty).

gpprofile: output ground profiles from model files.

gpdcreport: analysis of inversion report (from dinver).

gpviewdcreport: plot inversion reports (from dinver).

gpdcmisfit: recompute misfits of models produced by an inversion.

2.2.2 Libraries

qtbwave: computation of dispersion, ellipticity, and auto-correlation curves.

qtbwavegui: graphical objects for qtbwave.

qtbcompatibility: former qtbsurfacewave kept for file format compatibility.

dinverground: library used by dinverdc that manage all ground models made of parameterized profiles.

Geopsy plug-ins:

geopsyarray: array analysis of ambient vibrations (FK, High Resolution FK, MSPAC, FK for linear arrays)

geopsydamping: attenuation in buildings

geopsyhv: computation of H/V spectral ratios

structureratios: computation of spectral ratios for building structures

geopsyptmotion: particle motion

geopsynr: adjust time shifts and stack records of active source experiments (surface wave and refraction)

geopsytfa: time-frequency analysis using a Wavelet tranform.

geopsyrefra: computation of travel-time-distance curves for phase picking (to be modified for a better integration with dinver)

Dinver plug-ins:

dinverdc: surface wave inversion (including first P/S wave arrivals)

geopsy softwares are all built upon the following standard libraries: Qt 4, fftw3, LAPACK 3, libslink and libmseed. They are available for all platforms supported by Qt 4 (Linux, Mac OS X and Windows for the most used).

3 Software dissemination

3.1 Online services

geopsy is available at www.geopsy.org, a web site active from February, 2005. It offers various services:

software download: *sesarray* package is available for free in various formats. A complete source tree is distributed mainly for all Linux platforms where the distribution of binary archives is generally not possible. Binary packages are regularly prepared for Windows XP, Windows Vista and Mac OS X (version 10.5 only, Intel and PPC architectures). Every month or more often if needed a new release is issued with bug fixes and new improvements. We provide a patch generator to smoothly upgrade from previous releases to the current one.

Versioning: a cvs repository is running from the beginning of *geopsy* project (around 2004). Every single changes brought to the code are carefully commented.

Online documentation: documentation of geopsy application started at the same time as NERIES project (June 2006). However, due to the number of continuous changes brought to the code during these two years (new tools and bug fixes), it has not been possible to achieve a complete manual. At present, the softwares reached a mature stage. No major modification is planned before providing a complete documentation for geopsy and dinver applications.

Online API: (Application Programmer Interface) this is the description of all internal functions. It is particularly useful for libraries that can be re-used by third parties. This task has been initiated. Not all the code is currently covered. This is a mandatory step to encourage other developers to participate to this project.

Bug report: since May 2008, an automatic quality control and debug facility is available within all *geopsy* softwares. In case of crash or unexpected warning, the user is kindly invited to send us a report (essentially made of a backtrace), in the simplest way: add his/her email, optionnally a few comments and a click to send it. On the server side, the bug reports are automatically dissected before manual inspection and sorting. In less than a month, we collected around 50 reports and we were able to fix 80% of them directly, without complementary information.

Forum: since August 2007, a forum has been run to provide free support between users and to reduce the number of requests we originaly received by email.

3.2 Sesarray courses

At the end of SESAME project, it was decided to provide at least once a course (about one week duration) about ambient vibrations and related softwares oriented towards site characterization. A first edition of this course took place in Grenoble, November 2005. Only one third of the total number of candidatures we received could be satisfied by this first edition (15 participants). Another course was directly planned to April 2006 in Berlin. During these past two years, we provided four other editions of this course with the help of local institutes which indeed asked us for sucha course (Caracas, October 2006; Algiers, July 2007; Bangalore, November 2007; Istanbul, May 2008). Little by little, we constitued a database for course materials enriched by NERIES experience and user requests. This is currently the main source of documentation for

the code. It contains both for fundamental concepts and application examples on how to use the software.

In the future, we would like to develop an e-learning framework to reach a larger audience and in a slightly more efficient way. All the information given to participants during only one week is difficult to digest for most of them, especially if they are not familiar with ambient vibrations. Additionaly, the content of these courses can be of interest for private operators but booking their employees for a full week is usually difficult. E-learning might be a good opportunity to provide these courses "a la carte" and over longer period of time to let participant digest the information received.

3.3 Publications

Referencing these softwares is not an obligation, however, we appreciate that users properly reference this work, released for free, in all publications or reports achieved with these softwares. Here is a classified list of the papers published in the litterature closely linked to these softwares.

Frequency-wavenumber, high resolution, spatial autocorrelation techniques, wavenumber limits linked to array geometries

Wathelet, M., D. Jongmans, M. Ohrnberger, and S. Bonnefoy-Claudet (2008). Array performances for ambient vibrations on a shallow structure and consequences over Vs inversion. Journal of Seismology, 12, 1-19.

