Three Dimensional Modelling of EEG Signals

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Contents

Discrete Fourier Transform

We can obtain a discrete signal by sampling continuous data. According to Nyquist's theorem the sampling frequency f_s needs to be set to at least double of the highest frequency f_{max} we need to recover.

$$f_s \geq 2f_{max}$$

Next equation is the DFT formula, where $x(n)$ is a time-series and $X(k)$ is its DFT, for $k = 0, \ldots, N-1$.

$$X(k) = \sum_{n=0}^{N-1} x(n)\, e^{-j\,\frac{2\pi}{N}\,nk}$$

The inverse DFT for $n = 0, \ldots, N-1$ is defined as follows:

$$x(n) = \frac{1}{N} \sum_{k=0}^{N-1} X(k)\, e^{j\,\frac{2\pi}{N}\,nk}$$

Digital Signal Filtering

Finite-duration impulse response (FIR) filters can be described by the following difference equation

$$y(m) = \sum_{k=0}^{M} b_k \, x(m-k)$$

The FIR filter transfer function given by next equation contains no poles. Hence, FIR filters are also called all-zero filters.

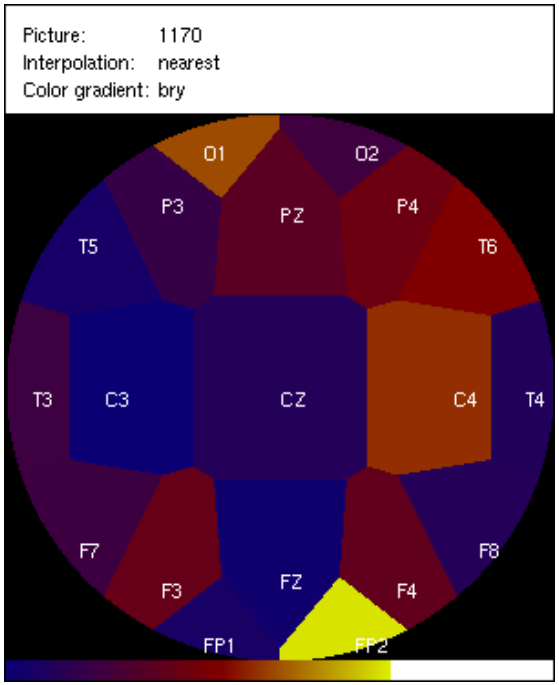
$$H(z) = \sum_{k=0}^{M} b_k \, z^{-k}$$

Interpolation Methods

In order to visualize the data we need to do interpolation for pixels between the known points. This is not an easy task because of non-uniform location of EEG electrodes.

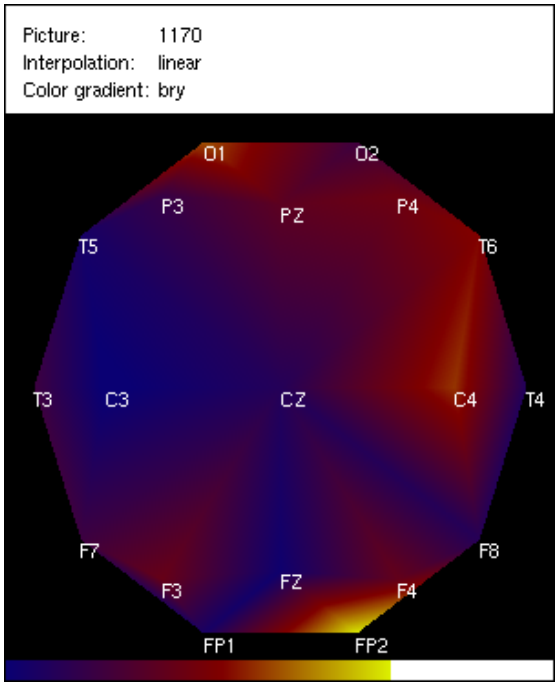
- Nearest Neighbor Interpolation
- Linear Interpolation
- Cubic Interpolation
- Spline Interpolation
- Weighted Distance Interpolation

Nearest Neighbor Interpolation



Nearest neighbor interpolation is one of the simplest interpolation methods used. It fills the nearest points with the same value which results in discontinuous areas. This approach is not visually impressive and it's not commonly used.

