UDQ User's Manual

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1 Introduction

UDQ[1] is a package (program and data files) to make it possible to view seismicity in three dimensions, using Google Earth or another "Earth browser." This is done by converting seismicity data into files in KML[2] with earthquake depth replaced by elevation, since current browsers do not allow subterranean viewing. The UDQ program reads in a set of commands, which may be typed in directly, or (more repeatably) piped from a file; these commands cause the program to read seismicity data from an input file, and write the information to an output file in KML format.

This output file is then packaged with a set of icons (also part of the distribution) using the `zip` utility to make a KMZ[3] file, which can be imported into Google Earth.

UDQ includes the ability to:

1. Limit what is shown by geographic, temporal, or magnitude boundaries.

2. Split data into different time segments to reduce the load in displaying all the events.

3. Split data into different time segments, with large earthquakes showing up in later segments as semi-transparent icons. This is useful in examining aftershock clusters, where the mainshock can be kept visible for reference.

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[1] Upside-Down Quakes

[2] The Keyhole Markup Language used to define datasets for viewing; Wernecke (2009) provides a useful introduction.

[3] This is a compressed version of the KML file, which may (optionally) contain material referred to in it in separate directories.

2   Installation

The package is distributed as a gzipped tarfile called `udq-1.3-tar.gz`. Uncompressing and untarring this (which may be done by running the command `tar xvzf udq-1.3-tar.gz`) will create a directory `udq-1.3` containing the UDQ source and five subdirectories: `doc,` containing the program manual and an explanatory paper; `images,` containing files of different icons; `examples,` containing files to create some example files; `kml`, containing the KML files that should be produced by these examples; and `bin,` where the executable will be put.

The program itself is written in Fortran-77[4] and can be compiled by running `make udq`. Options for the Fortran compiler are set in the associated `makefile`. The executable will be placed in the local subdirectory `bin`.

3   Operation

There are two steps to creating a KMZ file. The first is running `udq` to produce the KML file, usually named `doc.kml`. The second is using `zip` to combine this with the `images` directory to produce the final KMZ file.

The program can be invoked either by typing

`udq`

which will allow you to enter commands from the keyboard, or by typing

`cat commandfile | udq`

which will cause the program to read the commands contained in file `commandfile`. The second course is preferable if you plan to do anything more than once. Note that `udq` includes commands that name input and output files; these are not given on the command line, but in the file of commands.

To create a KMZ file, suppose that you have used `udq` to produce a KML file named `doc.kml` in the main directory of `udq-1.3`, which contains the `images` subdirectory. Then running the command

`zip -r myfile.kmz doc.kml images/`

will create the KMZ file `myfile.kmz`, containing both the KML and the image icons that it needs.

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[4]The language I know best, though no doubt not the optimal one for this purpose.

3.1 Basic Commands

The program reads seismicity information from an *input file*, whose name is given by the `input` command. This file must contain the following earthquake information:

1. Earthquake time, given as year, month, day, hour, minute, and seconds. These values should be separated by blanks.

2. Earthquake location, given as latitude (positive for North) and longitude (positive for East), in decimal degrees; again, these should be separated by blanks from each other and the surrounding information.

3. Earthquake depth, in kilometers, positive down. This will be converted into elevation above the Earth's surface so that all events will be visible.

4. Earthquake magnitude

A sample seismicity file[5] might look like:

```
1906 04 18 13 12 26 37.77 -122.55 10 7.9
1922 01 31 13 17 28 40.700 -125.553 15 7.2
1952 07 21 11 52 16 34.927 -119.060 15 7.3
1980 11 08 10 27 35 41.110 -124.300 17 7.3
1992 04 25 18 06 06 40.350 -124.068 18 7.2
1992 06 28 11 57 38 34.184 -116.532 11 7.3
1999 10 16 09 46 46 34.515 -116.435 5 7.2
2005/06/15 02:50:54.19 41.2920 -125.9530 16.00 7.20
```

The last line illustrates that slashes and colons may be used to separate the fields; in fact, this line is in the default ("readable") format output by the ANSS Catalog Search,[6] which means that catalogs from this source can be used directly.