G. Di Giulio, C. Cornou, M. Ohrnberger, M. Wathelet, and A. Rovellii (2006). Deriving Wavefield Characteristics and Shear-Velocity Profiles from Two-Dimensional Small-Aperture Arrays Analysis of Ambient Vibrations in a Small-Size Alluvial Basin, Colfiorito, Italy. Bulletin of the Seismological Society of America, 96, 1915–1933.

Specific to spatial autocorrelation technique

A. Köhler, M. Ohrnberger, F. Scherbaum, M. Wathelet and C. Cornou (2007). Assessing the reliability of the modified three-component spatial autocorrelation technique. Geophysical Journal International, 168 (2), 779-796.

Wathelet, M. , D. Jongmans, and M. Ohrnberger (2005). Direct Inversion of Spatial Autocorrelation Curves with the Neighborhood Algorithm. Bulletin of the Seismological Society of America, 95, 1787–1800.

Neighbourhood algorithm implemented in Dinver, dispersion curve inversion

Wathelet, M. (2008). An improved neighborhood algorithm: parameter conditions and dynamic scaling. Geophysical Research Letters, 35, L09301, doi:10.1029/2008GL033256.

Wathelet, M., D. Jongmans, and M. Ohrnberger (2004). Surface wave inversion using a direct search algorithm and its application to ambient vibration measurements, Near Surface Geophysics 2, 211–221.

H/V techniques

Bard P. Y. (2008) The H/V technique: capabilities and limitations based on the results of the SESAME project - Foreword. Bulletin of Earthquake Engineering 6(1), 1-2.

Bonnefoy Claudet S., Kohler A., Cornou C., Wathelet M., and Bard P. Y. (2008) Effects of Love waves on microtremor H/V ratio. Bulletin of the Seismological Society of America 98(1), 288-300.

Chatelain J. L., Guillier B., Cara F., Duval A. M., Atakan K., and Bard P. Y. (2008) Evaluation of the influence of experimental conditions on H/V results from ambient noise recordings. Bulletin of Earthquake Engineering 6(1), 33-74.

Guillier B., Atakan K., Chatelain J. L., Havskov J., Ohrnberger M., Cara F., Duval A. M., Zacharopoulos S., and Teves Costa P. (2008) Influence of instruments on the H/V spectral ratios of ambient vibrations. Bulletin of Earthquake Engineering 6(1), 3-31.

4 File tree description

A CD-ROM attached to this report contains the following information:

Softwares: latest release for all platform at the date of this report. Refer to documentation for installation or to www.geopsy.org. In any case, always check on www.geopsy.org for the latest release.

```
sesarray-src-2.0.0.tar.gz       11M
sesarray-mac-2.0.0.dmg          17M
sesarray-win-2.0.0.exe          7.8M
```

Documentation/User: user manual for geopsy and dinver (not complete)

```
geopsy:
basic-agc.html                  1.9K
basic-dc.html                   2.4K
basic-fftw.html                 3.1K
basic-filter.html               4.0K
basic.html                      5.4K
database-create.html            6.3K
database-groups.html            7.7K
database-headers.html           14K
database-importsignals.html     18K
database-prefs.html             17K
database-structure.html         6.9K
database.html                   17K
fk-loadfiles.html               3.3K
fk-processing.html              14K
fk.html                         2.0K
frame                           1.3K
hv-loadfiles.html               3.1K
hv-processing.html              6.6K
hv-run.html                     9.5K
hv-windowing.html               12K
hv.html                         34K
images                          4.0K
index.html                      4.7K
installation.html               14K
```

```
introduction.html               7.8K
license-fdl.html                24K
license-gpl.html                21K
references.html                 2.5K
signature                       968
tools.html                      1.7K
tutorials                       4.0K
tutorials-array.html            1.7K
tutorials-db.html               18K
tutorials-hv.html               1.8K
tutorials-refra.html            1.9K
tutorials.html                  2.3K
unlinked.html                   1.5K
viewers-graphic.html            15K
viewers-map.html                5.1K
viewers-table.html              7.5K
viewers.html                    4.7K
dinver:
index.html                      3.5K
installation.html               14K
introduction.html               2.9K
license-fdl.html                24K
license-gpl.html                21K
newplugins.html                 3.7K
newplugins_c.html               1.8K
newplugins_cpp.html             12K
newplugins_ext.html             3.6K
newplugins_for.html             4.5K
newplugins_matlab.html          3.4K
references.html                 2.0K
unlinked.html                   1.5K
```