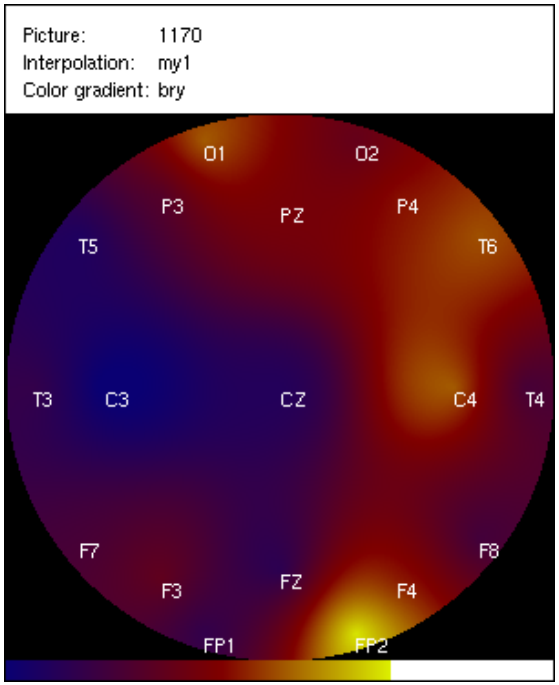
Linear Interpolation



Linear interpolation is a curve fitting method using linear polynomials. It's one of the simplest ways to interpolate data. Planes formulas using definition for a plane defined by 3 points.

$$ax_1 + by_1 + cz_1 + 1 = 0$$
$$ax_2 + by_2 + cz_2 + 1 = 0$$
$$ax_3 + by_3 + cz_3 + 1 = 0$$

Weighted Distance Interpolation



Weighted distance interpolation is experimental type of interpolation based on weighted distance for each point. It gives less precious results but much better in terms of visual look.

Interpolation Methods Comparison

For this purpose we can use basic function such as

$$f_{(x,y)} = -x\, e^{-x^2-y^2}$$

which we'll interleave within the array. Next we'll compute square of the sum of difference between this array and the interlaced one and divide it by number of elements.