Commands are available for writing out only part of a catalog to the output KML file: see `area start finish`, and `magnitude` in the command reference.

The `input` command is the only one required, though it is usual for a file to contain the `execute` command, which causes the program to cease reading commands and actually read and write the files. The simplest set of commands would thus be

```
input catalog.txt
execute
```

which would write the entire catalog to a KML file with the default name `doc.kml`. If the `execute` command is omitted, the end-of-file will trigger the execution, so even this command could be omitted.

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[5]In this case, all California earthquakes of magnitude 7.2 and above since 1900.
[6]`http://www.ncedc.org/anss/catalog-search.html`

The default is to create a file that will display all the earthquakes in the catalog. But if more than a few thousand events are visible at once, updating the display when when the user moves through it will be much slower. It is thus useful to be able to limit the number of events shown. In UDQ this is done using the `<Folder>` element in KML, which allows the viewer to display only a subset of the data.[7] The number of folders is set by the command

```
nsplit n
```

where `n` is the number of folders to be created. There are obviously many ways in which the earthquakes could be placed into different folders; in this version the only option is grouping by time, with equal numbers of events in each folder. For example, if the catalog contained 10,000 earthquakes, setting `nsplit 10` would create 10 folders, the first one containing the first thousand shocks, the next the second thousand, and so on. The time intervals covered will not necessarily be equal; for a catalog of an aftershock sequence, in which the rate of seismicity decreases with time, each folder will cover a longer interval than the previous one.

This behavior may be partially overridden using the command `split time`, which forces a folder boundary at the time given; this time may be expressed either as `year month day hr min sec` or `year day-of-year hr min sec`. This feature is useful for looking at an aftershock sequence, when the time can be set to just before the mainshock to force any prior events into a separate folder.

How earthquakes are actually represented on the screen is controlled by two additional commands.

The command

```
size big small magtop magbot
```

sets the scaling factors for the icons, such that earthquakes of magnitude `magtop` have icons scaled by `big`, and those of magnitude `magbot` have icons scaled by `small`. Intermediate magnitudes are scaled linearly between these values, after rounding to the nearest 0.5 magnitude unit. The defaults are scalings from 0.05 to 1.5, applied to magnitudes 0.5 and 9.5 respectively.

The command

```
fadeout mag time
```

arranges that an earthquake of magnitude `mag` will persist until `time` days after it occurs, fading out gradually during this interval. The time over which an earthquake appears scales exponentially with magnitude. If this command is not issued, the time assigned to an earthquake icon is simply the instant of its occurrence, rather than an interval. It is important to realize that the fading-out is done by creating a series of increasingly-translucent icons that cover different time intervals. Only those that fall inside a particular time interval on the display (as set in Google Earth by the time slider bar) will appear: but this does mean that if that bar is set to the full time interval, all the icons will appear overlaid on each other.

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[7]The `<region>` element is another method of doing this, and methods for applying this in UDQ are under development.

Finally, the command

```
name string
```

will put the character string `string` into the `<name>` element in the KML document; this will thus become the name assigned to these data by the viewer. The individual folders will also be named, but these names are automatically set to show the times they cover.

3.2 Examples

The `Examples` directory includes two catalogs, and two command files. Running UDQ with these command files will produce two KML files that can be compared with the KML files in the `kml` directory.

The first example is the command file `northisl`, which causes UDQ to read from the catalog file `nzcat` and creates the file `nzdoc.kml`. The catalog file was created from the New Zealand National Seismic Catalog[8] and contains earthquakes of magnitude 3.5 and above within a region below New Zealand, from 1999 through 2008 The command file is

```
name GeoNet Catalog
input tmp
output nzdoc.kml
area -42 -37 170 177
magnitude 4.0
start 2001 1 0 0 0
finish 2008 9 1 0 0 0
fadeout .05 7
nsplit 10
execute
```

Here the `fadeout` command is set so that even a large earthquake would "disappear" after 0.05 days: that is to say, almost immediately. The earthquakes that are visible will thus be only those that occur in the time interval set by the browser time bar. The `area`, `start`, `finish`, and `magnitude` commands are set so that the final file contains only magnitude 4 and larger events beneath the North Island in the 21st century.