Documentation/API: function description for all libraries (not complete)

```
build_array.pdf         112K      12 pages
dinver.pdf              109K      11 pages
dinvercore.pdf          227K      39 pages
dinvercpp.pdf           104K      10 pages
dinverdc.pdf            96K       8 pages
dinverdccore.pdf        114K      11 pages
dinverext.pdf           118K      12 pages
dinverfor.pdf           99K       9 pages
dinverground.pdf        132K      13 pages
dinvergui.pdf           92K       8 pages
geopsy.pdf              133K      16 pages
geopsyarray.pdf         146K      22 pages
geopsycore.pdf          302K      71 pages
geopsygui.pdf           171K      27 pages
geopsyhv.pdf            141K      19 pages
geopsynr.pdf            130K      15 pages
geopsytfa.pdf           102K      10 pages
```

```
max2curve.pdf           136K      16 pages
monostation.pdf         136K      17 pages
multistation.pdf        177K      32 pages
qtbguitools.pdf         237K      49 pages
qtbtools.pdf            425K      114 pages
qtbwave.pdf             247K      45 pages
qtbwavegui.pdf          154K      24 pages
scifigs.pdf             605K      158 pages
spac2disp.pdf           88K       8 pages
structureratios.pdf     116K      12 pages
```

Documentation/Help: command line information (general description, detail of all options) the user can get from all applications.

```
build_array.pdf         38K   2 pages
dinver.pdf              41K   3 pages
figue.pdf               44K   3 pages
geopsy.pdf              46K   5 pages
gpdc.pdf                40K   2 pages
gpdcreport.pdf          37K   2 pages
gpec8.pdf               32K   1 pages
gpell.pdf               37K   2 pages
gpgroup2phase.pdf       33K   1 pages
gpmodel2param.pdf       34K   1 pages
gpparam2model.pdf       31K   1 pages
gppoisson.pdf           33K   1 pages
gpprofile.pdf           35K   2 pages
gprefra.pdf             28K   1 pages
gpsh.pdf                36K   2 pages
gpsignal.pdf            35K   1 pages
gpsort.pdf              34K   1 pages
gpspac.pdf              39K   2 pages
gpviewdcreport.pdf      39K   2 pages
max2curve.pdf           46K   3 pages
spac2disp.pdf           41K   2 pages
```

Course/Lectures: slides presented during lectures of *sesarray courses*

```
ISTANBUL2008_CAPON_LECTURE.pdf                466K   24 slides
ISTANBUL2008_ESG_BLINDTEST.pdf                452K   21 slides
ISTANBUL2008_FK_LECTURE.pdf                   9.2M   93 slides
ISTANBUL2008_HV_LECTURE.pdf                   45M    44 slides
ISTANBUL2008_INVERSION_LECTURE.pdf            2.0M   58 slides
ISTANBUL2008_MASW.pdf                         1.3M   11 slides
ISTANBUL2008_NOISE_GENERAL_LECTURE.pdf        2.7M   29 slides
ISTANBUL2008_SPAC_LECTURE.pdf                 1.4M   27 slides
```

Course/Tutorials: slides presented during exercices of *sesarray courses*

```
ISTANBUL2008_TUTORIAL_FIGUE.pdf               1.7M   18 slides
```

```
ISTANBUL2008_TUTORIAL_FK_ARRAY_RESPONSE.pdf   4.3M   56 slides
ISTANBUL2008_TUTORIAL_HV-1.pdf                9.1M   38 slides
ISTANBUL2008_TUTORIAL_HV-2.pdf                2.7M   15 slides
ISTANBUL2008_TUTORIAL_INVERSION.pdf           1.7M   38 slides
ISTANBUL2008_TUTORIAL_MASW.pdf                2.6M   23 slides
ISTANBUL2008_TUTORIAL_SPAC.pdf                814K   14 slides
```

History: for each library or application, this is the log of all modifications with developer comments. This is not always good English. For people deeply involved in the project it helps to trace the date of major evolutions of the code.

```
build_array.log          36K
dinver.log               49K
dinvercore.log           38K
dinvercpp.log            6.9K
dinverdc.log             43K
dinverdccore.log         13K
dinverext.log            6.3K
dinverfor.log            973
dinverground.log         26K
dinvergui.log            761
figue.log                28K
geopsy.log               101K
geopsyarray.log          58K
geopsycore.log           96K
geopsydamping.log        21K
geopsyfigs.log           4.8K
geopsygui.log            53K
geopsyhv.log             57K
geopsynr.log             3.5K
geopsyptmotion.log       20K
geopsyrefra.log          18K
geopsytfa.log            5.1K
gpdc.log                 7.2K
gpdcreport.log           8.2K
gpec8.log                610
gpell.log                7.1K
gpgroup2phase.log        4.8K
gpmodel2param.log        2.8K
gpparam2model.log        2.9K
gppoisson.log            5.6K
gpprofile.log            7.1K
gprefra.log              5.5K
gpsh.log                 5.7K
gpsignal.log             3.6K
gpsort.log               3.0K
gpspac.log               6.8K
gpviewdcreport.log       575
max2curve.log            24K
monostation.log          7.7K
multistation.log         4.1K
```

```
qtbcompatibility.log     15K
qtbfortran.log           14K
qtbguitools.log          80K
qtbtools.log             104K
qtbwave.log              22K
qtbwavegui.log           17K
scifigs.log              201K
sesarray.log             9.8K
spac2disp.log            19K
structureratios.log      4.5K
```