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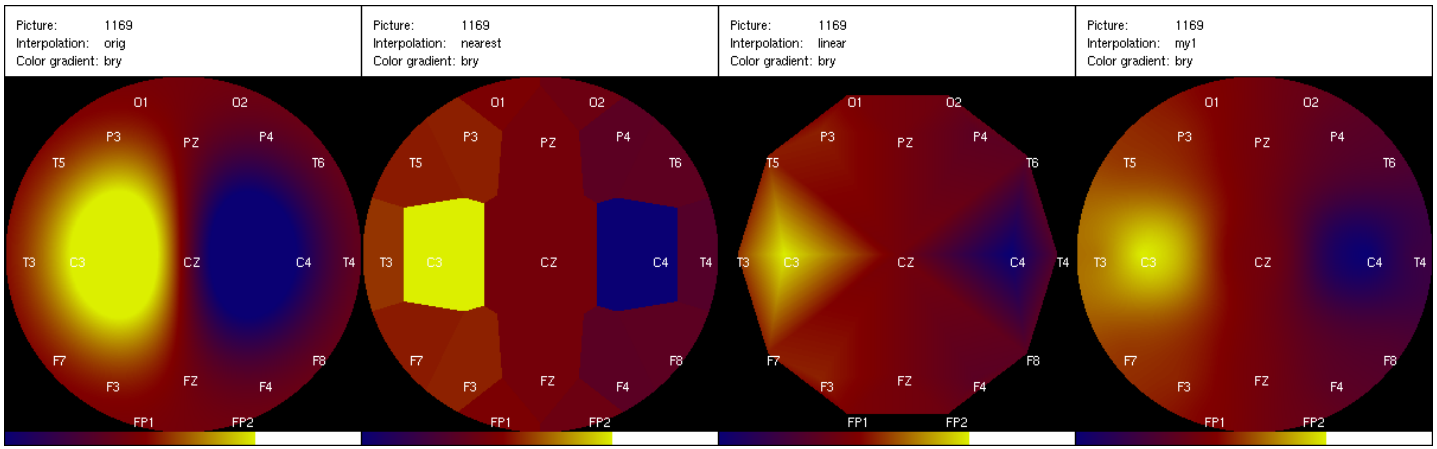
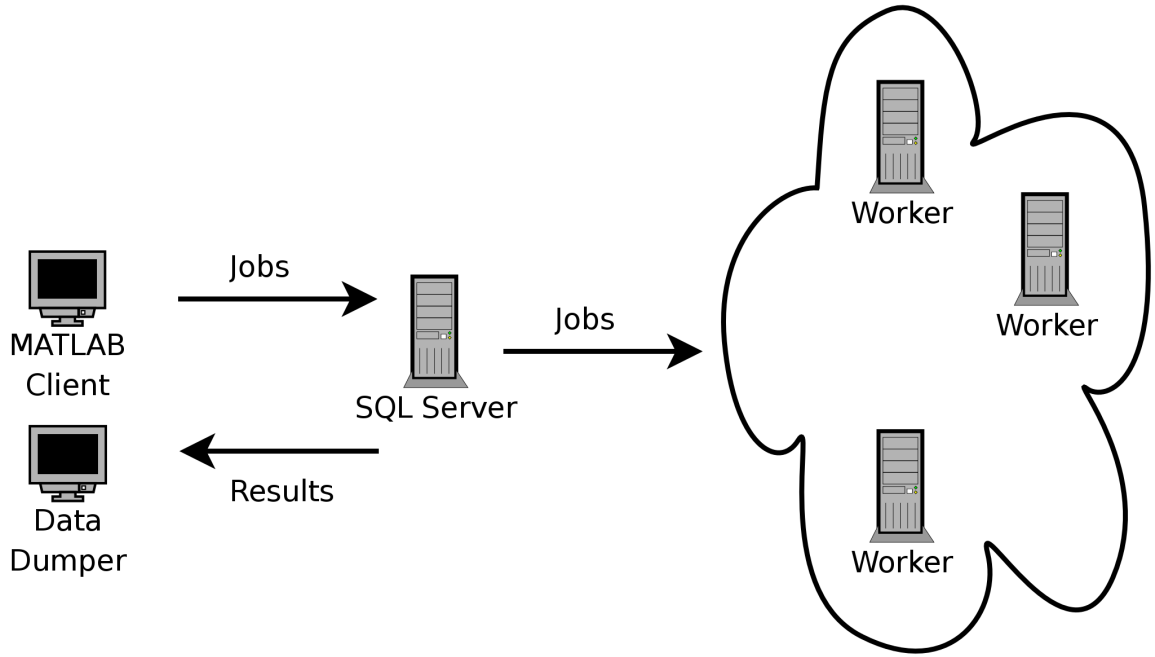
Interpolation method	Nearest Neighbor	Linear	Weighted Distance
Result	135.15	201.34	117.31