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[8]Available online at http://magma.geonet.org.nz/resources/quakesearch/

```
name Northridge Earthquake Sequence from LSH
inpu test.nort
outp nortdoc.kml
area 34.0 34.5 -118.8 -118.2
magn 1.7
star 1993 7 1 0 0 0
fini 1995 1 1 0 0 0
fade 1200 6.7
nspl 10
spli 1994 1 17 12 30 00
exec
```

The second example (above) is the command file **northridge**, which reads from the catalog file **northrid** and creates the file **nriddoc.kml**. The catalog file was created from the relocation of Southern California earthquakes by Lin *et al.* (2007)[9] and contains earthquakes of magnitude 1.5 and above between 1990 and 1999, within a box bounded by 34°N and 34.5°N, and 118.75°W and 118.25°W. This example shows, first of all, that only the first four characters of a command are needed. In this case the **fadeout** command is set so that the mainshock will be visible for 1200 days. The **nsplit** command splits the data into 10 groups, each with the same number of symbols: the groups for the initial part of the aftershock sequence thus cover a shorter time that those for later parts. The **split** command then introduces a split just before the mainshock, so that the KML file contains 11 folders, with the first ending just before the mainshock and the second starting at the same time, so that any foreshocks can be separated out.

3.3 Command Reference

This section describes the available commands, in alphabetical order. The command names are <u>underlined</u>.

<u>altscale</u> **a b** can be used to scale depth to altitude in an arbitrary fashion. If the depth is d (reckoned negative down) and the altitude is h (reckoned positive up, above the terrain) the scaling is $h = ad + b$; a is dimensionless, b is in kilometers. Earthquakes that would remain below the surface are not plotted. The default "upside down" scaling corresponds to $a = -1$ and $b = 0$. See **flatten** and **float** for two options that cover the most common cases.

<u>area</u> **south north west east** sets the geographic limits within which earthquakes in the catalog will be put into the KML file. The limiting latitudes are **south** and **north**, and the limiting latitudes are **west** and **east**, which east longitudes reckoned positive, and all coordinates in decimal degrees.

<u>clear</u> **cmdname** will delete the most recent occurrence of the command **cmdname**; for example **clear area** would delete the most recent occurrence of the **area** command.

<u>color</u> **cname** sets the icon color. There are four possibilities for **cname**: **white**, which is the default;

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[9]Available online at http://www.data.scec.org/research/socal_LSH.html

`black`; `red`; and `magenta`. These have been chosen to be colors not otherwise usually present in a Google Earth image (except for black, if atmospheric perspective is turned off); magenta is included because (like black) it is one of the base colors for CYMK printing, and thus good for use in material that is to be printed.

<u>`execute`</u> should be the last command, since it tells the program to stop reading commands and begin operations, reading from the catalog and writing out the KML.

<u>`fadeout`</u> `time magnitude` sets the timescale over which earthquakes will fade with time, by setting the time to invisibility to `time` (in days) for a magnitude `mag`. The actual algorithm for fading assigns times $t_s(\alpha)$ and $t_e(\alpha)$ to the start and end times for an icon of transparency α. Only a limited number of icons are used (see Section 4), so internally α is represented by an integer running from 0 (no icon) to 10 (fully opaque). Then $r_s = 0.1\alpha + 0.05$ and $r_e = 0.1\alpha - 0.05$, making the times $t_s = t_0 + \tau(1 - r_s)/r_s$ and $t_e = t_0 + \tau(1 - r_e)/r_e$, where t_0 is the origin time of the earthquake. With this functional form, an earthquake will "vanish" after an interval of 19τ; this result, and a dependence of τ on magnitude of $\tau = \tau_0 10^M$, is what is used by the `fadeout` command to set τ_0.

<u>`finish`</u> `yr mo day hr min sec` sets the end time; earthquakes after this time will not be put into the KML file. The time can also be given as `finish yr doy hr min sec`; that is, the commands `start 2009 2 16 20 33 05` and `start 2009 47 20 33 05` are equivalent.