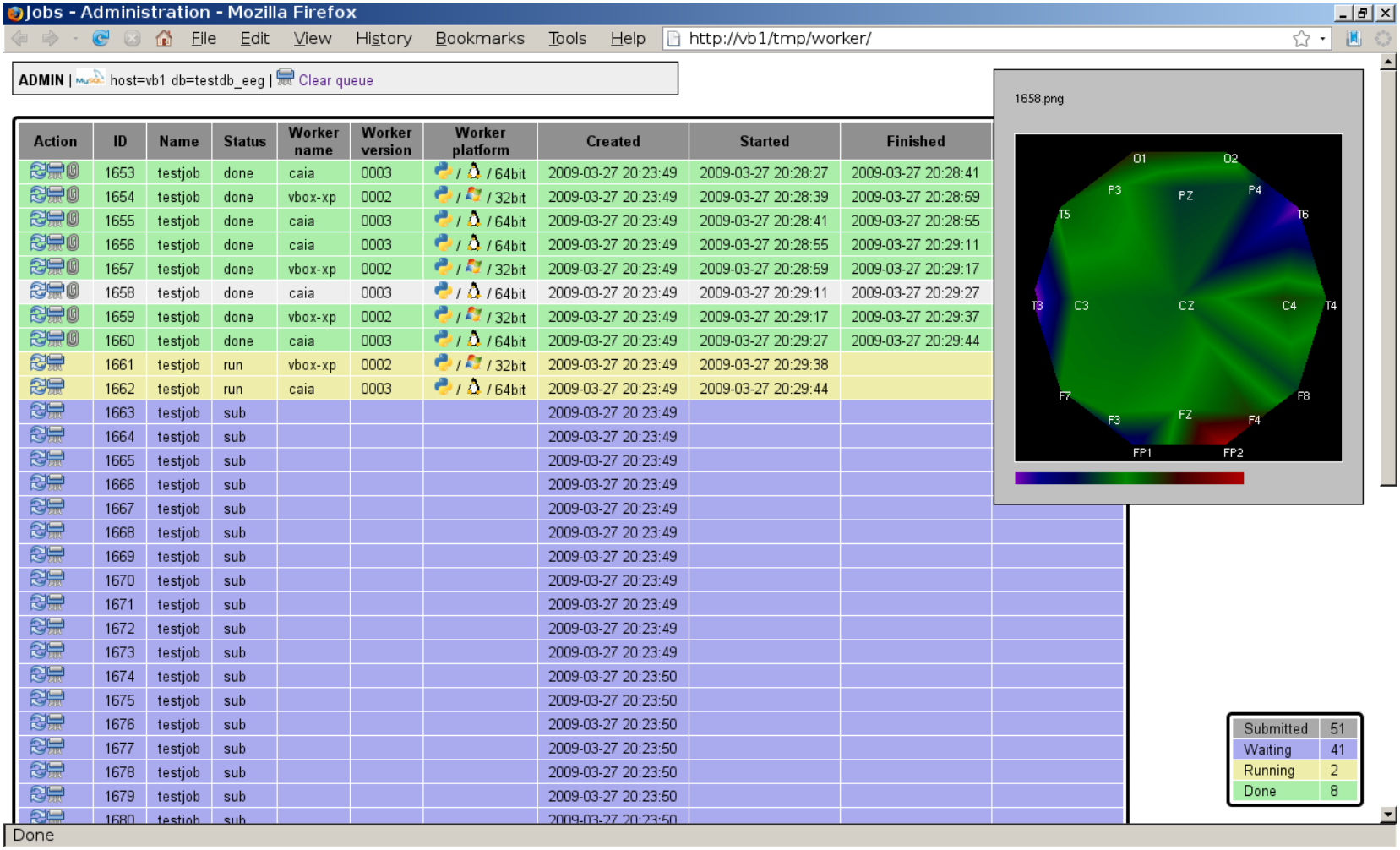
System Structure

Node and system structure of the distributed computing platform was inspired by MATLAB Distributed Computing Toolbox and the MATLAB Distributed Computing Engine.

- Database Server
- Worker
- Web Interface
- Job Submitter
- Data Dumper



Web Interface



Action	ID	Name	Status	Worker name	Worker version	Worker platform	Created	Started	Finished
	1653	testjob	done	caia	0003	/ 64bit	2009-03-27 20:23:49	2009-03-27 20:28:27	2009-03-27 20:28:41
	1654	testjob	done	vbox-xp	0002	/ 32bit	2009-03-27 20:23:49	2009-03-27 20:28:39	2009-03-27 20:28:59
	1655	testjob	done	caia	0003	/ 64bit	2009-03-27 20:23:49	2009-03-27 20:28:41	2009-03-27 20:28:55
	1656	testjob	done	caia	0003	/ 64bit	2009-03-27 20:23:49	2009-03-27 20:28:55	2009-03-27 20:29:11
	1657	testjob	done	vbox-xp	0002	/ 32bit	2009-03-27 20:23:49	2009-03-27 20:28:59	2009-03-27 20:29:17
	1658	testjob	done	caia	0003	/ 64bit	2009-03-27 20:23:49	2009-03-27 20:29:11	2009-03-27 20:29:27
	1659	testjob	done	vbox-xp	0002	/ 32bit	2009-03-27 20:23:49	2009-03-27 20:29:17	2009-03-27 20:29:37
	1660	testjob	done	caia	0003	/ 64bit	2009-03-27 20:23:49	2009-03-27 20:29:27	2009-03-27 20:29:44
	1661	testjob	run	vbox-xp	0002	/ 32bit	2009-03-27 20:23:49	2009-03-27 20:29:38	
	1662	testjob	run	caia	0003	/ 64bit	2009-03-27 20:23:49	2009-03-27 20:29:44	
	1663	testjob	sub				2009-03-27 20:23:49		
	1664	testjob	sub				2009-03-27 20:23:49		
	1665	testjob	sub				2009-03-27 20:23:49		
	1666	testjob	sub				2009-03-27 20:23:49		
	1667	testjob	sub				2009-03-27 20:23:49		
	1668	testjob	sub				2009-03-27 20:23:49		
	1669	testjob	sub				2009-03-27 20:23:49		
	1670	testjob	sub				2009-03-27 20:23:49		
	1671	testjob	sub				2009-03-27 20:23:49		
	1672	testjob	sub				2009-03-27 20:23:49		
	1673	testjob	sub				2009-03-27 20:23:49		
	1674	testjob	sub				2009-03-27 20:23:50		
	1675	testjob	sub				2009-03-27 20:23:50		
	1676	testjob	sub				2009-03-27 20:23:50		
	1677	testjob	sub				2009-03-27 20:23:50		
	1678	testjob	sub				2009-03-27 20:23:50		
	1679	testjob	sub				2009-03-27 20:23:50		
	1680	testjob	sub				2009-03-27 20:23:50		

Technology Used

- Operating Systems
  - Debian Linux
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- Infrastructure
  - MySQL
  - Apache
- Multimedia
  - ImageMagick
  - MEncoder

Results - Visualization - Nearest Neighbor Interpolation

(Loading movie...)

Results - Visualization - Linear Interpolation

(Loading movie...)

Results - Visualization - Weighted Distance Interpolation

(Loading movie...)

Results - Comparison of the computational time

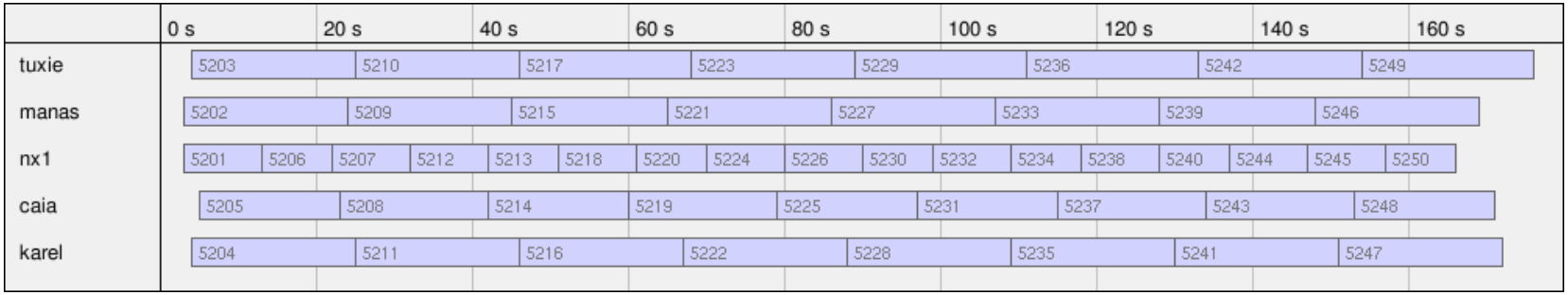
Signal Length [samples]	*Time [s]*		
	Single computer	*Cluster 1*	*Cluster 2*
50	457	176	57
100	914	340	109
200	1829	670	211
500	4574	1660	518