<u>`flatten`</u> sets all the altitudes to zero, irrespective of the depth of the event, to provide a two-dimensional map of the seismicity. This can be convenient if you want to compare with ground features more accurately, since it avoids parallax.

<u>`float`</u> h_0 plots the earthquakes "right-side-up", but with h_0 km added to their depths to bring them above the surface. Earthquakes that would remain below the surface are not plotted.

<u>`input`</u> `filename` sets the name of the file containing the seismicity data (the catalog); see Section 3.1 for the format needed for a catalog. This command is required.

<u>`magnitude`</u> `minmag` sets the smallest magnitude earthquake to include in the KML file; for example, `magnitude 2.99` means that earthquakes of magnitude 3 and above would be included.

<u>`name`</u> `namestring` sets the `<name>` element for the entire file to the character string `namestring`; this string will be shown by Google Earth as the name of the file.

<u>`nsplit`</u> `n` splits the data into `n` folders, which together cover the entire time interval shown, and individually cover non-overlapping time spans, chosen to contain the same number of earthquakes.

<u>`output`</u> `filename` sets the name for the KML file; the default is `doc.kml`.

<u>`review`</u> will display the commands that are currently entered, and that will be used when the `execute` command is run.

<u>`shape`</u> `sname` sets the icon shape. There are three possibilities for `sname`: `dot` (or `circle`), which is the default; `square`; and `triangle`.

size big small magtop magbot This sets the scaling factors for the icons. Earthquakes of magnitude magtop have icons scaled by big, and those of magnitude magbot have icons scaled by small. Intermediate magnitudes are scaled linearly between these values, after rounding to the nearest 0.5 magnitude unit. The defaults are scalings from 0.05 to 1.5, applied to magnitudes 0.5 and 9.5 respectively.

split yr mo day hr min sec introduces a time that will force a boundary between folders, splitting one folder into two; only one such "forced split" may be introduced using this command. It will be applied after the process introduced by nsplit, which splits the data into folders containing equal numbers of events. If nsplit is not set, split would set one boundary that would create two folders. The time may be given either as yr mo day hr min sec or as yr doy hr min sec; see start or finish.

start yr mo day hr min sec The start command sets the start time; earthquakes before this time will not be put into the KML file. The time can also be given as start yr doy hr min sec; that is, the commands start 2009 2 16 16 59 31 and start 2009 47 16 59 31 are equivalent.

4   Icons and Icon Names

All the icons used are in the images directory. The naming convention is name.rr.gg.bb.tt.png, where name is a string that describes the shape of the icon; rr, bb, and gg are hexadecimal codes for the level of red, green, and blue; and tt gives the level of transparency (0 to 99). Thus the icon named dot.ff.ff.ff.99.png is a white dot that is nearly opaque, and the icon named sq.00.00.00.01.png is a red square that is nearly transparent. Except for tt equal to 01 and 99, the values are at multiples of 10, since finer variations in transparency are cannot be distinguished easily.

The internal icon names (used in the KML file) start with the letters A through K to denote the transparency levels. For each transparency, names are then generated for different magnitudes, rounded to the nearest tenth; these names correspond to different scalings of the icon. So, for example, A6.5 corresponds to the icon with transparency 01 (nearly transparent), scaled for magnitude 6.5, while K6.5 corresponds to the same scaling for the icon with transparency 99 (nearly opaque).

5   Miscellaneous

To report bugs or ask questions, contact Duncan Agnew at the address given above.

The code for reading commands and using them to guide the execution was developed by Bob Parker.

Fred Klein suggested the altscale, flatten, and float, commands, and showed me how to make

the program read the ANSS format.

References

Lin, G., P. M. Shearer, and E. Hauksson (2007), Applying a three-dimensional velocity model, waveform cross correlation, and cluster analysis to locate southern California seismicity from 1981 to 2005, *J. Geophys. Res.*, **112**, B12,309, doi:10.1029/2007JB004986.

Wernecke, J. (2009), *The KML Handbook: Geographic Visualization for the Web*, Addison-Wesley, Upper Saddle River, NJ.