Results - Comparison of the computational time per job

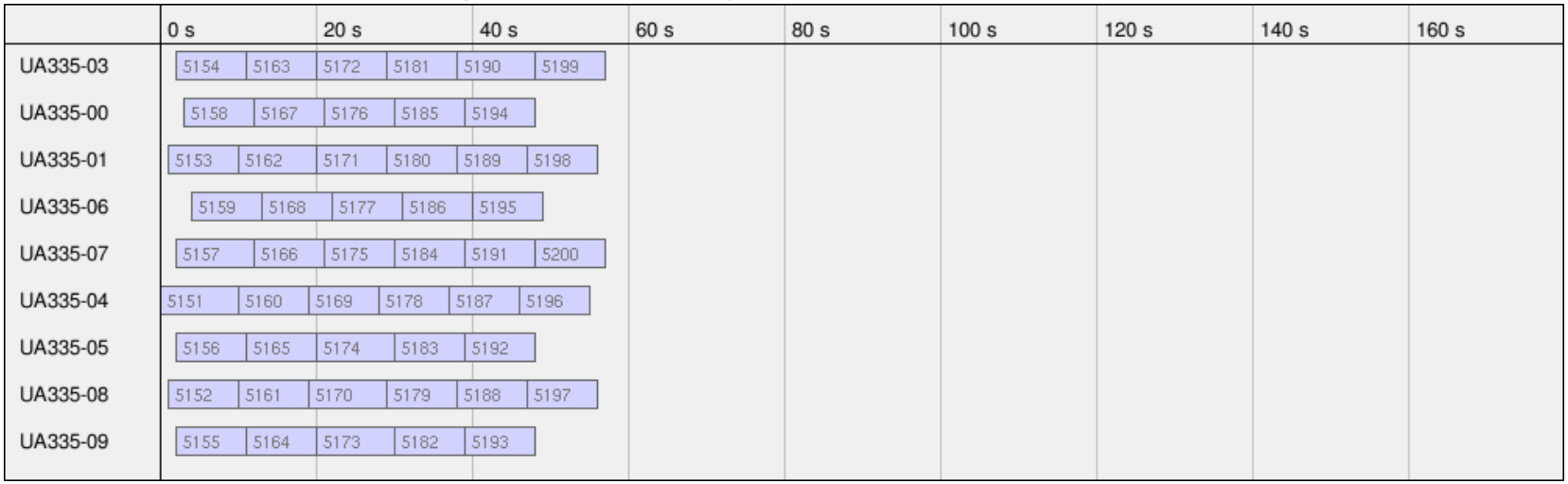
Signal Length [samples]	*Time [s]*		
	Single computer	*Cluster 1*	*Cluster 2*
50	9.140	3.520	1.140
100	9.140	3.400	1.090
200	9.145	3.350	1.055
500	9.148	3.320	1.036

Results - Cluster Load

Cluster 1 - Home network



Cluster 2 - School classroom



Future Plans

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- Revise Python libraries usage. MySQL-Python could be replaced by more advanced SQLAlchemy which provides connector for SQLite, Postgres, MySQL, Oracle, MS-SQL, Firebird, MaxDB, MS Access, Sybase, Informix and DB2 databases.

Questions and Answers

Thank you